DEVELOPMENT OF FRAMEWORK FOR BUILDING CHANGE INFORMATION MODELLING (BCIM)

LEONG KAR KANG

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) Quantity Surveying

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

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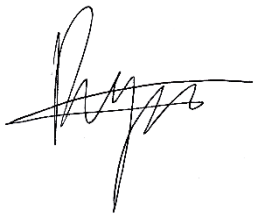
DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : 

Name : Leong Kar Kang

ID No. : 17UEB06577

Date : 16/05/2020

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I certify that this project report entitled **"DEVELOPMENT OF FRAMEWORK FOR BUILDING CHANGE INFORMATION MODELLING (BCIM)"** was prepared by **LEONG KAR KANG** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) Quantity Surveying at Universiti Tunku Abdul Rahman.

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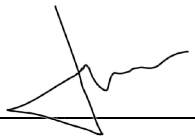
Signature : 

Supervisor : Mr. Li Zi Qian

Date : 16/05/2020

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ABSTRACT

Construction change is an important aspect of the project, as changes often result in time delays, cost overruns, quality defects, negative impacts and very often lead to disputes. Related to this, many initiatives have been proposed to mitigate the impact brought about by changes. One of the methods is to leverage digitalised construction, such as Building Information Modelling (BIM). BIM has transformed the construction project into a digital construction, in the form of virtual 3D building in which provides detailed information as well as identifying their relationship between objects. The research aims to develop a Building Change Information Modelling (BCIM) for managing changes in construction project. These existing researches often focused mainly on visualization and identification of change without being completely integrated with BIM. The research attempts to identify the current practices in the construction industry with a view to develop an integrated framework. Central Limit Theorem was adopted in this research to ensure the reliability and validity of the data. A total of ninety-seven sets of questionnaire responses were used in the research and a total of three interviewees were successfully interviewed who working as a quantity surveyor in a consultancy firm in the Klang Valley area. The interview and questionnaire surveys were conducted to solicit the current practices of change management and BIM, including the shortcoming of current practices. This research identified nine essential features that must be included in the BCIM system. The nine features, including facilitating knowledge capture and sharing from BIM model and process, developing a standard change procedure, comparing two revisions of models, showing updated components to the original model with reason of changing, remaining data confidential, cloud-based to enhance data interoperability, synchronizing data on a serve with mobile device application, integrating BIM and change management, and integrating the company's database with the proposed system. In addition, the findings also revealed that there was a significant difference in the perception between the respondent groups about the benefits of BIM, to improve information flow. In more details, the category with less than five years working experience has been defined as a significant difference category on the perceptions of BIM has been able to improve information flow. This research is expected to develop an integrated framework to enhance the performance of project design changes, improve coordination with all parties and manage the project efficiently throughout the project lifecycle.

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LIST OF SYMBOLS / ABBREVIATIONS

BIM	Building Information Modelling
CM	Change Management
BCIM	Building Change Information Modelling
PCO	Potential Change Order
HVAC	Heating, Ventilation and Air-conditioning
RFP	Request for Proposal
RFI	Request for Information
ICKMS	Integrated Change and Knowledge Management System
EPPMS	Electronic Product and Process Management
GEN 1	Generation One of Change Management
GEN 2	Generation Two of Change Management
GEN 3	Generation Three of Change Management
CCS	Change Control System
GDP	Gross Domestic Product
CAD	Computer-Aided Design
IBPLM	Integrated Building Lifecycle Process Model
3D	Three Dimensional
2D	Two Dimensional
M&E	Mechanical & Electrical
SPSS	Statistical Package for the Social Sciences
ICT	Information and Communications Technology
WEB	World Wide Web
MEP	Mechanical, Electrical and Plumbing

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Construction is one of the most fragmented industries. This is because the project participants such as client, architect, contractor etc, can be the ones who demanding change after the start of the project. Most of the construction projects, very often changes are not limited to design phase, but also happens throughout the construction phase (Hao, et al., 2010). Change is the modification to the original scope of the project and subsequently will cause the project to require more resources to complete the task (Hanna, et al., 2002). Moreover, change in construction industry is generally acknowledged as one of the key sources of a construction project's cost overrun, delay, and low quality (Burati, Farrington and Ledbetter, 1992). The consequence brought about by changes are the incurrent of additional cost, delay which frequently lead to conflicts between contractor and client. In fact, changes in a project can incur 7% to 10% cost overrun from the contract sum and affect the productivity of the final product (Moselhi, Assem and El-Rayes, 2005).

In 1963, a notable person who has good knowledge in Internet of Technology, also known as father of computer graphics, developed "Sketchpad" for the very first computer-aided design (CAD) with the graphical user interface. With 2D, the details of the projects are in the drawing itself, including design, figure, description and so on, which are important for the construction. Upon removed drawing from the project file, an important, integrated part of the project is removed entirely. It then started to develop continuously for the construction industry. Within 1970 to 1980, the sketchpad is further evolved to a certain extent that able to display of model as well as record of shape in detail information. The continuously development of the sketchpad has triggered the invention of Building Information Modelling (BIM) in 1986 (CADAZZ, 2004).

In addition, Building Information Modelling (BIM) has transformed the construction project to certain extent as BIM is an Information Technology enabled approach to overcome the limitations of traditional 2D designs. According to National Institute of Builkding Sciences (2007), construction industry will depend much on digitalization industry in the future. National Building Specification (2018) reported that the increasing number of construction players to adopt BIM because of its wide usage in many stages of construction project lifecycle and creating significant benefits for the stakeholders (Seo and Ju, 2014). Figure 1.1 shows the worldwide adoption of BIM from 2011 to 2018. In Malaysia, Construction Industry Development Board (2018) has established a platform called myBIM Centre in 2017 and this platform is targeted to increase and promote the use of BIM. On the other hand, BIM as a modelling technology and is also defined as "a digital representation of physical and functional characteristics of a facility" (BSA, 2012). In other words, the digital data depends much on the user's inputs to construct a completed digital modelling (Conover, et al., 2009). From various definition, as a digital data of BIM, is in the form of virtual 3D building in which provides detailed information as well as identifying their relationship between objects. Therefore, BIM technology can actually increase the value and effectiveness for any of the project.

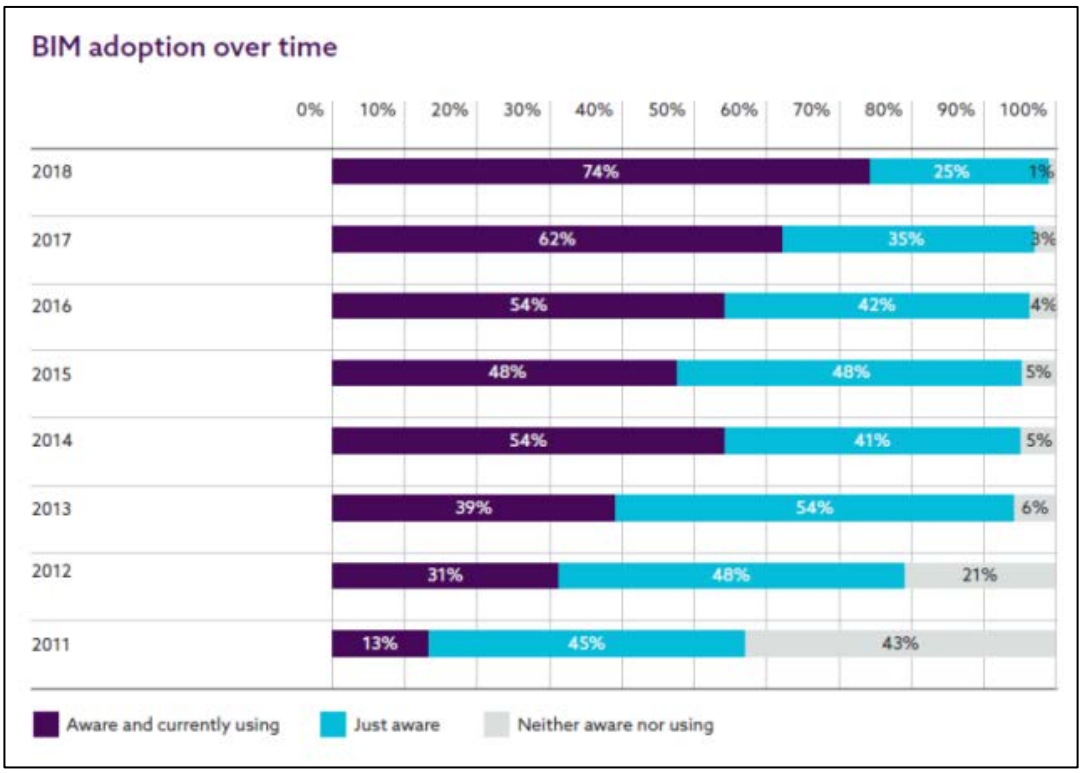

Figure 1.1: Worldwide Adoption of BIM from 2011 to 2018 (National Building Specification, 2018)

1.2 Problem Statement

According to Maisarah and Julia (2017), many construction firms are still adopting paper-based working drawing and 2D designs in the construction project. The complexity of project and high demand by client has triggered the need of BIM in construction industry. BIM, the evolution of 2D model-based, is able to reduce design error and, in consequence, reduction of design changes. Juszczyk, Tomana and Bartoszek (2016) mentioned that it is impossible to have no design changes throughout the project. The construction industry is considered as an extremely fragmented due to owner's preference to change the scope of work, consultant related variations, contractor's inefficiency in planning and unforeseen issues. In short, all of these changes in the construction process create difficulties for all project stakeholders and increase the possibility of contractual dispute. However, the integration of BIM and change management or software would improve the productivity of the project in dealing with any changes due to the efficiency of monitoring, controlling and updating in projects' life cycle (Sun, et al., 2006; Du, El-Gafy and Zhao, 2015; Heravi and Charkhakan, 2015; Valeh, Osama and Zhu, 2017).

