BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION MODEL
FOR CONSTRUCTION PROJECT DESIGN STAGE

SUZILA BINTI MOHD

A thesis submitted in
fulfilment of the requirement for the award of the
Degree of Master of Science in Technology Management

Faculty of Technology Management and Business
Universiti Tun Hussein Onn Malaysia

SEPTEMBER 2015
ABSTRACT

Building Information Modelling (BIM) provides significant benefits to construction players. However, BIM in construction projects seem not fully been implemented. This is due to lack effective strategy of implementing BIM in project design stage. Added to the matters, most of the construction players fail to get benefits using BIM because they are facing difficulty to implement BIM. This research aims to assist construction players to implement BIM in construction project design stage. Literature review was carried out to discover BIM implementation in construction project design stage and examples of models in construction field, which the research model has similar purposes with the models. Semi-structured interviews have been done with design team, which currently involved and have been involved in projects using BIM for residential and commercial projects in Malaysia. All data obtained from the interviews were analysed using content analysis technique. The findings from the interviews revealed that, construction players need an assistance in a form of model to implement BIM in construction project design stage. Therefore, both data from literature review and the interviews were used to develop a model, which has been named as ‘BIM Implementation Model for design team’. The model is one of the ways to assist design team to implement BIM in construction project design stage. Apart from that, the model would assist design team a place to start and follow with several elements in each level of the model. Thus, the model could increase BIM implementation in project design stage.
ABSTRAK

### CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE</td>
<td>i</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xvi</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xviii</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xx</td>
</tr>
<tr>
<td><strong>CHAPTER 1</strong></td>
<td></td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Research Background</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Problem Statement</td>
<td>4</td>
</tr>
<tr>
<td>1.4 Research Questions</td>
<td>7</td>
</tr>
<tr>
<td>1.5 Research Aim and Objectives</td>
<td>7</td>
</tr>
<tr>
<td>1.6 Scope of Research</td>
<td>7</td>
</tr>
<tr>
<td>1.7 Significant of Research</td>
<td>8</td>
</tr>
<tr>
<td>1.8 Research Methodology</td>
<td>8</td>
</tr>
<tr>
<td>1.9 Research Organisation</td>
<td>10</td>
</tr>
<tr>
<td>1.10 Summary</td>
<td>12</td>
</tr>
<tr>
<td><strong>CHAPTER 2</strong></td>
<td></td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>13</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>13</td>
</tr>
<tr>
<td>2.2 Construction Project Design Stage</td>
<td>13</td>
</tr>
<tr>
<td>2.3 Building Information Modelling (BIM)</td>
<td>24</td>
</tr>
</tbody>
</table>
2.3.1 BIM in the Malaysian Construction Industry 25
2.3.2 Definition of BIM 26
2.4 BIM Application in Project Design Stage 29
2.4.1 Visualise Project Models 29
2.4.2 Generate Fabrication or Shop Drawing for Various Building Systems 32
2.4.3 Utilise Project Model Parameters by Using Code Review 34
2.4.4 Preview Design Clashes Analysis 35
2.4.5 Assist in Preparing Cost Estimating 35
2.4.6 Assist in Preparing Project Scheduling 36
2.5 BIM Adaptation in Project Design Stage 37
2.6 BIM Tools in Design Stage 38
2.7 Benefits of Implementing BIM in Project Design Stage 41
2.8 Challenges in Implementing BIM 42
2.8.1 Legal or Contractual Issues Relating to BIM 43
2.8.2 Cost Issues 43
2.8.3 Skill and Knowledge Issues 44
2.8.4 Lack of Effective Strategy to Implement BIM 44
2.9 Potential Improvement of BIM Implementation in the Construction Industry 45
2.10 Model Related to BIM and Construction Field 46
2.10.1 Capability Maturity Model (CMM) for Software 46
2.10.2 The Business Process Operation (BPO) Maturity Model 48
2.10.3 The STEPS Model 49
2.10.4 The People Capability Maturity Model (People CMM) 49
2.10.5 The Bew-Richards BIM Maturity Model 51
2.10.6 BIM Maturity Matrix (BIm³) 52
2.10.7 Performance Measurement (PM) Migration Path Model 53
2.10.8 Similarities Between the Models 54
2.10.9 Selection of Maturity Levels for the Research Model 55
2.11 Theoretical Framework 59
2.12 Summary 61

CHAPTER 3 RESEARCH METHODOLOGY 62
3.1 Introduction 62
3.2 Research Purposes 62
3.3 Research Approaches 64
3.4 Research Strategies 67
3.5 Data Collection 71
3.5.1 Literature Review Related to BIM, Project Design Stage and Model Related to BIM and Construction Field 75
3.5.2 Semi-Structured Interview with Design Team 76
3.5.2.1 Respondent Selection 77
3.5.2.2 Development of Interview Questions 77
3.5.2.3 Pilot Study 78
3.6 Data Analysis Technique 80
3.6.1 Development of BIM Implementation Model for Design Team 81
3.6.2 Evaluation of Research Model 82
3.7 Summary 83

CHAPTER 4 DATA ANALYSIS AND FINDINGS 84
4.1 Introduction 84
4.2 Objectives of Interviews 84
4.3 Discussion on the Data from Interviews 85
4.3.1 Respondent’s Background 85
4.3.2 Current Practices of BIM Implementation in Project Design Stage 87
4.3.2.1 Understanding on BIM 88
4.3.2.2 Design Process for Construction Projects 93
CHAPTER 4  BIM IMPLEMENTATION FOR CONSTRUCTION PROJECT DESIGN

4.3.2.3 Design Process for Construction Project Using BIM 98
4.3.3 The Effects of BIM Implementation in Project Design Stage 106
4.3.3.1 Issues Related to Project Design 106
4.3.3.2 Benefits of BIM Implementation in Project Design Stage 110
4.3.4 Challenges of BIM Implementation in Project Design Stage 114
4.3.4.1 Challenges Faced by Design Team to Implement in Project Design Stage 114
4.3.4.2 Potential Improvement on BIM Implementation 120
4.4 Key Finding From Interviews 125
4.5 Summary 128

CHAPTER 5  BIM IMPLEMENTATION MODEL FOR DESIGN TEAM 129

5.1 Introduction 129
5.2 The Model: BIM Implementation for Design Team 129
5.3 Model Development Process 130
5.3.1 Step 1: Research Model Purposes 131
5.3.2 Step 2: Concept of Research Model 132
5.3.3 Step 3: Procedure of Research Model Development 132
5.3.4 Step 4: Details of the Model Elements 133
5.4 Evaluation of the Research Model 140
5.4.2 Evaluator’s Background 141
5.4.2 Evaluation on BIM Implementation Model for Design Team Model Elements 142
5.4.3 Benefits of Using BIM Implementation Model for Design Team 145
5.4.4 Barriers to Use BIM Implementation Model for Design Team 146
5.4.5 Improvements of BIM Implementation Model for Design Team 147