In addition, it is found that extensive personal experience is required to make decision in the construction projects and there is lack of standard procedure for dealing changes. In other words, the changes are mostly manually managed and implemented without identifying possible consequences. This issue is commonly seen as negatively affecting the efficiency of projects. Put it simply, a platform is needed to capture lesson learned and best practice throughout the project to assist team members for making decisions or addressing problem for the up-coming project (Ibbs, Wong and Kwak, 2001; Valeh, Osama and Zhu, 2017).

The existing change management studies only focused on identifying changes without fully integrating with BIM (Sun, et al., 2006; Langroodi and Staub-French, 2012; Liu, et al., 2013; Karimidorabati, Haas and Gray, 2016; Mejlaender-Larsen, 2016; Valeh, Osama and Zhu, 2017). These studies only leverage BIM for visualization purpose without capturing the information to BIM model. The need to associate the knowledge and information to the BIM models and standard change procedure is vital to be developed. Therefore, this research is to minimize the gap by proposing a framework for the integration of change management with BIM. It is envisaged that the framework would benefit the ongoing project as an improvement in the performance of project design changes and better coordination with all parties.

1.3 Aim and Objectives

This research aims to develop a Building Change Information Modelling (BCIM). The aim is achieved through the following objectives:

i. To discuss the benefits of Building Information Modelling.
ii. To explore the current approaches of change management.
iii. To propose a framework for Building Change Information Modelling (BCIM).

1.4 Research Methodology

Mixed method research allows the combination of numerical measurement and in-depth exploration on the current change management and BIM. In order to propose BCIM system that could beneficial to construction project, the mixed method adopted to explore the current practices of change management and BIM, including the limitation of current approaches. Three hundred sets of questionnaires were distributed to the consultant quantity surveyor within Klang Valley area, and total five requests have been sent to consultant quantity surveyor for conducting interviews. Of the 314 sets of questionnaires, 97 sets of questionnaire responses were used in this research, and a total of 3 interviewees were successfully interviewed. The data collected are used to combine the interviewee's opinion and gather the fact from respondents in a single study in order to develop the framework for BCIM. Besides that, descriptive and inferential statistics were employed by using SPSS, whereas the interviews transcribed and narrative analysis were conducted to explore the current practices of change management and the requirements for the development of the BCIM framework, as well as the limitation of current approaches. The research findings used to develop an integrated framework for managing changes efficiently.

1.5 Scope of Study

The scope of study is limited to consultant firm in Klang Valley area, where majority of the consultant firm uses BIM for cost estimation and identify changes at early stage of project, while the use of BIM in contractor and developer firms are lower compared to consultant firm. The target respondent and interviewee for this research is the quantity surveyor, because most of the quantity surveyors have a higher level of involvement in dealing with BIM and change management throughout the project.

1.6 Chapter Outline

Chapter 1 outlines the background study of the research. It also covers the problem statement and rationale of this research. Subsequently, it reveals the aim and objectives, research methodology, and research scope. Lastly, it introduces the summary of each chapter in this research.

Chapter 2 outlines a brief definition on both BIM and CM as well the benefits that brought to the construction industry. It also covers the construction changes classification. It further reviews the change management process, current approaches of change management and limitation of current approaches to change management.

Next, chapter 3 outlines the brief definition of research. Subsequently, it explains the type of research method, approaches to data collection and data analysis method. It also covers the research design for this research. It also reveals the target respondents and sample size for this research. Lastly, it develops final year project milestone.

Chapter 4 represents the data collected from questionnaires and interview transcripts. In particular, this chapter analyses and evaluates the data collected from sampling to provide the insight into the research topic. The framework of BCIM is drawn in a diagram. The finding for this research is further reported in detail.

Lastly, chapter 5 concludes the research findings of the research. It covers the research implication and the limitation of the entire research. Finally, the recommendations for this research are revealed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a brief definition of both BIM and CM and the benefits to users who adopt BIM and CM. It also covers the change of orders that occur during the different phases of the construction project. A brief literature review of the type of change management that has been adopted in the construction industry and review of the various type of change management concept. Lastly, this chapters reveals the limitation of current approaches.

2.2 Building Information Modelling (BIM)

American National Institute of Building Sciences (2004) explains BIM as "a computable representation of the physical and functional characteristics of a facility and its related project/ life-cycle information using open industry standards to inform business decision making for realizing better value". BIM is an intelligent 3D model-based process for the purpose of displaying of design, managing project, and planning of project entirely (Autodesk, 2019). BIM is also referred as "a modelling technology and associated set of processes to produce, communicate and analyse building models" (Eastman, et al., 2008). Gao, Koch and Wu (2019) perceive that BIM is able to provide appropriate data to different user's needs due to the rich data storage, and intelligent modelling tool. Harness (2008) explains that BIM is the process and technology used to create the model which then can serves as a shared knowledge resources for information about the model and form a reliable basis for decisions making throughout the project from inception onward. BIM is able to provide design mistake reduction by detecting clash of components, especially for mechanical and electrical elements (Love, et al., 2011). Fountain and Angar (2018) further point out that such digital models are meant to "stimulate the construction project in a virtual environment".

2.3 Benefits of Building Information Modelling (BIM)

BIM provides numerous benefits to all the construction project. The following identified benefits of BIM offers to the construction industry that are to improve information flow, better design visualization, resolve conflicts, improve cost estimation, maintain control, reduce uncertainty, cost and time saving.

2.3.1 Improve Information flow

According to Olatunji, et al. (2010); Boukara and Naamane (2015), BIM provides a digital model-based for user to improve the flow of information at any stage of the project, such as design stage and construction stage. The digital model enables architects, Mechanical, Electrical and Plumbing (MEP) engineers, contractors, facilities managers, and clients to have simple access to different stages of the building life cycle. Therefore, the software allows team members to update and input information in a give-and-take manner simultaneously.

2.3.2 Better Design Visualization

The intelligent 3D model-based of BIM provides project team members with the ability to visualize the design through a virtual life system (Olatunji, et al., 2010; Boukara and Naamane, 2015; Autodesk, 2015). In other words, this visualization is an animation of real-life concepts. For instance, a virtual model design is very helpful to Mechanical and Electrical Engineering in optimizing the layout of the heating, ventilation and air-conditioning (HVAC) system, where these systems are very difficult to be arranged without clashing each other under conventional tools (Laine, Hanninen and Karola, 2007). Therefore, should the model can be visualised, it will benefit the team members during the early stage.

2.3.3 Resolve Conflicts

The BIM software helps to automate clash detection on potential design conflict to ensure the final design is workable and buildable during construction phase (Boukara and Naamane, 2015; Autodesk, 2015; Agyekum-Kwatiah, 2018). For example, HVAC systems that clashes with a beam will be easily detected by BIM. This automatic clash detection will eliminate the unnecessary need for changes during the construction stage. Through clash detection in BIM software, intense clashes can be identified and automatically detected.

2.3.4 Improve Cost Estimation

In addition, BIM helps every project with accurate cost estimation due to its auto-quantification (Azhar, Hein and Sketo, 2009; Olatunji, et al., 2010; Boukara and Naamane, 2015; Kjartansdottir, et al., 2017). It is an extremely fast and convenient to acquire the auto-quantification of materials from the similar project that has already been carried out and, thus, the budget concerns can be dealt with as soon as the cost of estimate is identified during the feasibility phase.

2.3.5 Maintain Control

BIM is regarded to be a process for creating and managing project data because the digital model-based workflow of BIM is able to autosave the model and retrace the history of the model (Autodesk, 2015). Therefore, the use of history may prevent BIM users to lose their important information or data. In other words, the autosaving and retracing function plays an important role in securing the works of the project entirely before the completion of the project.

2.3.6 Reduce Uncertainty

Conventional application has increased the uncertainty due to fragmented processes (Underwood and Isikdag, 2010), but the BIM model provides reliable information due to timely delivery and timely receive of information between team members, ensuring that parties have access to up-to-date project information at all times (Autodesk, 2015). In other words, by bringing all project documents/ information to a single view, BIM enables team members to collaborate and communicate more effectively.

2.3.7 Cost and Time Saving

The BIM provides a significant cost reduction due to the intelligent 3D model-based of BIM that reduces the need for rework in preparing drawings and construction works. In addition, the model contains more information than a drawing set, which is convenient for team members to acquire more information rather than relying on drawings. Therefore, the speed and computerized of BIM software is a remarkable tool for cost and time saving (Azhar, Hein and Sketo, 2009; Autodesk, 2015; Boukara and Naamane, 2015; Kjartansdottir, et al., 2017).

2.4 Definition of Change in the Construction Industry

Change in industry sector is defined as alteration to conditions and assumptions (Sun, et al., 2006; Sun and Meng, 2009). In construction industry, project is considered as unique product which is subjected to a high degree of changes. Motawa, et al. (2007) identify change as any unplanned and change to execution sequence. An unplanned development can be known as “unintended change” with no proper planning to deal with the changes. Nevertheless, the anticipated change is those change with intentionally to make change to the original scope of contract. The changes in project usually happen during the project before it happens (Motawa, et al., 2007). Furthermore, Jarratt, et al. (2011) note that change can be emergent, which arise spontaneously and are not anticipated.

2.5 Classification of Construction Changes

In construction industry, it is common to have changes at any of the project stages caused by the various causes throughout the project life cycle. Changes occur at any of the project stages would bring a negative or positive impact towards the project such as additional cost incurrence of, delay construction work programme, quality and etc. Hence, it is best to identify in the context of the various stages of a construction project as the construction project is unique. Construction changes can happen at three different stages, namely inception stage, design stage, and construction stage (Hao, et al., 2010).

2.5.1 Inception Stage

At the initial, stakeholders might initiate changes due to certain unanticipated changes in terms of their financial issues, personal preferences and etc. Mohamad, Nekooie and Al-Harthy (2012) found that there are three major causes of changes by employer which including modification to the original design, variation order work and lack of sufficient information during design brief. Specification changes are mainly triggered by change of original project scope by the employer or the employer’s representative (Hwang, Zhao and Goh, 2014). On the contrary, specification changes may be due to external causes, including materials, availability of tools and machineries, condition of economic and government policies (Alaghbari, et al., 2007).

2.5.2 Design Stage

Stakeholders take further consideration and carefully when preparing M&E drawings and Architectural drawings during design stage because design error will cause significant to the project outcome. This could lead to the need for rework and additional resource expenditures to be required (Han, Love and Pena-Mora, 2013). The project team members often misinterpret the employer's needs due to lack of communication between design team and employer during design stage (Thomson, et al., 2003; Love, Frani and Edwards, 2004). Mohamad, Nekooie and Al-Harthy (2012) identified the causes of design change in most of the projects are improper design, inconsistent of drawings, discrepancy between contracts, incompleteness to carry out land survey. Andi and Minato (2003) stated that human mistakes and errors are the main causes of design changes.

2.5.3 Construction Stage

Lastly, changes in construction stage usually is initiated by main contractor and sub-contractor. Furthermore, both are responsible to deal with all changes made in construction stage. This is because the main contractor has full responsibility for the operations of the site when the ownership of the site is granted to the main contractor. Mohamad, Nekooie and Al-Harthy (2012) identified causes of change in construction stage by contractors are due to propose of alternative construction method and materials, rectify of works, and poor quality of end products. Apart from that, Sun and Meng (2009) listed other important causes that will initiate changes in the construction stage, including poor site management, delays in appointing subcontractor, low quality of workmanship, low productivity, and poor logistic control. Site condition is the main cause of changes in construction stage when contractor has started their work on site. This condition of neighbourhood (Love, et al., 2002) and condition of land (Mohamad, Nekooie and Al-Harthy, 2012) will cause change to project.

2.6 Change Management (CM)

Sun, et al. (2006) interpret the purpose of change management is to identify possible changes, evaluate the impacts of changes and coordinate changes before or after the changes of the event throughout the project. Due to time consuming in change management process, it is advisable to manage changes that give noticeable impact to the project. Construction Industry Institute (1994) defines change is to make changes to an agreement between project team members. Moreover, Construction Industry Institute (1994) considers the scope of project, organisation of project, method of work execution, method of control, and allocation of risk that are subjected to the changes in the project. On top of that, change management is an overall work process that involves proactive measures to effectively manage the change, time, cost and quality (Mejlaender-Larsen, 2016).

2.7 Benefits of Change Management

The benefits of change management include the quality of work and productivity improvement, time saving, cost saving, efficiency improvement, collaboration and communication improvement.

2.7.1 Improve Productivity

According to Change Management Coach (2017), the quality can be improved by team members who always assesses the overall of change during the process of change management. A change management process can lower the risk associated with change. In addition, a clearly defined change management process method can identify the responsibility of each party. For instance, the final decision making can only be made by client instead of by designer or contractor.

2.7.2 Time Saving

The change management reviews the change order is time consuming, but having the change management process indirectly saves time for the project, i.e. the contractor may reduce the chances of rework that wastes time to perform unnecessary tasks (Change Management Coach, 2017).

2.7.3 Cost Saving

According to Change Management Coach (2017), the adoption of CM process would result in a substantial cost savings during the construction as the process starts by identifying the right parties once the contract has been awarded. The right person is the architect, designer, contractor, client and etc, who provides their expertise and makes a comparison before any change is implemented.

2.7.4 Improve Efficiency

Change Management Coach (2017) explains CM in project provides a way to anticipate the impact of potential change or ripple effect of the main source of change with project key members and subsequently respond to the change by the remedial works.

2.7.5 Improve Collaboration and Communication

The information pertaining to change can be known by every parties such as client, consultant, contractor and etc. This is because if any change initiated by the parties are to be reviewed by other parties for approval through the change management process (Change Management Coach, 2017).

2.8 Change Management Process

The change management process structure provides a guideline for every project team member to process change orders in construction project (Du, El-Gafy and Zhao, 2016). Table 2.1 shows the various change management process by different researchers. It will be described in detail in the subsequent section.

Table 2.1: Change Management Process

Change Management Process	Previous Study						
	Ibbs, Wong and Kwak (2001)	Motawa, et al. (2007)	ORACLE (2009)	Jarratt, et al. (2011)	Cho, et al. (2015)	Mejlaender-Larsen (2016)	
General Project Execution Phase							
Promote a balanced change culture	✓						
Start-up		✓					
Identify the contract requirements			✓				
Filtration and Assessment Phase							
Identification						✓	
Recognize change	✓						
Identify and evaluate		✓					
Identify the potential change and create a potential change order file			✓				
Engineering change request raised				✓			
Identification of possible solution				✓			
Identify change					✓		
Filtration						✓	
Evaluate change	✓						
Determine entitlement, measure effect and calculate the cost of the change			✓				

Table 2.1: Change Management Process (Continued)

Risk/ impact assessment of solution				✓		
Operate change					✓	
Evaluation						✓
Approval and Implementation Phase						
Implement change	✓					
Approval and propagation		✓				
Negotiate and execute the change order			✓			
Selection and approval of a solution by change board				✓		
Implementation of solution				✓		
Re-establish the plan					✓	
Approval						✓
Implementation						✓
Control Strategy Phase						
Post change		✓				
Continuously improve from lessons learned	✓					
Review of particular change process				✓		
Maintain complete records of the executed change			✓			

2.8.1 General Project Execution Phase

For general project execution, the change management strategies adopted are to promote a balanced change culture, start up and identify the contract requirements.

2.8.1.1 Promote a Balanced Change Culture

Parties of project focus on the communication and documentation among team members to ensure the success of the project. These actions will eventually solve the conflicts between the team members through the communication process. In addition, the team members will begin by identifying the potential changes and prepare for the changes proactively (Ibbs, Wong and Kwak, 2001).

2.8.1.2 Start-Up

Start-up is to prepare a project team ready for effective change management and the purpose is to prepare the team for both anticipated and unanticipated changes (Motawa, et al., 2007).

2.8.1.3 Identify the Contract Requirements

Project parties shall identify the contract criteria at the beginning of the stage before the change can be recognized (ORACLE, 2009).

2.8.2 Filtration and Assessment Phase

For the filtration and assessment phase, the change management strategies adopted are to identify, recognize change, identify and evaluate, identify the potential change and create a potential change order file, engineering change request raised, identification of possible solution, identify change, filtration, evaluate change, determine entitlement, measure effect and calculate the cost of the change, risk/ impact assessment of solution, operate change and evaluation.

2.8.2.1 Identification

Mejlaender-Larsen (2016) explains change management routines are established in order to manage change in a formal process. The change manager prepares both list of design change request and potential change from team members and presents it to the Change Board.

2.8.2.2 Recognize Change

Ibbs, Wong and Kwak (2001) interpret the need for team members to identify potential changes in an open discussion group. Once changes have been identified, the team member may determine the changes as required or elective. Team members are responsible for assessing the effects of the changes to the project, and action should be taken if negative impacts appeared.

2.8.2.3 Identify and Evaluate

According to Motawa, et al. (2007), the potential changes have to be identified by project team members at the early stage. Evaluation is necessary to be carried out for providing precise decision-making process before the approval by the key members.

2.8.2.4 Identify the Potential Change and Create a Potential Change Order File

The potential change is required to be identified before potential change order (PCO) file is created by any of the project team member such as client, consultant, contractor, nominated sub-contractor and etc. The purpose of the PCO is to track changes and provide a basis for evaluation (ORACLE, 2009).

2.8.2.5 Engineering Change Request Raised

Team members can request engineering change, either in electronic or paper form, with the necessary information such as reason, type of change and consequences. A change request will be sent to the engineering database for team member to review (Jarratt, et al., 2011).

2.8.2.6 Identification of Possible Solution

According to Jarratt, et al. (2011), the potential solutions must be identified in order to proceed with the evaluation of the potential solutions.

2.8.2.7 Identify Change

The project team members identify the changes by collecting, checking and reviewing the information from new changes item, plan changes as well as design changes (Cho, et al., 2015).