5.5 Summary 149

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS 150

6.1 Introduction 150
6.2 Research Overview 150
6.3 Conclusion 154
6.4 Contribution of Research 155
6.5 Limitations of Research 156
6.6 Recommendations for Further Research 157
6.7 Concluding Remark 157

REFERENCES 158

APPENDICES

LIST OF PUBLICATIONS

VITA
LIST OF TABLES

2.1 Definition of BIM. ........................................ 26
2.2 Types of BIM Tools in Project Design Stage. ........ 41
2.3 Summary of Models Similarities ......................... 55
2.4 Selection of Maturity Levels for Research Model. .... 56
3.1 Respondents Feedback on Interview Questions. ...... 79
4.1 Respondents’ Backgrounds. ............................ 86
4.2 Understanding on BIM. .................................. 88
4.3 Purpose of BIM Implementation in Project Design. ... 90
4.4 Design Stage Activities. ................................ 94
4.5 Construction Players Involved in Project Design Stage. 95
4.6 Design Process for Project Using BIM. ............... 98
4.7 Level of Development (LOD). .......................... 102
4.8 The use of LOD. ........................................ 104
4.9 Types of BIM Tools. .................................... 104
4.10 Summary of the BIM Tools Used by Respondents. ... 106
4.11 Project Design Issues. .................................. 107
4.12 Benefits of BIM Implementation in Project Design Stage. 110
4.13 ‘People’ Factor. ........................................ 115
4.14 ‘Process’ Factor. ....................................... 117
4.15 ‘Technology’ Factor. ................................... 118
4.16 Potential Improvement to Increase BIM Implementation in Project Design Stage. 121
5.1 Details of Key Aspects of BIM Implementation Model for Design Team. 135
5.2 Evaluator’s Information. ............................... 141
5.3 Model Contents. ........................................ 142
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4</td>
<td>Model Capability.</td>
<td>143</td>
</tr>
<tr>
<td>5.5</td>
<td>Model Usability.</td>
<td>144</td>
</tr>
<tr>
<td>5.6</td>
<td>Summary of Model Elements Evaluation.</td>
<td>145</td>
</tr>
<tr>
<td>5.7</td>
<td>Benefits of Using BIM Implementation Model for Design Team.</td>
<td>146</td>
</tr>
<tr>
<td>5.8</td>
<td>Benefits of Using the Model</td>
<td>146</td>
</tr>
<tr>
<td>5.9</td>
<td>Barriers to Use the BIM Implementation Model for Design Team.</td>
<td>147</td>
</tr>
<tr>
<td>5.10</td>
<td>Barriers of Using the Model</td>
<td>147</td>
</tr>
<tr>
<td>5.11</td>
<td>Potential Improvements to Improve BIM Implementation Model for Design Team.</td>
<td>148</td>
</tr>
<tr>
<td>5.12</td>
<td>Summary of Potential Improvements to Improve the Model</td>
<td>148</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Research Methodology Process.</td>
<td>9</td>
</tr>
<tr>
<td>2.2</td>
<td>Activities in Project Design Stage</td>
<td>14</td>
</tr>
<tr>
<td>2.3</td>
<td>Design Team (Adopted from: Klinger and Susong, 2006; Winch, 2010; Levy, 2010).</td>
<td>17</td>
</tr>
<tr>
<td>2.5</td>
<td>Example of 2D Design and 3D Model.</td>
<td>30</td>
</tr>
<tr>
<td>2.6</td>
<td>Visual simulation of 4D Model for Scheduling (HSE Contractor Inc, 2013).</td>
<td>31</td>
</tr>
<tr>
<td>2.7</td>
<td>Example of 5D Model for Project Estimating (Construction Management Software (CMS), 2008).</td>
<td>32</td>
</tr>
<tr>
<td>2.8</td>
<td>General Instruction of Structural Steel Connections (Autodesk, 2007).</td>
<td>33</td>
</tr>
<tr>
<td>2.9</td>
<td>4D Structure Steel Design (Cadalyst, 2013).</td>
<td>34</td>
</tr>
<tr>
<td>2.10</td>
<td>Example of Design Clashes (Logiseek, 2013).</td>
<td>35</td>
</tr>
<tr>
<td>2.11</td>
<td>BIM Throughout a Building Life-cycle (PWD, 2011).</td>
<td>37</td>
</tr>
<tr>
<td>2.12</td>
<td>Capability Maturity Model (CMM) for Software (Paulk <em>et al.</em>, 1993).</td>
<td>47</td>
</tr>
<tr>
<td>2.13</td>
<td>The BPO Maturity Model (Lockamy III and McCormack, 2004).</td>
<td>48</td>
</tr>
<tr>
<td>2.14</td>
<td>The STEPS Model (Robinson <em>et al.</em>, 2005).</td>
<td>49</td>
</tr>
<tr>
<td>2.15</td>
<td>The People Capability Maturity Model (Curtis <em>et al.</em>, 2009).</td>
<td>50</td>
</tr>
<tr>
<td>2.16</td>
<td>The Bew-Richards BIM Maturity Model (Jayasena and Chitra, 2013).</td>
<td>51</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
</tr>
<tr>
<td>RFI</td>
<td>Request for Information</td>
</tr>
<tr>
<td>PWD</td>
<td>Public Work of Department</td>
</tr>
<tr>
<td>BIM</td>
<td>Building Information Modelling</td>
</tr>
<tr>
<td>AEC</td>
<td>Architecture, Engineering and Construction</td>
</tr>
<tr>
<td>FM</td>
<td>Facilities Management</td>
</tr>
<tr>
<td>HK</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>UTHM</td>
<td>Universiti Tun Hussein Onn Malaysia</td>
</tr>
<tr>
<td>NCI</td>
<td>National Cancer Institute</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and Maintenance</td>
</tr>
<tr>
<td>2D</td>
<td>2-dimensional</td>
</tr>
<tr>
<td>3D</td>
<td>3-dimensional</td>
</tr>
<tr>
<td>4D</td>
<td>4-dimensional</td>
</tr>
<tr>
<td>5D</td>
<td>5-dimensional</td>
</tr>
<tr>
<td>6D</td>
<td>6-dimensional</td>
</tr>
<tr>
<td>7D</td>
<td>7-dimensional</td>
</tr>
<tr>
<td>n-D</td>
<td>n dimensional</td>
</tr>
<tr>
<td>M&amp;E</td>
<td>Mechanical and Electrical</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>MEP</td>
<td>Mechanical, Electrical and Plumbing</td>
</tr>
<tr>
<td>QS</td>
<td>Quantity Surveyor</td>
</tr>
<tr>
<td>MoE</td>
<td>Ministry of Education</td>
</tr>
<tr>
<td>CIDB</td>
<td>Construction Industry Development Board</td>
</tr>
<tr>
<td>BOE</td>
<td>Board of Engineers</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>HVAC</td>
<td>Ventilation and Air-Conditioning</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>BDS</td>
<td>Building Description System</td>
</tr>
<tr>
<td>GLIDE</td>
<td>Graphical Language for Interactive Design</td>
</tr>
<tr>
<td>AEC-FM</td>
<td>Architectural, Engineering and Construction-Facilities Management</td>
</tr>
<tr>
<td>IBC</td>
<td>International Building Code</td>
</tr>
<tr>
<td>ADA</td>
<td>America with Disabilities Act guideline</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>BOA</td>
<td>Board of Architect</td>
</tr>
<tr>
<td>CMM</td>
<td>Capability Maturity Model</td>
</tr>
<tr>
<td>BPO</td>
<td>Business Process Operation</td>
</tr>
<tr>
<td>BIm³</td>
<td>BIM Maturity Model</td>
</tr>
<tr>
<td>SEI</td>
<td>Software Engineering Institute</td>
</tr>
<tr>
<td>KM</td>
<td>Knowledge Management</td>
</tr>
<tr>
<td>IPD</td>
<td>Integrated Project Delivery</td>
</tr>
<tr>
<td>PM</td>
<td>Performance Measurement</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strength, Weaknesses, Opportunities and Threats</td>
</tr>
</tbody>
</table>
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>BIM Maturity Matrix Model</td>
</tr>
<tr>
<td>B</td>
<td>Interview Questions</td>
</tr>
<tr>
<td>C</td>
<td>Evaluation Questions</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction industry is one of the contributor to the economy of Malaysia. It has contributed a total worth of MYR 194 billion to the Malaysian gross domestic product in year 2011 to 2015 (Unit Perancang Ekonomi, 2015). Other than that, it is also important in supporting social development through the provision of basic infrastructure in Malaysia (Construction Industry Development Board (CIDB), 2007). According to Unit Perancangan Ekonomi (2015), the uses of technology in the construction industry has increased the rate of Malaysia economy.