2.8.2.8 Filtration

The Change Board will assess the change through formal process in which the changes are initially prepared by change manager (Mejlaender-Larsen, 2016).

2.8.2.9 Evaluate Change

The team member will take into consideration whether to accept and implement the change or take long time to check whether the change is necessary to implement if the change is without a time constraint (Ibbs, Wong and Kwak, 2001).

2.8.2.10 Determine Entitlement, Measure Effect and Calculate the Cost of the Change

ORACLE (2009) explains employer or consultant evaluates the PCO in the following sequence: establishing entitlement, measuring effects and pricing costs. Once the activities have been conducted, the client or consultant will determine whether additional time and cost are to be granted.

2.8.2.11 Risk/ Impact Assessment of Solution

The project team members will assess the impact of every possible solution that have made to the change request (Jarratt, et al., 2011).

2.8.2.12 Operate Change

Cho, et al. (2015) explain when the changes that have been identified and confirmed shall save to the database including its impact.

2.8.2.13 Evaluation

Change Board will comment the impact of the changes to the change manager in order for change manager to consider whether is viable to proceed with the changes (Mejlaender-Larsen, 2016).

2.8.3 Approval and Implementation Phase

For approval and implementation phase, the change management strategies adopted are to implement change, approval and propagation, negotiate and execute the change order, approval on the workable solution, re-establish the plan, approval and implementation.

2.8.3.1 Implement Change

The team members are required to inform all the pending change that will directly or indirectly affecting the project by proposing a change to the upper management for their decision-making. Monitoring the process of the implementation should be carried out as well (Ibbs, Wong and Kwak, 2001).

2.8.3.2 Approval and Propagation

The client or project manager reviews and approves on the particular changes based on the gathered information of estimated impact of the changes to the project (Motawa, et al., 2007).

2.8.3.3 Negotiate and Execute the Change Order

The client reviews the response to a request for proposal (RFP) by the contractor. The client either reject or approve the proposal. Both the client and contractor should work together because collaboration might allow both parties to find a middle solution during the negotation process based on trust. However, if there is a dispute between the parties, they can resolve their problem by arbitration or litigation or dispute resolution board (ORACLE, 2009).

2.8.3.4 Selection and Approval of a Solution by Change Board

The Engineering Change Board shall review the approved solution for the proposed change and finalize the approval prior to implementation (Jarratt, et al., 2011).

2.8.3.5 Implementation of Solution

According to Jarratt, et al. (2011), the engineering change should be pending for approval to implement either immediately or phase by phase.

2.8.3.6 Re-Establish the Plan

The plan in the temporary database will be re-established and stored through change database and establishment of the plan. Finally, decision will be made based on analysis and comparison with the original plan (Cho, et al., 2015).

2.8.3.7 Approval

The Change Board will decide the changes that submitted by the change manager (Mejlaender-Larsen, 2016).

2.8.3.8 Implementation

The change manager has to coordinate with all the team members on the change implementation by ensuring project team members have received the decision either accept or reject by the Change Board. Besides that, it is the responsibility of the change manager to transfer the right information to the project team members before the change is implemented (Mejlaender-Larsen, 2016).

2.8.4 Control Strategy Phase

For control strategy phase, the change management strategies adopted are to improve continuously from reviewing of executed change process and documenting complete records of the change that have made previously.

2.8.4.1 Post Change

According to Motawa, et al. (2007), the project team members will investigate the direct and indirect causes of the changes that triggered to the dispute resolution where the parties suffered losses as a result of the changes.

2.8.4.2 Continuously Improve from Lessons Learned

According to Ibbs, Wong and Kwak (2001), the project team members are required to share and discuss the root causes, and to evaluate the mistakes that they encountered for the purpose of the lesson learned.

2.8.4.3 Review of Particular Change Process

Jarratt, et al. (2011) describe the change should be reviewed by the project team members for the purpose of gain new experience and the lessons that have learnt from the change.

2.8.4.4 Maintain Complete Records of the Executed Change

ORACLE (2009) explains the project team members should document all the changes in a proper manner. The project team members can create standard forms such as changes procedure, contract document log, issue log, request for information (RFI) log, PCO log and etc for the purpose of documentation. Therefore, standardisation process will allow the organization to manage changes easily.

2.9 Current Approaches of Change Management

A plenty of research on change management has been initiated and proposed to benefit project team members in terms of time, cost and quality. BIM with change management feature will identify changes during design stages, and systematic manage changes to mitigate the negative impact of necessary changes instead of elimination of all project changes (Sun, et al., 2006).

2.9.1 Change Management Toolkit

Sun, et al. (2006) designed a change management toolkit for team members to apply change management process. It consisted of two components, a knowledge component and a support component. The knowledge component contains a standard of change process to provide a standard change management procedure and knowledge management provides a guideline for user to understand the problem of change management, and lesson learned. Whereas the support component is used as a change prediction tool and reschedules the project sequentially among team members in the tool as a result of a change event. This is to outline a standard of process and as a supporting tool for this system.

2.9.2 BIM-Based Ontology of Design Changes

Langroodi and Staub-French (2012) developed a BIM-based ontology of design changes to identify changes in the model and compare the revised model with the original model. In addition, this research has also classified the causes of changes in six classes. The taxonomy developed including “nature of design change by its type”, “changed attributes of the altered component”, “dependencies between the components”, “the level of change effect on other components”, “timing” and “impact on cost and schedule”. Langroodi and Staub-French (2012) classified the cause of change into two categories, namely first subclass and second subclass. In first subclass, the change occurrences as a natural consequence of developing model, however, in second subclass, the change occurrences are not a natural consequence of developing model. It is found the important to recognize the causes of change prior to decision-making. This developed auto-classification of the cause of change may provide adequate information on the change made to the model for further analysis.

2.9.3 Integrated Change and Knowledge Management System (ICKMS)

Liu, et al. (2013) developed an Integrated Change and Knowledge Management System (ICKMS) to automate the process in Integrated Change and Knowledge Management (ICKM). The purpose of this system is to provide an effective mechanism for simultaneously manage change, capture lesson learned during change management processes and uphold information exchange between two differences of change and knowledge management activities. In addition, the Integrated Building Lifecycle Process Model (IBPLM) was introduced for the purpose of identifying and documenting all potential changes. The proposed system therefore facilitates a smooth and timely flow of information between team members involved in change and knowledge management.

2.9.4 Automated Workflow-Based Change Management Process

Karimidorabati, Haas and Gray (2016) proposed an automated workflow-based change management process model to be part of Electronic Product and Process Management (EPPMS). The purpose of the proposed model is to improve change management process via automated work-flow process through web-based. In this research, the proposed model is categorized as Generation Three of Change Management (GEN 3) which further compares with Generation One of Change Management (GEN 1) and Generation Two of Change Management (GEN 2). (GEN 1) is a fully paper-based process such as hardcopy documentation, while (GEN 2) is IT-based process such as PDF softcopy documentation. As a result, both (GEN 1) and (GEN 2) are a “loose process”. In other words, due to human mistakes, there is a high chance to have typo, missing information, inability to provide up-to-date information to related parties for decision-making and etc, which result in inaccurate and low traceability. Instead, (GEN 3) improve traceability of change requests, improve accuracy information and improve compliance due to automatic notification of all project team members as (GEN 3) include a platform consisting of “Internet, workflow engine, Database Management System, Document Management System, and Cloud-based software”.

2.9.5 Change Control System

Mejlaender-Larsen (2016) introduced change control system (CCS) to facilitate effective change processing, which serve to report and follow-up the changes and utilises BIM to manage change in design. At the initial, any changes which have been identified is required to go through the CCS process, which consists of identification, filtration, evaluation, approval and implementation for decision-making process by the team members. Once the decision has been made, the changes will be updated into BIM model for team members to visualize whether it is feasible to implement the change or whether it will cause more clashes due to the change.

2.9.6 Building Information Model Based Visualization

Valeh, Osama and Zhu (2017) proposed a building-information-model-based visualization for the design-change management of project team members to see the ripple effect of a design change. The purpose of this model is to visualize the "as-planned" building information model with the "as-changed" model to track and highlight the change sequence and a list of components that are affected by the main source of change. This information helps client to understand the impacts of a proposed change. Autodesk Revit Architecture 2014 and Revit Application Programming Interface was chosen for auto-adjustment of building components, and automatic detect and quantify changes respectively. The developed model consists of three main modules. The first module is the data acquisition module, the BIM model is presented for client to review. The second module is the data analysis module, and all the ripple effect of the design changes will be detected by BIM detection system. The third module is reporting and highlighting module, all the affected components will be shown in the report and this information is intended to assist the client in the decision-making process.

2.10 Limitation of Current Approaches

The integration of CM with BIM focuses only on the phase of execution. In other words, it does not apply change management activities that are not directly made on the models. Besides that, it required the comprehensive user manual inputs of project characteristics, which is difficult to capture timely and accurate inputs from the user. The lack of integration between change management with software in construction industry undermines the efficient management of project design changes as well as communication issue (Sun, et al., 2006; Heravi and Charkhakan, 2015; Du, El-Gafy and Zhao, 2015; Valeh, Osama and Zhu, 2017). Apart from that, the system does not capture lesson learnt, store important information and best practice to make recommendations on the problem (Ibbs, Wong and Kwak, 2001; Valeh, Osama and Zhu, 2017). Should lesson learnt is captured, the project can be managed more effectively. Although, the proposed system can make comparison with a changed model with a planned model, but there is an issue in comparison with two or more revisions of the model. In other words, there is lack of the capacity to capture the continuously changed model.