In order to manage the construction industry efficiently, information and communication technology (ICT) has provided better management solution to the construction industry. The implementation of ICT in the construction industry has become a norm since year 1990 (Forbes and Ahmed, 2011). Moreover, Forbes and Ahmed (2011) stated that ICT is a technology that encompasses computer hardware, software and communication devices of sharing and accessing information conveniently. It has been used widely to avoid construction project problems such as low productivity of construction projects, low quality of end projects, project delaying, construction cost overrun and disputes among construction players (Kadir et al., 2005; Arayici et al., 2009; Khosnava et al., 2012; Haron, 2013).

Thus, ICT has introduced a new technology, namely building information modelling (BIM) in order to overcome the construction problems (CIDB, 2007; Forbes and Ahmed, 2011; Public Work Department (PWD), 2013). The implementation of
new technology such as BIM in construction projects has reduced issues on project delay, construction cost overrun, disputes among construction players; and it has increased project quality as well as productivity of construction projects (Azhar, 2011; Eastman et al., 2011; Zakaria et al., 2013).

BIM has been used widely by the architecture, engineering, construction and facilities management (AEC-FM) industry for the purpose of managing construction project life-cycle (Levy, 2010). It has also been introduced to the construction industry in many countries such as United States of America (USA), Australia, Hong Kong (HK) (Monteiro and Martins, 2013; Ahmad Latiffi and Mohd, 2014), Finland, Denmark and Norway (Eastman et al., 2011; Crotty, 2012). In Malaysia, the idea to implement BIM was introduced by the Director of Public Works of Department (PWD) in year 2007. The idea was proposed when Malaysian government are aware about the potential of BIM in avoiding construction cost overrun and project delay as well as to avoid design problems at early stage of construction project (PWD, 2013; Ahmad Latiffi et al., 2013; Zakaria et al., 2013). Since then, PWD has encouraged all construction players to implement BIM in construction projects (PWD, 2013). Correspondingly, the implementation of BIM in construction projects need to be explored in order to identify the capabilities of BIM in managing construction projects effectively.

1.2 Research Background

Adaptation of technology in the construction industry is moving rapidly towards the era of modernisation and globalisation. ICT has played a significant role in this transformation. The use of ICT permeates in various industries including in the construction industry and it is seen as a major driver for improving performance of the industry (CIDB, 2007; Eastman et al., 2011; Hosseini et al., 2012; Zhang, 2013). According to Forbes and Ahmed (2011), ICT has introduced BIM as a tool to manage construction projects effectively by reducing construction problems such as project delay, construction cost overrun and disputes among construction players.

BIM is seen as a concerted action to ensure collaboration among construction players such as architect, engineers, project manager and contractors (Furneaux and Kivvits, 2008; PWD, 2013). The positive effects from the implementation of BIM in
construction projects have been highlighted by many construction players as a need in managing construction projects in order to reduce construction problems (Bryde, Broquetas and Volm, 2013). According to Bryde et al. (2013), there are thirty five (35) examples of BIM projects in USA, UK and France, which had been contributed positive effects to construction projects. The positive effects can be traced in terms of construction cost, project duration, project quality, communication and collaboration among construction players (Bryde et al., 2013).

Moreover, the successful of BIM in managing construction projects can be seen through several successful erected projects. These projects are the Freedom Tower in New York City, USA; Birmingham City University in UK; One Island East project in HK, and Sydney Opera House in Australia (Furneaux and Kivvits, 2008; Winch, 2010; Royal Institution of Charted Surveyor (RICS), 2013). Apart from that, there are also several construction projects in the construction industry of Malaysia were identified to be employing BIM. These projects are Sultan Ibrahim Hall (formerly known as Multipurpose Hall of Universiti Tun Hussein Onn Malaysia, UTHM) in Batu Pahat, Johor (Construction Research Institute of Malaysia (CREAM), 2012; Mohd and Ahmad Latiffi, 2013); National Cancer Institute (NCI) of Malaysia in Putrajaya (Ahmad Latiffi, Mohd and Brahim, 2014); Educity Sports Complex in Nusajaya, Johor; and Ancasa Hotel in Pekan, Pahang (PWD, 2011; Ahmad Latiffi et al., 2013; Mohd and Ahmad Latiffi, 2013).