2.11 Summary

The review of literature is one of the strategies for a deeper understanding of both BIM and CM – leading to the development of the research objectives to be investigated. The chapter details the BIM and CM, including definitions of both CM and BIM, the benefits of both BIM and CM, the classification of construction changes, the change management process, current approaches to change management and limitation of current approaches. Finally, both BIM and CM could deliver a lot of benefits to users, but both software are standing alone itself which lack of integration to manage design changes efficiently.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter covers the research methodology of dissertation. In more details, this section explains the meaning of research, methods of research, research design, methods of data collection, sample size and method, type of data analysis, and research milestone.

3.2 The Meaning of Research

First of all, research defined as ‘voyage of discovery’, whether there is something new has found during the research or even if nothing has discovered, the completed study may use to further support for the existing theory (Fellows and Liu, 2015). The Concise Oxford Dictionary defines research as “careful search of inquiry; endeavour to discover new or collate old facts etc. by scientific study of a subject; course of critical investigation” (Soanes and Stevenson, 2004). In other words, the research is also known as ‘inquiry’, ‘study’ or even ‘investigation’.

The Economic and Social Research Council (2007) further explains research as “any form of disciplined inquiry that aims to contribute to a body of knowledge or theory”. It means the intented research that is going to conduct must be designed and structured appropriately in order to conduct the research.

In addition, there is a problem with a research project that drives research, and thus the purpose of research is to acquire knowledge throughout the study.

3.3 Research Method

Research method uses as a technique to question research objectives. There are four types of research method including quantitative, qualitative, triangulation, and mixed method research. In this research, mixed method research was chosen to obtain details result. Williamson and Johanson (2013) define mixed method research as “multi-method” and “hybrid approach”, in other words, both quantitative method and qualitative method are involved in the same study. Creswell and Clark (2007) explain mixed method research is a research design involves philosophical assumptions that outline the way to collect and analyse of data and to combination of both quantitative and qualitative methods in a single study. Besides that, Creswell and Clark (2007) claimed that the use of single method only provide a small view of the whole picture, however the combination of both quantitative and qualitative approaches provide a better understanding of research problems. The mixed method research is also used to reduce the bias.

Hence, there are about 80% of the data were collected from quantitative method by using questionnaire and about 20% of the data were collected from qualitative method by conducting semi-structured interviews. The quantitative method ensures the gathered facts of current practice of BIM and change management are accorded with theories by using Likert scale (Fellows and Liu, 2015). Whereas, the qualitative method allows interviewees to express their point of view on the current practices in change management and the requirements for the development of the BCIM framework, as well as the limitation of current approaches by using open-ended question (Fellows and Liu, 2015). Therefore, the mixed method research being chosen was to gain better understanding about the current status of BIM and change management with combining the interviewee’s opinion based on their experience and also gather the fact from respondents, with the purpose of developing an integrated framework for managing changes.

3.4 Research Design

First of all, it has not been until recently that the pace of technology has changed tremendously, especially in construction sector. Therefore, the speed of today's ever changing the digital world has triggered this research started by focusing on technology in related to construction sector as it is notable that construction sector is one of the most affecting the country's gross domestic product (GDP) industry.

It is vital to identify the topic to be studied as the technology in related to construction sector is too broad and it is difficult to study the entire field in a single report. BIM is therefore chosen as the main study for this research, as BIM has become the current trend in the construction industry today. It appears in the media, Government policy as well as the conference on the various aspects of BIM.

When the study topic has identified, it then started with the seeking for study sources and review topic related to BIM. The sources from book, journal article, news and official information. Besides that, the literature review carried out concurrently with problem identification, in other words, the problem was found while reviewing the literature in related to BIM topic.

Reviewing of the literature has identified the lack of fully integration of BIM with other potential software in the current construction sector and the changes defined as the most significant for any construction project in terms of schedule, price and quality. As these three elements are interrelated, the cost will inevitably increase as the time is extended.

The defined problem has derived the need to establish aim and objectives in order to solve the problem or minimise the research gap. Therefore, this research is to develop Building Change Information Modelling (BCIM) to make full use of the integration of BIM with change management and benefits to all construction projects.

Basically, the primary data of quantitative and qualitative approaches have chosen to explore the current BIM approaches and change management approaches from the targeted consultant quantity surveyor, who have a high level of involvement in dealing with BIM and changes. Whereas, the secondary data were obtained by reviewing journal articles, internet, published reports, books and more for this research. When the data were completely collected, descriptive statistics, inferential statistics and narrative analysis were used to analyse the results to determine the direction of the study. These techniques are important for summarising the data in an appropriate manner.

Certain data require a specific approach to data analysis. Narrative analysis has been chosen to uncover more accurate data. In addition, descriptive statistic was chosen to summary the dataset, whereas the inferential statistic was used to take the findings from a representative sample group and generalize the group to a larger population. When the data were analysed, it was necessary to assemble and examine the results and discuss the results of concrete evidence in the context of the literature.

Conclusion in this research is a precise statement. The conclusions relate to the aim and objectives set at an early stage, and the two chapters are interrelated. By reviewing the validity of the study, the recommendation for implementation as well as the recommendation for future research is needed.

The writing of this report started from the literature review stage to the report production stage in order to complete the research. This report is vital in which it contains important sources that have been made and discovered for the development of BCIM framework. Figure 3.1 shows the research design workflow for this research study from the scope identification to the final stage of the report writing.

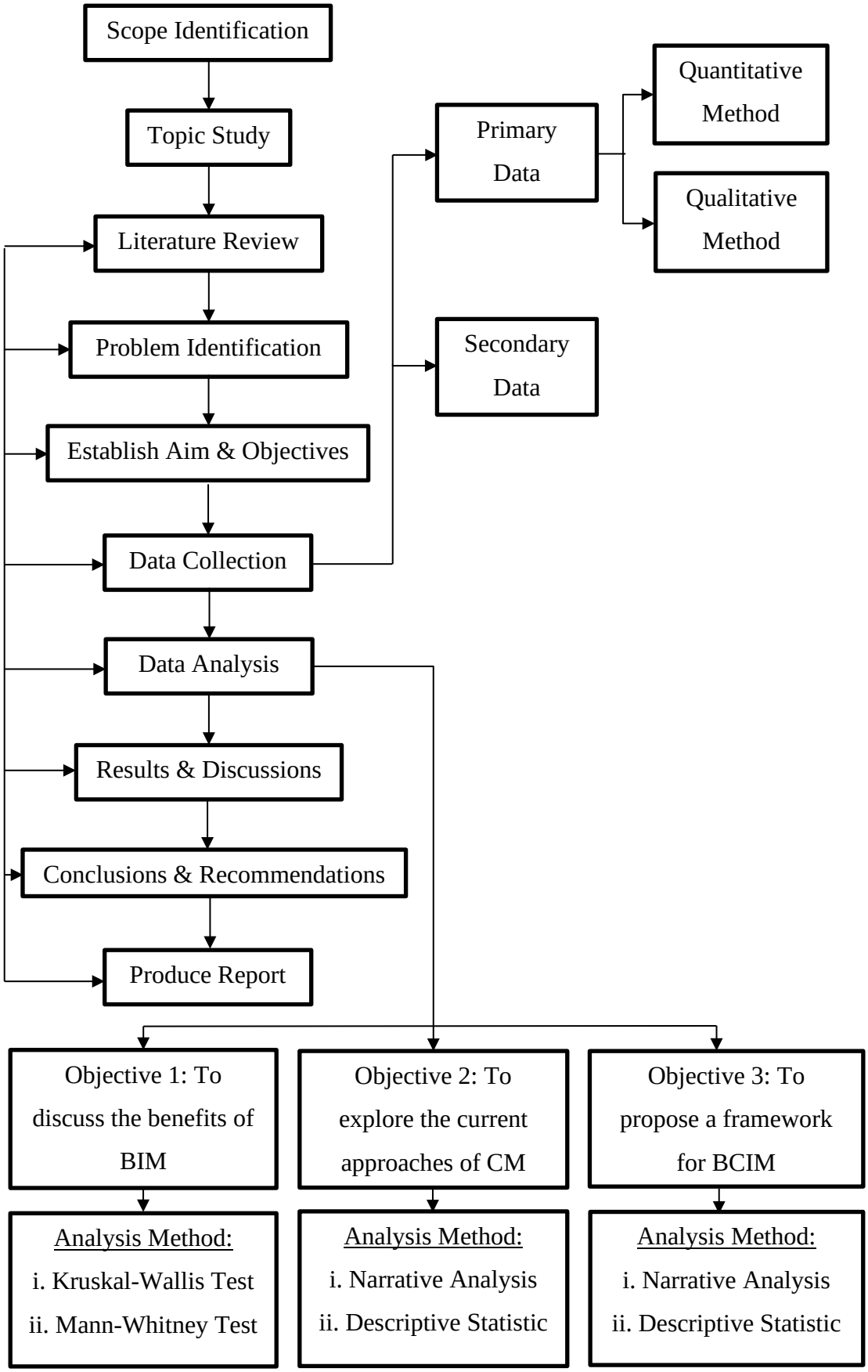

Figure 3.1: Research Design Workflow

3.5 Approaches to Data Collection

In research, there are two different approaches to data collection, namely primary data collection (fieldwork) and secondary data collection (desk study) (Naoum, 2013). Data collected is used for statistical analysis and the nature of a research investigation determine the approach to be adopted for conducting research. Primary data is also known as first hand data in which the data is first carried out through direct efforts and experience, specifically to undertake research problem (Surbhi, 2017). Generally, there are few types of approaches in fieldwork, namely survey approach, case study approach, problem-solving approach, observational approach, and experimental studies (Naoum, 2013). Whereas, the secondary data is also known as second-hand information which have carried out by another person (Surbhi, 2017). In other words, secondary data is readily available data to any person wishing to review and to be used as a reference. There are two types of approaches in desk study, namely statistical format and descriptive documents (Naoum, 2013).