BIM has capabilities in managing construction projects starting from pre-construction stage to post-construction stage (Levy, 2010; Eastman et al., 2011; Crotty, 2012). It has to be implemented in each of the stages in order to manage all activities in construction projects especially in project design (Yan and Damian, 2008; Weygant, 2011; Newman, 2013). Project design has been considered as an important activity in construction projects (Eastman et al., 2011; Memon et al., 2011) because other activities such as cost estimating and project scheduling can only be started and refined after the completion of project design (Eastman et al., 2011; Memon et al., 2011). Therefore, it is crucial to implement BIM in the stage of project design in order to increase accuracy in preparing cost estimating, project scheduling, site analysis, and project productivity (Fallon and Palmer, 2007; Eastman et al., 2011). The ability of BIM in visualising project design and detect design clashes during design stage can reduce request for information (RFI), design changes and incomplete design specification during construction stage. The possibilities of those problems occur
during construction stage can be avoided earlier in pre-construction stage (Kymmell, 2008; NCCER, 2008).

Moreover, BIM can also be integrated with post-construction activities such as facilities management (FM), operations and maintenance (O&M) (Newman, 2013; Abdullah et al., 2014). The implementation of BIM in project design helps facility manager to manage FM by visualising all information in 3D model. In addition, all information in the model can be easily shared and to be used by the contractor (Sabol, 2008; Abdullah et al., 2014). BIM can also improve space management, where facility managers can use the 3D model to visualise project plan and configure space more efficiently (Sabol, 2008; Abdullah et al., 2014).

Correspondingly, the main importance of BIM implementation in project design stage lies on the use of three dimensional (3D) parametric authoring tools as object based modelling software (Mohamad Kamar, 2012). There are several types of modelling software or also known as BIM tools are used to manage project design in construction projects. These tools are such as Revit (architecture, structural, mechanical and electrical (M&E)), Bentley System (architecture, structural and M&E) and Tekla structure. The tools are capable to visualise project model, preview design clashes and generate fabrication drawing for various building systems (Azhar, 2011; Eastman et al., 2011; Ahmad Latiffi et al., 2013; Monteiro and Martins, 2013; PWD, 2013).

Utilising BIM technology allows effective and better plan for construction projects activities, which can overcome the potential errors in design, disputes among construction players, construction cost overrun and project delay (Eastman et al., 2011). BIM also has potential for improving communication, collaboration between construction players, reducing cost at every stage in construction projects and reduce safety issues in construction projects (Smith and Tardif, 2009; Cheng and Ma, 2012; Sunindijo and Zou, 2013).

1.3 Problem Statement

Low productivity of construction projects, low quality of end projects, project delay and construction cost overrun are the four main construction problems lead to construction project failure (Arayici et al., 2009; Forbes and Ahmed, 2011; Khosnava
et al., 2012 and Haron, 2013). Most of the problems that were identified by Arayici et al. (2009), Forbes and Ahmed (2011), Khosnava et al. (2012) and Haron (2013) occurred due to weakness in managing project design. This shows that, project design is one of important element lead to the success of managing construction projects (Eastman et al., 2011; Memon et al., 2011). Therefore, many attempts were done by construction players especially by the design team (client, architect, structural engineer, M & E engineer and contractor) to improve quality of project design by implementing BIM (Kymmell, 2008; Forbes and Ahmed, 2011).

Nowadays, the implementation of BIM in project design stage is seen as one of the effective ways to reduce construction problems. Even though BIM implementation gives positive effects to construction projects, most of the design team is facing difficulty to implement BIM. In addition to that, some were failed to obtain the benefits of using BIM (Cheung et al., 2012; CREAM, 2014). According to Zakaria et al. (2013), most of the construction players are having difficulty to implement BIM as they do not know what, how, where, who and when to begin with BIM in construction projects especially in the Malaysia construction industry. This matters happened due to several factors, such as lack of knowledge as well as skill on BIM; cost to adopt BIM tools as well as training are expensive and lack of effective strategy to implement BIM (Furneaux and Kivvits, 2008; Arayici et al., 2012, Zakaria et al., 2013).

One of the main setbacks for the implementation of BIM in construction projects is due to lack of knowledge and skill on BIM. Construction players are required to dominate knowledge and skill on BIM before deciding to implement BIM (Eastman et al., 2011: Azhar, 2011; Ahmad Latiffi et al., 2013). Apparently, possessing relevant knowledge on BIM is important to lead construction players to the right way of implementing BIM. It will also increase awareness among construction players regarding the benefits of implementing in construction projects (Gu and London, 2010; MH Government, 2012; Zakaria et al., 2013). Meanwhile, possessing relevant skill on BIM will also guide construction players on how to manage project design, cost estimating, project scheduling, site coordination and facilities management by using BIM tools such as Revit families (Azhar, 2011; Newman, 2013).

The second factor that explained about the slow adoption of BIM in construction projects is due to cost of implementing BIM tools (revit families), new hardware (computer) and BIM training. The cost for these tools are expensive and it could be a barrier for small and medium construction companies to implement BIM in their work
Therefore, in order to manage construction projects using BIM, construction players must ensure to gain benefits from using BIM or else all the investment on BIM will be wasted and useless.

Another factor that lead to slow adoption of BIM among construction players is due to lack of effective strategy of implementing BIM in an organisation (Arayici et al., 2012); for example: absent of a comprehensive BIM standard guideline (Zakaria et al., 2013; CREAM, 2014) and adoption model to implement BIM (Zakaria et al., 2013). Literally, there is no clear consensus on how to implement BIM in construction projects (Azhar, 2011). On top of this, there is no single BIM document that provides instruction on its application and implementation (Azhar, 2011; Zakaria et al., 2013). Continuation from the matters, many construction players have developed their own version of BIM implementation guideline. However, the informal guideline somehow has resulted in confusion among construction players, which render the construction players to feel doubted to implement BIM (Zakaria et al., 2013; CREAM, 2014).