Both quantitative and qualitative data collection methods have been used in this research to obtain broad information on current practices of BIM and change management, as well as the limitation of current approaches. All the primary data were collected through questionnaire surveys and conduct interviews with quantity surveyor who have experience in BIM and change management process, while secondary data were obtained by reviewing journal articles, internet, published reports, books and more for this research.

3.5.1 Interview Guide

The comprehensive interview guide was prepared for the interview. Table 3.1 shows details of the interview guide, including six themes and ten questions for interviews. Generally, the themes were established through the literature review. The themes identified are important for the collection of the current practice of BIM, the limitation of the company's current practice, the solution for limitation, the suggestion of requirement, and the current practice of change management for the development of the Building Change Information Modelling (BCIM) framework. The interview guide sample was attached to Appendix B and the order of questioning might vary from interview. Besides that, additional questions may arise during the interview session.

The semi-structured interviews were conducted through face-to-face basis with consultant quantity surveyor in their office. The interviews used open-ended questions for interviewees to answer based on their experience and opinion. Moreover, the interviewees were mostly from the previous visited site project and internship company.

Table 3.1: Details of the Interview Guide

Possible Questions	Themes
"What is the BIM software that your company using?"	Current Practice of Building Information Modelling (BIM)
"Why the software being chosen?"	
"To what extent you think BIM would benefit your project and why do you think it is beneficial?"	Advantages of BIM
"What are the difficulties you have encountered?"	Problem of the Company's Current Practice
"How are you going to solve the difficulty?"	Solution for the Company's Current Practice
"What are the criteria to be included in the new system?"	Criteria for Building Change Information Modelling (BCIM)

Table 3.1: Details of the Interview Guide (Continued)

"How did the current change management process being implemented in your company?"	Current Practice of Change Management
"What is the approach that used to deliver message to parties?"	
"Did BIM being implemented for managing changes?"	
"Did a change event being capture?"	

3.5.2 Questionnaire Design

The questionnaire of this research is categorised into four sections, as shown in Table 3.2. First section gathers the demographic information of the respondents, including gender, age, academic qualification and working experience. These data are the independent variables to reveal the relationship with the dependent variables collected in the other section. However, section two includes important features for the development of the BCIM framework. The section two requires respondents to identify the features that should be included in the BCIM framework. Whereas section three consists of current approaches of change management. The section three requires respondents to reveal current practices of change management. Section four consists of the benefits of BIM. The section four requires respondents to identify the benefits of BIM. Generally, the questionnaire used close-ended questions, typically using 7-scale Likert scale as shown in Table 3.3. The questionnaire survey sample was attached to Appendix A. Moreover, the questionnaire surveys used the google form base and the generated link would be sent by e-mail, facebook, linkedin, and printed paper-based questionnaire.

Table 3.2: Questionnaire Design

Section	Item
1	Respondents' Demographic Information
2	Proposal of Framework for Building Change Information Modelling (BCIM)
3	The Current Approaches of Change Management
4	The Benefits of Building Information Modelling (BIM)

Table 3.3: Level of Agreement (7-Scale Likert Scale)

Ratings	Definitions
1	Strongly Disagree
2	Disagree
3	Somewhat Disagree
4	Neither Agree nor Disagree
5	Somewhat Agree
6	Agree
7	Strongly Agree

3.6 Sampling

Naoum (2013) defines sample as part of population which is extracted to provide a good representation of the population, thus sample can consider as representative. The selected research sample should have similar characteristics with population, this is to act as representative of the population as a whole. In other words, sampling is the method of choosing a group of individuals from a population to make statistical inferences about the sample. The following described the sampling method and the sampling size for this research.

3.6.1 Sampling Method

Generally, the sampling method, including random sampling and selected sampling, is the technique used to select a representative sample. Random technique selects respondents without intentionality; however, the non-random technique selects respondents with intentionality.

Naoum (2013) explains random sampling suitable to any of the research when the characteristics of the sample is not essential, such as respondent's background. Whereas, selected sampling only suitable to research study when the specific characteristics of the sample is required (Naoum, 2013). The selected sampling usually carry out in a form of interview. This approach usually started by obtaining a list of names of participants and exclude participants who do not have the specific characteristcs to achive this study. Therefore, to choose random sampling or selected sampling is usually based on nature of the study.

In this research, specific characteristics of the sample is required for the development of framework for BCIM. Therefore, selected sample was used to select quantity surveyor working in a consultant firm. In more details, the consultant quantity surveyors would provide more comprehensive information for this research as they have a higher level of involvement in dealing with BIM and change management throughout the project.

3.6.2 Sampling Size

The sample size plays an important role to determine the validation inferences about a population from the sample. According to Cochran (1977), the determination of the minimum sample size for the population has a reasonable accuracy of 384. Sample size determination can be expressed as the below equation (Cochran, 1977):

$$n = \frac{Z^2 pq}{e^2}$$

$$n = \frac{1.96^2(0.5)(1-0.5)}{0.05^2} = 384$$

where,

n = sample size

At 95% confidence level, Z = 1.96

q = 1-p, p=0.5, q=0.5

e = margin of error, normally assume to be 5%

According to Sang and Jong (2017), Central Limit Theorem specifies that the mean of a sample of data will be closer to the mean of the entire population as the sample size increases, regardless of the actual distribution of the data. In other words, the Central Limit Theorem is that the average sample mean will reflect the actual population mean. In fact, due to time constraint and weak relationship in the construction industry, the sample size of 384 has been replaced by the Central Limit Theorem with thirty number of values in each sample to be considered valid and reliable for this research. Therefore, Central Limit Theorem was adopted to ensure that this research accurately predicts the characteristics of the population.

Moreover, there is no limit for interview to be conducted, but it has to conduct interviews until it has reached the saturation. In fact, the results of the interview have not reached the data saturation, therefore survey is carried out subsequently to complement the data findings from interviews.

3.7 Data Analysis Method

This section explains the data collected from questionnaire surveys were analysed by Cronbach's Alpha Coefficient Reliability Test, Descriptive Statistics, Normality Test, Kruskal-Wallis and further test by using Mann-Whitney Test. The Statistical Package for the Social Sciences (SPSS) was employed to run the various test as previously stated. It also explains the data collected from interview transcripts were analysed by Narrative Analysis.

3.7.1 Cronbach's Alpha Coefficient Reliability Test

Cronbach's Alpha Coefficient Reliability Test is a measure of scale reliability to determine the nearness relationship between a set of items as a group (Gliem and Gliem, 2003). In this research, Cronbach's Alpha test was carried out to examine the validity of all data collected from the multiple-question Likert scale. Table 3.4 shows the Rule of Thumb for Reliability Test. It mentions Cronbach's Alpha value more than 0.70 is considered acceptable for the interpretation of data (Gliem and Gliem, 2003). Cronbach's Alpha Coefficient Reliability can be expressed as the following equation (Gliem and Gliem, 2003):

$$\propto = \frac{\mathrm{N} \cdot \bar{\mathrm{c}}}{\bar{\mathrm{v}} + (N-1) \cdot \bar{c}}$$

where,

N = the number of items

$\bar{c}$ = average covariance between item-pairs

$\bar{v}$ = average variance

Table 3.4: Rule of Thumb for Reliability Test (Gliem and Gliem, 2003)

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 \geq \alpha \geq 0.8$	Good
$0.8 \geq \alpha \geq 0.7$	Acceptable
$0.7 \geq \alpha \geq 0.6$	Questionable
$0.6 \geq \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.7.2 Normality Test

The normality test is important because it is supplementary to the graphical measurement of normality (Ghasemi and Zahediasl, 2012). The key checks for assessing normality are Kolmogorov-Smirnov test. By considering the Kolmogorov-Smirnov test, the significant value above 0.05 is considered normality, whereas the significant value below 0.05 is considered non-normality. In this research, all variables for the benefits of BIM with different independent groups have been chosen to test for normality.

3.7.3 Descriptive Statistics

Naoum (2013) classifies descriptive statistics is a type of analysis method which is the most simplest to be used because this method provide general overview of the results in either percentages or actual numbers. In this research, descriptive statistics were employed to provide mean, standard deviation, and rank each variable from the highest to the lowest for the objectives, including exploring current approaches of change management and proposing a framework for Building Change Information Modelling (BCIM).