Additionally, the role of effective strategy such as BIM standard guideline and adoption model is important to answer all questions and enquiries from the construction players, which are where they to start, how is the BIM process work, what can BIM produces and who are responsible towards the process (Arayici et al., 2012; Building and Construction Authority (BCA), 2013). The guideline will help construction players to achieve all benefits of BIM implementation in construction project in a right way. Since BIM implementation in project design could reduce construction problems during construction stage, this research has develop a model that could assist design team to implement BIM in project design stage. The model could assist design team in a proper way to implement BIM, so they could gain all benefits of using BIM and increase efficiency in managing construction project life-cycle.
1.4 Research Questions

The research questions are as follows:

(i) To what extent did construction players use BIM in project design stage?
(ii) How BIM implementation in project design stage gives effect to construction players?
(iii) What are challenges of BIM implementation in project design stage?
(iv) How to assist construction players to implement BIM in project design stage?

1.5 Research Aim and Objectives

The aim of this research is to assist construction players to implement BIM in project design stage. In order to achieve the aim, the following research objectives are established:

(i) To determine the extent to which construction players use BIM in project design stage.
(ii) To identify the effects cause from BIM implementation in project design stage to construction players.
(iii) To identify the challenges of BIM implementation in project design stage.
(iv) To develop a model that could assist construction players to implement BIM in project design stage.

1.6 Scope of Research

The scope of this research is focused on construction projects in Malaysia, which have used and currently using BIM. The projects are residential and commercial projects. Therefore, all information regarding implementing BIM in design stage were obtained from design team, which are client, architect, structural engineer, Mechanical, Electrical and Plumbing (MEP) engineers as well as contractors. The contractor are involved in this research because most of the projects using BIM in Malaysia is using design and build (D&B) as project delivery method. According to Chappell (2007), contractor is involved in managing project design in design and build project.
Moreover, all respondents involved in this research must have been involved and currently involved in projects using BIM. This is important in order to gain their understanding and experiences in managing projects using BIM. Moreover, the information also important to discover current BIM practices in Malaysian construction projects. The information is very useful to identify level of BIM implementation in Malaysian construction projects.

1.7 Significance of Research

This research is expected to contribute to design team and the construction industry with:

(i) giving recommendation to design team on how to implement BIM in project design stage in a construction project. This could increase BIM implementation in construction projects.

(ii) producing a model that could assist design team to implement BIM and get benefits of using BIM in managing construction projects.

1.8 Research Methodology

Research methodology is one of the approaches in doing research. It is an approach to plan, to review and to control research process (Fellows and Liu, 2008). Figure 1.1 shows research methodology process for this research in order to achieve research aim and objectives.
Formulation of Problem Statement
Determine Research Aim and Objectives
Identification of Research Scope

Identifying Types of Research Strategy and Data Collection Technique:
1) Research Strategy: Survey
2) Data Collection Technique:
   ii) Semi-structured interview: Semi-structured interviews with design team (client, architect, structural engineer, MEP engineer and contractor)

Data Analysis: Content analysis
Results and Findings
Model Development
Conclusion and Recommendations

**Figure 1.1: Research Methodology Process**

Based on Figure 1.1, the research methodology process is divided into three (3) stages. The first stage is the process to identify research issues, topic selection, problem statement and research objectives. The researcher had brainstormed for research topic and had identified current issues on BIM implementation in construction projects. Moreover, the researcher has identified which construction projects in Malaysia are using BIM for the purpose of data collection.

The second stage shows types of research strategy and data collection technique used in this research. Survey is adopted in this study as the research strategy. Meanwhile, literature review and semi-structured interview were used in this study as data collection technique. The literature review is made to gain information on BIM implementation in project design stage and types of model, which related to BIM and construction field. All information on BIM and project design stage was gathered from books, journal articles, international conference papers, and materials available on the internet. Moreover, semi-structured interviews are conducted as data collection in this study to gain information from the design team on current BIM implementation in project design stage.

The final stage, stage three is divided into four (4), which are data analysis, results and findings, model development, conclusion and recommendations. All data gained from semi-structured interviews with design team are analysed using content
analysis. Both data from literature review and semi-structured interview were used for the purpose of model development. The content analysis view data representation through texts, images and expressions (Krippendorff, 2012).

Microsoft excel is used to assist researchers in analysing all the data. Conclusion and recommendation are the last chapter in this thesis. The conclusion summarised all chapters in this thesis. Meanwhile, recommendations are produced based on limitation to fulfil this study and recommendations made by the researcher in order to improve this research in the future. Details of research methodology process were discussed in Chapter 3.

1.9 Research Organisation

The research consists of six (6) main chapters. The chapters are as follows:

(i) **Chapter 1: Introduction**

This chapter consisted of introduction to research, background of research, problem statement, research questions, research objectives, scope of research, significance of research, research methodology, research organisation and summary of the chapter.

(ii) **Chapter 2: Literature Review**

Chapter 2 contained of literature reviews on construction project design stage and BIM. All information in this chapter consisted of introduction to construction project design stage; construction players in project design stage and issues on project design. This chapter also discussed on BIM in construction projects; definitions of BIM; implementation of BIM in the Malaysia construction industry; application of BIM in project design; tools; benefits; challenges to implementing BIM; future development of BIM in the construction industry and BIM adaptation in project design stage. Apart from that, this chapter also discussed about model development technique, which are related to BIM and construction field. The discussion contained of examples of model related to research model, similarities between the model and selection of maturity level
for the research model. This chapter end with explanations on theoretical framework and summary.

(iii) **Chapter 3: Research Methodology**

Chapter 3 discussed on research approaches, research strategies and data collection method. This is followed by methodology adopted for the research and discussion on each adopted approaches, methods used for data collection and data analysis.

(iv) **Chapter 4: Results and Findings**

This chapter consisted of findings from semi-structured interviews with the design team. Moreover, this chapter focused on current BIM practices in project design stage among design team. The trends of BIM implementation in project design stage are explored, which include BIM implementation in project design stage, effects of BIM implementation in project design stage, challenges of BIM implementation in project design stage and potential improvements of BIM implementation in project design stage.

(v) **Chapter 5: BIM Implementation Model For Design Team**

This chapter presented the establishment of the proposed model for this research. The establishment of the model was developed based on data gained from literature review and semi-structured interviews with design team. It discussed the model development process, starting from its design and followed by a description of the model. This chapter also explained the main features and content of the model.

(vi) **Chapter 6: Conclusion and Recommendations**

The main conclusion is drawn out in this chapter and the limitations of the research are highlighted. It revealed the finding and suggested recommendations for future research and it ended with a concluding remark.
1.10 Summary

This chapter has presented the main issues of BIM implementation in project design stage and justification for the need of research on BIM in project design stage. The aim and objectives of the research are stated in this chapter. This chapter also explored about the research planning and methodology used in this study. The structure of this study is presented at the end of the chapter.

The next chapter focused on literature review related to project design stage, BIM and model related to BIM and construction field.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed on application of BIM in project design stage. It consisted of introduction to construction project design stage, BIM in construction projects; its definitions, history and the implementation in the Malaysia construction industry. Furthermore, this chapter also explained on BIM application, BIM tools, it benefits to construction projects, challenges to implementing BIM, future of BIM in the construction industry and adaptation of BIM in project design stage. Moreover, models development technique, which related to BIM and construction field are also discussed in this chapter. Discussion on those elements is important to identify current practices of BIM implementation in project design stage and development of model that could assist construction players to implement BIM in project design stage.

2.2 Construction Project Design Stage

Construction project is symbolising social, cultural and technological development. It consists of numerous people, activities and requirements to fulfil client goals (NCCER, 2008; Jackson, 2010). A construction project can be divided into three (3) main stages, which are pre-construction, construction and post-construction (Cooper et al., 2005; Kazi, 2005; NCCER, 2008; Charted Institute of Building (CIOB), 2010). Figure 2.1 shows the construction project process.
Pre-construction Stage

- Project Design
- Project scheduling
- Cost Estimating
- Site Coordination
- Managing Materials and Machineries

Construction Stage

- Excavation of Foundation
- Framing
- Roofing and Siding
- Plumbing and Heating
- Electrical Work
- Interior Finishes

Post-construction Stage

- Final Inspection and Acceptance
- Project Close Out
- Owner Move In
- Warranty
- Project Evaluation

Figure 2.1: Construction Project Process (Adopted from: Cooper et al., 2005; Kazi, 2005; NCCER, 2008; CIOB, 2010)

Based on the figure, project design is the first activity in pre-construction stage. According to Eastman et al. (2011) and Memon et al. (2011), project design is considered as an important activity in construction projects. Project design has been produced by construction players in project design stage. Eastman et al., (2011) also mentioned that, project design is an activity, which consists of all information regarding a construction project. The information are such as project size, cost and building elements. Figure 2.2 shows the main activities in project design stage.

Figure 2.2: Activities in Project Design Stage (Adopted from: Klinger and Susong, 2006; Autodesk, 2008; Jackson, 2010; Crotty, 2012)

There are four (4) main activities in project design stage shown in Figure 2.2, which are programming and feasibility which also known as conceptual design, schematic design, design development as well as construction document or also known as detail design (Klinger and Susong, 2006; Autodesk, 2008; Jackson, 2010; Crotty, 2012). Details on each activity are as follows:

(i) **Programming and Feasibility Study**

Programming and feasibility study are usually done prior to the design process. It also known as conceptual design process (Weiler and Scholz-Barth, 2009). The
information that comes out during this stage is the project size, number of rooms, the use of each space and requirement for each function (Autodesk, 2008; Jackson, 2010). According to Jackson (2010), client is responsible to brief the architect regarding his or her needs and expectation to the project. Moreover, client also needs to clarify about his or her project’s budget to architect (Autodesk, 2008; Jackson, 2010). The information on project budget is important because architect is responsible to carry out the project design based on client needs and budget (McCarthy, 2007; Jackson, 2010).

(ii) **Schematic Design**

Schematic design also called as preliminary design, serves to establish the general scope of project, conceptual design, scale and relationships among the component of a project (Klinger and Susong, 2006; American Institute of Architect (AIA), 2009). Moreover, the objective of schematic design is to arrive at a clearly defined, feasible concept and to present all the information in a form that achieve client understanding and acceptance (Hess et al., 2007; AIA, 2009; Autodesk, 2008).

Furthermore, schematic design information can be used to demonstrate basic spaces, scale and relationship of each building components (AIA, 2009; Autodesk, 2008). Typically documentation at the end of schematic design will include several important items such as site plan, plans for each level, all elevations, key sections, outline specification, statistical summary of design area as well as other characteristics in comparison to the programme, a preliminary construction cost estimate, and illustrative of materials (Hess et al., 2007; AIA, 2009; Autodesk, 2008).

An architect will develop project design, which consist of several information such as a preliminary site plan, exterior elevation, floor plan and building sections (Klinger and Susong, 2006; Hess et al., 2007). The project design will contain only approximate dimensions. As part of schematic design process, architect may agree to provide services such as lifecycle cost analysis, energy studies, economic feasibilities studies, special rendering, models, brochures and promotional materials for the client. However, it is depends on client-architect agreement on ‘additional services’ where stated in American Institute of Architects (AIA) B201 form client-architect agreement form (AIA, 2009). AIA B201 is a document, which defines the architect’s traditional scope of services for design and construction contract administration in a standard form that client and architect can modify to suit the needs of the projects (AIA, 2009).
According to Klinger and Susong (2006), schematic design is only present 20 per cent of design effort. Client has to review and leave comments toward the design produced by architect after completion of this stage. The architect needs to obtain formal client approval in writing as prove or evidence that the client had agreed with the design (AIA, 2009).

(iii) **Design Development**

Design development is a third activity in design stage. The main objective in design development is to provide final design of project together with building systems in the project (AIA, 2009; Autodesk, 2008). Basically, the design development activity will be continued based on client comment and approval in schematic design. The architect will develop a detailed site plans, floor plans and building sections. In this stage, others design team which are structural and MEP engineers will collaborate to complete the design development. Structural engineer will produce detail drawings regarding building structural, building specifications, type of materials, and design sections. Meanwhile, MEP engineer will produce detail drawing regarding electrical, mechanical and plumbing system for a building. All the detailed drawing will be referred to drawings, which have been produced by architect. The architect drawing is the baseline to structural and MEP engineer detail drawings (Klinger and Susong, 2006; AIA, 2009).

The deliverables of the design development stage is similar to those of schematic design (AIA, 2009). This stage is important to allow the preparation of a preliminary construction estimate. Apart from that, the primary purposes of design development is to further define and describe all important aspects of the project so that what remains is the final step of creating construction documents (AIA, 2009). Klinger and Susong (2006) stated that design development only present 50 per cent of design effort. The client will review and leave he or her comments regarding the project design (AIA, 2009).

(iv) **Construction Document**

Construction document stage starts after obtained the client approval on design development. The approved design development will become a firm foundation for the construction document stage (Reiling, 2007). Construction document stage is the stage
which the architect, structural and MEP engineers focus on the preparation of
drawings and specifications that will issue for bidding and construction of
project (Reiling, 2007; AIA, 2009).

At this stage, design team has to finalise the project design (Hess et al., 2007;
AIA, 2009; Autodesk, 2008). A construction document consists of complete
drawing and accurate dimension of site plan, floor plan and elevations. The elevations
also include complete information regarding detail selection of materials, complete
mechanical, electrical, lighting, foundation, as well as structural drawings (Klinger and
Susong, 2006; AIA, 2009; Jackson, 2010).