3.7.4 Kruskal-Wallis Test

Kruskal-Wallis test is one of the methods of inferential statistics for data analysis and is also known as bivariate statistical analysis. This data analysis method uses a small part of group as a guideline to make predictions for larger groups (Naoum, 2013). According to Guo, Zhang and Zhong (2013), the test determines whether the medians of two or more groups are different on a continuous measure. In this research, Kruskal-Wallis test was employed to determine if there is a significant difference between the groups towards the continuous variable. The null hypotheses are tested to identify the rejected null hypothesis for all the variables in the benefits of Building Information Modelling (BIM). By considering Kruskal-Wallis Test, the alpha value less than 0.05 is considered as significant difference, thus it has to accept the alternative hypothesis as there is difference between the groups.

In more details, a follow-up test of Mann-Whiteney was carried out to further distinguishes which groups are different from each other. The alpha value less than 0.05 indicates that there is a significant difference between the groups towards the continuos variable.

3.7.5 Narrative Analysis

Narrative analysis is a qualitative research approach involves the researcher reformulation of stories presented by interviewees who provide opinion based on their experience (Neil, 2010). This narrative analysis provides better understanding by the interviewees who representing a small group of people to make predictions for a larger group. It comes under the umbrella of social constructionism. In this research, the interviews were transcribed and narrative analysis approach was employed to gain an understanding from an in-depth exploration of current status of BIM and change management from interviewees to achieve free-ranging discourse.

3.8 Project Timeline

The timeline for Final Year Project 1 (FYP1) and Final Year Project 2 (FYP2) is shown in Figure 3.2. This research began with a literature review from 27th May to 21st July 2019. From 1st July to 12th July 2019, the problem as well as the aim and objectives for this research began to be identified. The problem identification was followed by the identification of the research methodology that was appropriate for this research and it took 11 days for this particular stage to be completed. In addition, report writing for chapter 1, 2 and 3 started from 3rd June to 4th August 2019 and finally the report submission on 5th August 2019. Therefore, the total duration of this Final Year Project 1 was taken 51 days to complete.

The FYP2 started with the design of questionnaire and interview questions from 13th January 2020 to 3rd February 2020. The approval of both questionnaire and interview questions was granted on 3rd February 2020 and the data started to collect on 10th February 2020. A total of 24 days has been spent on data collection. Upon completion of the data collection, the data used to analyse and discuss the data. A total of 20 days was spent on data analysis and discussion from 2nd March 2020 to 27th March 2020. On 23rd March 2020, it started to report the conclusions and recommendations for this research. On 9th March 2020 to 22nd April 2020, the report writing for chapter 4 and 5 was carried out simultaneously as the review of chapter 1, 2 and 3. Finally, the report submission for FYP2 falls on 23rd April 2020. Therefore, the overall duration of this Final Year Project 2 was taken 74 days to complete. Last but not least, all the planned activities during FYP1 and FYP2 have been achieved without delaying the timeline allocated.

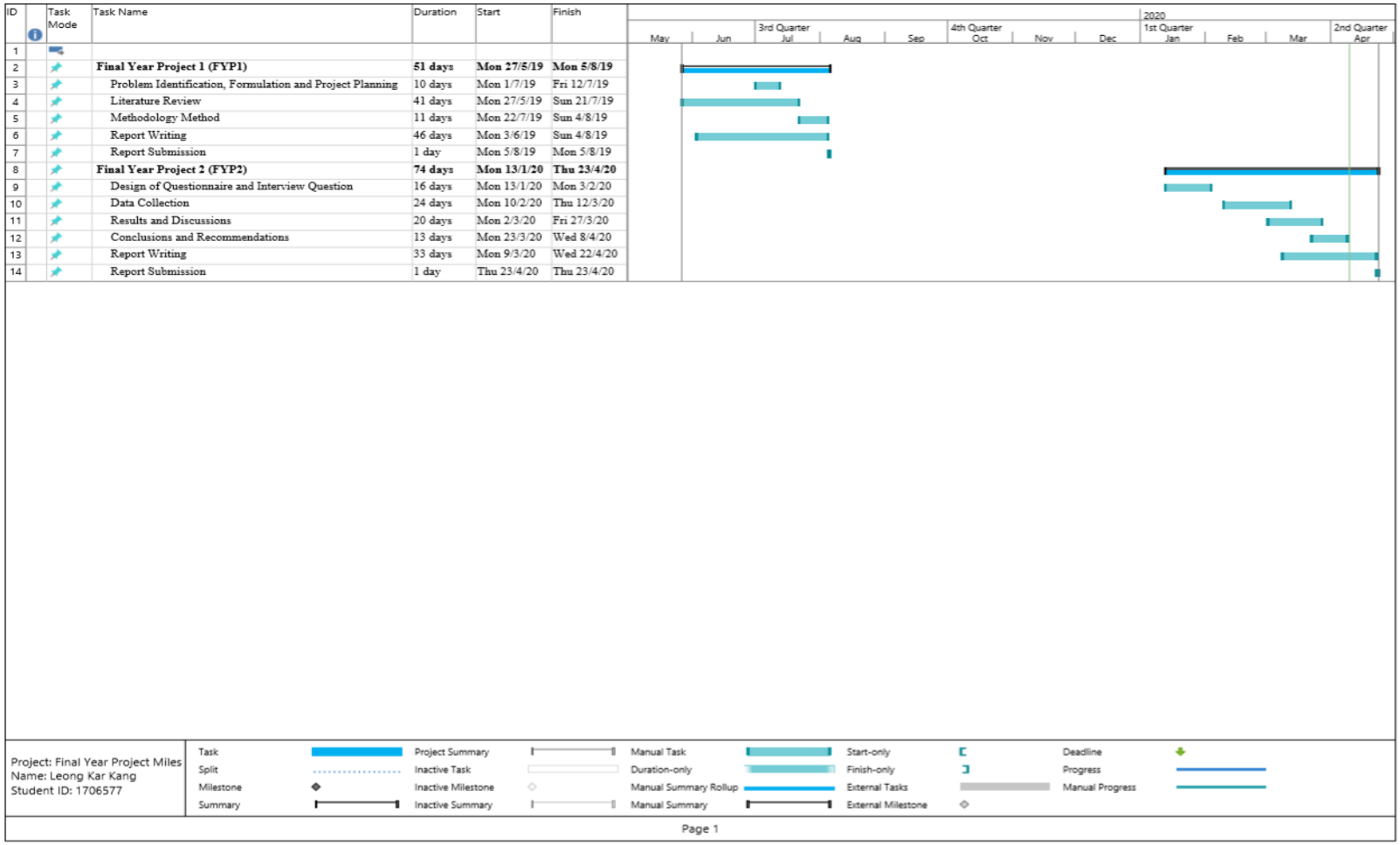

Figure 3.2: Development Progress of FYP1 and FYP2

3.9 Summary

The chapter details research definition and mixed research method that have applied into dissertation. This research used the Central Limit Theorem as one of the sample size approach. Furthermore, it also reviewed the type of data collection and the type of data analysis method used. Finally, it also covered the details of the research design from commencement to completion of research, and the project timeline for final year project 1 and 2.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter includes a summary of the demographic background of the interviewees and respondents. It also includes a reliability test to determine the nearness relationship between a set of items as a group. Next, the discussion on mixed method research. In more details, the qualitative part explains the results of the semi-structure interviews conducted, discussion is demonstrated based on the transcripts of the interviews. Whereas, the quantitative part interprets the data analysis using various techniques in Statistical Package for the Social Sciences (SPSS). Then, the discussion on the overall concept of Building Change Information Modelling (BCIM) is explained in Section 4.6, while Section 4.7 interprets the standard of change management process.

4.2 Result of Interview

There are total of three interviewees from consultant quantity surveyors were successfully interviewed. Table 4.1 summarized the company background, position and working experience of the three interviewees.

Table 4.1: Interviewee Profile

Interviewee	Company Background	Position	Working Experience
A	Consultant Firm	Professional Quantity Surveyor	6 – 15 years
B	Consultant Firm	Quantity Surveyor Manager in Contract	More than 16 years
C	Consultant Firm	Senior Quantity Surveyor	6 – 15 years

All the transcriptions from interviewees are being compiled into a documentation. The transcriptions are then disassembled further reassembled according to theme. Narrative analysis used to analyse the reassembled data for discussion. The transcript sample from interviewee A was selected as attached to Appendix C. Table 4.2 outlines the theme and sub-theme of the interview.

Table 4.2: Theme and Sub-theme of the Interview

Theme	Sub-theme
Criteria for Building Change Information Modelling (BCIM)	Mobile device application
	Data interoperability issue
	Standard of procedure for BCIM
	Data confidential
	Facilitate knowledge capture and share
	Integration of BCIM with company's database
	Comparison between two revisions of models
	Integration between change with BIM
	Outline updated components to the original model
Current Practice of Change Management	Capture lesson learned
	Standard of change process
	Identify changes in BIM model
	Notification of change event

4.2.1 Criteria for Building Change Information Modelling (BCIM)

This section will interpret the interview statistic and discuss the criteria for developing the BCIM framework.