The construction document also needs to be reviewed and approved by the client.
After obtaining client’s approval, the bidding tender will begin. Construction document
is important to contractor in preparing accurate cost estimate for the project. Moreover,
construction project will be constructed by the contractor based on information in the
construction document. According to Klinger and Susong (2006), construction
documents are the 100 per cent drawings for a project.

Basically, there are several construction players involved in managing project
design, which are client, architect, structural engineer, MEP engineers and contractor.
They are also known as design team (Klinger and Susong, 2006; Winch, 2010; Levy,
2010). Figure 2.3 shows the design team.

Figure 2.3: Design Team (Adopted from: Klinger and Susong, 2006; Winch, 2010;
Levy, 2010)

According to Klinger and Susong (2006), Winch (2010) and Levy (2010), client
can be divided into two (2), which are public sector and private sector. Meanwhile,
contractor consists of main contractor and sub-contractor. The design team is responsible to manage project design in order to increase project quality and avoid construction problems. Details on each design team are now discussed.

(i) **Client**

Client is the driving force behind the construction industry. According to Lock (2003) and Winch (2010), client is a person who has capital and desire to execute a project. Client is divided into two (2) different sectors, which are public and private sectors.

Public sector consists of ministries, local authorities and statutory boards. The examples of ministries are Ministry of Education (MoE), and Ministry of Public Work. Local authorities are Public Work Department (PWD), and Urban Utilities. Examples of statutory boards are Construction Industry Development Board (CIDB), and Board of Engineers (BOE). Public sector is responsible to provide free services to citizen. The examples of free services are such as road, hospitals, post-offices and schools (Kamara, Anumba and Evbuomwan, 2002; Winch, 2010).

Private sector or also known as non-government sector is a client that uses its own capital to develop own projects (Jackson, 2010). Basically, this type of client will rent their building to obtain capital and profits.

The roles of client in construction projects are to identify project needs, monitor project progress and prepare project cost. Basically, client will appoint consultants (architect, structural engineer and MEP engineer) to manage he or her construction projects. However, client also deserves to monitor the entire project progress to ensure the project runs smoothly (Abdullah, 2001; Winch, 2010).

(ii) **Architect**

Architect is a licensed professional trained in the art and science of project design. An architect is responsible to transform client’s programme into concept and develop the concept into building images and plans that can be constructed by contractor (Jackson, 2010). Architect also responsible to prepare design documentations and monitor design team works progress (Gahlot, 2002; Uher and Loosemore, 2004; Winkler and Chiumento, 2009). An architect also serves as client representative to monitor construction process during construction and post-construction stage (AIA, 2009). Other roles of an architect are to:
(a) develop schematic, preliminary and final designs (Gahlot, 2002; Uher and Loosemore, 2004; Winkler and Chiumento, 2009).

(b) coordinate design activities of other designers (structural engineer and MEP engineers). (Gahlot, 2002; Uher and Loosemore, 2004; Winkler and Chiumento, 2009).

(c) prepare tender documentation in the form of working drawings and specification (AIA, 2009).

(d) revise contract documentation (AIA, 2009).

(e) assist in resolving design-related problems (AIA, 2009).

(f) assist in controlling quality of construction projects (AIA, 2009).

(iii) **Structural Engineer**

Structural engineer is responsible to plan and prepare structural design for a project (Levy, 2010). Structural engineer is responsible to prepare structural working drawing or details design based on architect drawing (Gahlot, 2002; Levy, 2010). The roles of structural engineer are as follows:

(a) A design structure was created to withstand stresses and pressures such as weather and human use. A structural engineer needs to ensure that building structures are not bending, twist and collapse because it can cause to project delay, increase construction cost, and accident on site (Gahlot, 2002; Levy, 2010).

(b) Choose the appropriate materials, such as bricks, concrete and steels to meet the design specification (Gahlot, 2002; Levy, 2010).

(c) Collaborate with other construction players such as architect to discuss on safety design and aesthetic concepts of construction (Gahlot, 2002; Levy, 2010).

(iv) **Mechanical, Electrical and Plumbing (MEP) Engineers**

MEP engineers are responsible to prepare mechanical, electrical and plumbing design. However, MEP engineers will produce their design based on their discipline. Mechanical engineer is responsible to design the heating, ventilation, and air-conditioning (HVAC) system within a building (Gahlot, 2002; Jackson, 2010; Levy
Other roles of mechanical engineer are as the following (Gahlot, 2002; Jackson, 2010; Levy 2010):

(a) Provide structural engineer with the layout of underground utilities, which include pipe sizes, types and specifications.
(b) Confer with structural engineer to ensure that building structure and roof will have sufficient structural integrity to support the weight of equipment being designed.
(c) Confer with architect to ensure that sufficient spaces are allocated for equipment installation and for routine maintenance to take place.
(d) Provide structural engineer with size and location of floor penetrations required for HVAC, plumbing, electrical ductwork, and conduit that extends from floor to floor.

An electrical engineer is in-charge to design and prepare working drawing or details design for electrical power and distribution systems during and after construction process (Gahlot, 2002; Levy 2010). Other roles of electrical engineer mentioned by Gahlot (2002) and Levy (2010) are as follows:

(a) Supervise electrician in handling electrical works and considering the safety and quality requirement.
(b) Involve in preparing electrical design starting from concept and detail design, implementation, testing and handover.
(c) Researching suitable solutions for electrical ducting and estimating costs for whole electrical projects and timescale of a project.
(d) Collaborate with other construction players such as clients, architect, QS and contractor to detect design clashes between electrical, structural, and mechanical designs.

A plumbing engineer is in-charge to perform calculations on each size of plumbing equipment, prepare plumbing design, and construction document related to plumbing installation (Gahlot, 2002; Levy 2010). A plumbing engineer works under the supervision of mechanical, fire protection, and professional engineers. The role of plumbing engineer is to design the building primary plumbing equipment such as water tank, pumps, and fixtures (Boswell, 2013). According to Gahlot (2002), Levy (2010),
and Whole Building Design Guide (WBDG) (2013), other roles of plumbing engineer are as the following:

(a) Prepare design process of fluid flow system. The process is important to facilitate piping installation during construction stage.

(b) Design plumbing system. Plumbing system requires proper design and follows official plumbing code and ensuring code compliance.

(c) Advice on ideal location and capacity for treatment plan, septic tank, sump, and general direction in which waste is to be disposed depending on topography of the land, road and public sewer location.

(d) Prepare a schematic plumbing layout and details specification for the entire plumbing works.

Contractor

Contractor is a party who perform and complete a project based on tender contract. A contractor is responsible to plan, control, manage, and coordinate construction works to make sure that risks such as project delay and cost overrun could be avoided (Mosey, 2009; Health and Safety Execution (HSE), 2013). There are two (2) types of contractor, which are main contractor and subcontractor. The role of main contractor is to provide the total scope of works required in the contract. The main contractor must also control and coordinate all necessary production activities during construction stage. Subcontractor is responsible to manage tasks given by the main contractor (Boyle, 2003; Towey, 2012). Other roles of contractor in a construction project are as the following (Mosey, 2009; HSE, 2013):

(a) Plan, manage, and monitor the entire project process to avoid construction problems during construction stage.

(b) Provide labours and subcontractors to accomplish construction works. Labour need to accomplish construction works according to project drawing. Subcontractors need to accomplish construction works according to main contractor instruction.

(c) Supervise labours and provide materials and equipments for construction works.
As a conclusion, design team are responsible to manage project design. The cooperation among them is important in order to avoid construction problems. According to Sambasivan and Soon (2007), Forbes and Ahmed (2011) and Kikwasi (2013), low design constructability is one of factors contribute to several construction problems such as low of construction productivity, low of project quality, project delay, construction cost overrun and disputes among construction players (Sambasivan and Soon, 2007; Forbes and Ahmed, 2011; Kikwasi, 2013). The factor contributes to construction problems need to be explored in order to avoid it during managing construction projects. Other factors contribute to construction problems, which are related to project design, are specified in Figure 2.4.

<table>
<thead>
<tr>
<th>Project Design Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Design changes</td>
</tr>
<tr>
<td>• Design clashes</td>
</tr>
<tr>
<td>• Poor design constructability</td>
</tr>
<tr>
<td>• Poor 2-dimensional (2D) drawing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contribute to construction problems such as:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Low of construction productivity</td>
</tr>
<tr>
<td>• Project delay</td>
</tr>
<tr>
<td>• Low of project quality</td>
</tr>
<tr>
<td>• Construction cost overrun</td>
</tr>
<tr>
<td>• Disputes among construction players</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building Information Modelling (BIM) implementation in project design stage</td>
</tr>
</tbody>
</table>

Figure 2.4: Project Design Issues (Adopted from: Sambasivan and Soon, 2007; Forbes and Ahmed, 2011; Kikwasi, 2013)

Based on Figure 2.4, there are four (4) factors that contribute to construction problems which are changes in project design, design clashes, poor design constructability and poor 2D drawings. Details on each factor are as follows:

(i) **Changes in project design**

(a) Changes mean modifications of an original contract that effectively change the provision of contract, changes in design specifications, method of performance, facilities, equipment, materials, site and completion of work. All changes made must be recorded through letter confirming and approved by client, architect as well as engineers. Any changes in design during construction stage will effect to project delay, construction cost...
overrun and disputes among construction players (Emmitt and Yeomans, 2008; Emmitt and Ruikar, 2013).

(ii) **Design clashes**
(a) Basically, design clashes occur between architectural, structural and MEP designs. It happened when one of the designs has not been monitored properly after the designs changes. The design errors or clashes were high risk and only can be detected by contractor during the construction stage of the project (Wang *et al.*, 2013). The contractor will seek any solution, direction and resolution from the architect or engineers with RFI. The architect and engineer will provide a response that may or may not affect the project cost or schedule (McCarthy, 2010). However, late respond to RFI issues by contractor can cause to project delay.

(iii) **Poor design constructability**
(a) Constructability means prime use of construction knowledge and experiences in planning, design, procurement and field operation in order to achieve construction project objectives. Lack of design constructability is caused to construction cost overrun and quality of end product issues faced by the construction industry (Gambatese, Pocock and Dunston, 2007). Moreover, design clashes among the design disciplines (architect, structural and MEP designs) are difficult to identify and analyse. This problem can cause to low construction productivity and low of project quality (Haron, 2013).

(iv) **Poor of 2D drawing**
(a) Traditionally, project design will be produced by using computer aided design (CAD) system. The drawing will come out in 2D concept where the use of 2D drawing was difficult to be understood (Lee *et al.*, 2003; Haron, 2013). These problems also lead to insufficient drawing and specification.

In order to avoid all the construction problems, ICT has introduced building information modelling (BIM) to overcome construction problems (Forbes and Ahmed, 2011; Crotty, 2012). BIM is an emerging technology, which can improve
performances and productivities of design, construction, operation and maintenance process (Love et al., 2013). It can be applied in construction projects to manage construction projects stages appropriately especially project design stage. Moreover, the use of BIM in project design stage increases accuracy in preparing schematic design, design development and construction documentation.

2.3 Building Information Modelling (BIM)

Building Information Modelling (BIM) is used by construction players to increase efficiency and effectiveness in managing construction projects. It is known as an approach to manage construction projects with relief from several set of tools such as Autodesk Revit, Tekla, Vico Office, ArchiCAD and Bentley System (Robinson, 2007; Forbes and Ahmed, 2011; Monteiro and Martins, 2013). The used of the tools help construction players to manage construction projects by detecting common problems occur during construction stage such as design clashes, design changes and incomplete design specifications (Kymmell, 2008).

BIM has been utilised in construction projects to manage the continuous and availability of construction projects activities. The activities are design, cost estimating, project scheduling, site coordination and facilities management (Barrington, 2010; Eastman et al., 2011; Succar, 2013). Moreover, BIM implementation in construction projects can avoid project delay, construction cost overrun and disputes among construction players, which are client, consultants and contractors (Smith and Tardif, 2009; Forbes and Ahmed, 2011).

The AEC industry in USA, Australia, Finland and HK have expressed their interest in adopting BIM as a tool to manage construction projects (Azhar, 2011; Forbes and Ahmed, 2011; Eastman et al., 2011; Levy, 201). The first impression of BIM implementation can be seen through project design stage where BIM has improved design management tools in the AEC industry from 2D to 3-dimensional (3D) (Yan and Damian, 2008). Others than that, BIM provides many benefits to construction players. The benefits are detecting design clashing, increases accuracy in cost estimating, project scheduling, and improves communication as well as collaboration between construction players (Forbes and Ahmed, 2011; Reddy, 2012).
REFERENCES


Dore, C. & Murphy, M. (2012). Integration of Historic Building Information Modeling (HBIM) and 3D GIS for recording and managing cultural heritage sites. In Virtual Systems and Multimedia (VSMM), 2012 18th International Conference on (pp. 369-376). IEEE.