4.2.1.1 Mobile Device Application

Interviewee A and C mentioned that using the mobile device application will allow users to access the project anytime at anywhere. By doing this, construction parties are becoming more and more convenience to manage any changes via mobile application. Interviewee A suggested:

> *"Indeed, mobile application could convenient to a firm that involved international project because they can always monitor the status of the project from other country with the mobile application."*

Interviewee C noted:

> *"Due to uniqueness of construction project, a mobile device application is suitable for construction project."*

4.2.1.2 Data Interoperability Issue

Interviewee A, B and C, who mentioned that it is necessary to include the feature of data interoperability. This is one of the communication issues that has often arisen in most of the construction industry as a project involving numerous parties engaged in carrying out various trade of tasks. Interviewee A explained the difficulty:

> *"Our company does not consolidate input of information from all parties involved, which causes a lot of discrepancies in the final product."*

Interviewee A responded the solution:

> *"It is good to consolidate the information and BIM modelling into cloud and allow all relevant parties to access and edit on it."*

Besides that, interviewee B illustrated the difficulty and solution:

"We wish we could have a platform that can overwrite the data from our company's database once there is someone who is updating the data regards to the issue. With this platform, our company would not have too much useless data that would actually have the same data."

Furthermore, interviewee C explained:

"Initially, we plan to use google docs to eliminate the interoperability issue because google docs allow us to work together on a single document at the same time and provide real-time communication, but it does not incorporate with our company's database."

4.2.1.3 Standard of Procedure for BCIM

Interviewee B remarked that all organizations are subject to a standard of procedure in dealing with changes as a standardization. He interpreted the difficulty and solution:

"I noticed that actually every company has their own standard of procedure to deal with the particular issue but actually this is not a good practice because when I go another firm and I have to adapt their approach."

4.2.1.4 Data Confidential

Interviewee A and C mentioned all data in a firm shall remain confidential. By doing this way, the data will not leak outside the firm. All the essential information of a project must be secured in order to protect the interest of client. Interviewee C noted the difficulty:

"The purpose of remain data confidential because I wish I could only share certain information to certain party, especially the internship student."

Interviewee C noted the solution:

"I think this system is important to be separated into two types of group which are user with authority to edit and user only access to view. Cite an example, Lazada user who register as personal account is allow to buy product, however the Lazada user who register as business account can only sell product."

4.2.1.5 Facilitate Knowledge Capture and Share

Interviewee B and C, who explained the knowledge capture and share from BIM model and change process, are able to capture lesson learned accurately and precisely. They further explained:

"Technology able to capture all the important information including, decision taken while human is less reliable, because human error can occur"

Besides that, they added:

"Although technology allows knowledge capture and share, but meeting also important to be conducted after a change event, so construction parties will understand more about the issue."

Interviewee C explained the difficulty and solution:

"Considering the turning over of staff in my firm, this technology would helpful to my firm because all the important information and decision made are able to capture and share anytime that will enable me to review the decision made on a similar event."

4.2.1.6 Integration of BCIM with Company's Database

Interviewee A explained that the database in a company is the most valuable data that allows the company to know about its present performance. Besides that, the database is also the most important assets for a company. Interviewee A explained the difficulty:

> *"Actually, this is what I realized that all the software in our firm does not link to our company's database, which causes a lot of separate drawing that store in database, so it takes some time to search for it when we want to reuse the building model from a previous project."*

Interviewee A explained the solution:

> *"Ensure the connection of all the software to database."*

4.2.1.7 Comparison Between Two Revisions of Models

Interviewee A suggested the new system shall include the feature to compare two different revisions of model for a project. He added:

> *"This will easy for user who want to find any differences between the two models and also provide a visualization for user to visualise the two different models at the same time."*

4.2.1.8 Integration Between Change with BIM

Interviewee B suggested the new system shall integrate the change management with BIM for managing project in a single software. The integration of two different software will increase the productivity of the project as the user would operate under the software that provides two different functions.

4.2.1.9 Outline Updated Components to the Original Model

Interviewee B suggested the new system shall include the feature to show updated components to the original model with the reason of changing. Any adjustment made to the original model shall display the updated component with a thorough justification for tracking purpose. Therefore, all the users would aware of the modified components easily.

4.2.2 Discussion

This section interprets the interview transcripts reassembled in Section 4.2.1. It summarizes the criteria to be included in the Building Change Information Modelling (BCIM).

Interviewee A and C, who have working experience of 6 to 15 years agreed the use of mobile device application can manage the project smoothly and easily, especially for international projects. The construction project is unique and involves a high degree of participation from parties, as mentioned by interviewee C. Therefore, a high degree of flexible is required to transmit the message and track the status of the project by using mobile application to enable users to access the project anytime at anywhere.

Generally, interviewee A, B and C, who agreed to include the data interoperability feature. The interviews revealed that all the interviewees have the same issue of not being able to work together with construction parties on single documents with real-time communication, as a result of discrepancies in the final product. Throughout the interviews, it can be found that there is a need to consolidate the information and BIM models into a single platform that offers real-time communication to eliminate the interoperability issue.

In addition, interviewee B mentioned that the need to associate the BCIM with the standard of procedure in order to standardize the change process in BCIM. As suggested by interviewee B, this is one of the features to be included in BCIM. By combining the standard of the change management process with the BCIM, any company that adopts the BCIM is able to apply the standard of procedure when dealing with any changes as provided in the system.

Moreover, interviewee A and C suggested that the data in BCIM should remain confidential. This is to protect the important information to be shared and to ensure that the important data will not leak outside the firm. Interviewee C further explained that there is a need to categorize the different user level to do certain tasks. This different user level is able to ensure that the data remain confidential by allowing different users to have different authorities.

Based on the interviewee A, B and C, interviews uncover the capturing of lesson learned from BIM model and change process shall in a systematic way to ensure all important information is captured, shared and stored through Information and Communications Technology (ICT). Facilitating knowledge capture and sharing of information is therefore capable of eliminating human involvement intensively, and data are captured and shared more accurately and precisely.

Furthermore, BCIM needs to be integrated into the company's database to centralize the information, as mentioned by interviewee C. As the company's database is the most valuable assets, it enables a company to know its current performance and to increase the accessibility of the parties. Therefore, the BCIM shall be able to connect to the company's database for users to search the data more easily from the company's database.

On the other hand, interviewee B suggested that there is a need to integrate the change management with BIM for managing project (Sun, et al., 2006; Langroodi and Staub-French, 2012; Liu, et al., 2013; Karimidorabati, Haas and Gray, 2016; Mejlaender-Larsen, 2016; Valeh, Osama and Zhu, 2017). The integration of two different software could increase the productivity of the project due to better operation of the construction project.

Another feature to be included in the BCIM is outlining the variation/ updated components to the original model with the reason of changing, as suggested by interviewee B. Interviewee B has explained the purpose of including this feature is to easily track any changes, making it easy for users to know the updated components with details.

Besides that, interviewee A suggested that the BCIM shall be able to compare two different revisions of model for a project in order to make it easier for the parties to identify any differences between the two different models.

In a nutshell, the overall concept of BCIM is illustrated in Figure 4.2. It should be noted that the analysis identified the important criteria to be included in the BCIM framework.

4.2.3 Current Practice of Change Management

This section will interpret the interview statistic and discuss the current approaches of change management.

4.2.3.1 Capture Lesson Learned

Interviewee A and Interviewee B, with working experience of 6 – 15 years and over 16 years of working experience, agreed that the implementation of capture lesson learned is able to benefit ongoing and future projects. Cited an example by interviewee B, due to poor documentation of main contractor firm, it is not uncommon to send a superseded drawing instead of revised drawing to the sub-contractor who carried out the work and this issue ended up with the need for main contractor to add more resources to align the project schedule and also avoid from being imposed liquidated damage to main contractor. Interviewee C emphasized the difficulty:

> *"Due to the high turnover of staff in construction industry, it is best to adopt a strategy of sharing their experience via a meeting after the change event rather than sharing their experience at the completion of the project and also to ensure that involvement is mandatory for all construction parties including main contractor, sub-contractor, consultant, architect and etc."*

In fact, the interviewee A, B and C explained:

> *"We share the change event after the completion of project, because each meeting was busy with another discussion and thus keeping this to end of the project."*

4.2.3.2 Standard of Change Process

All interviewees claimed that the standard of procedure provides common frame for employee to deal with any changes. Interviewee A noted:

> *"So far, our consultant firm has well-developed of standard procedure for change, and the process will be reviewed with the upper management every two years."*

He explained:

> *"Technical team identified changes required for the work, notified and provided information to cost & contract team with details information. Cost & contract team typically come out with a cost estimation of the change and then get the client's approval and formalise the change instruction issuance."*

Besides that, he further explained:

> *"Our technical team also play an important role in the early stage of project because they have to identify changes on the pre-tender estimate stage to eliminate the changes before tender has been awarded."*

Interviewee C who has working experience of 6 – 15 years asserted that dealing with a change without a standard of procedure is more suitable to the chaotic situation occur in any projects. He noted:

> *"Project is unique which require a flexible solution towards the change."*

4.2.3.3 Identify Changes in BIM Model

Interviewee A mentioned that, due to the interest of the client and the stakeholder, projects are good to adopt Building Information Modelling (BIM) to identify the changes or clashes in the components. He said:

> *"It is common to use BIM to identify changes, and we insist to use in all the project for making the project right, and that will increase the reputation of my company. Cite an example, we are mostly handling big projects, normally the infrastructure project such as railway, roadwork and drainage have the high possibility of clashing items."*

He further added that:

> *"Nowadays, some of the client are forcing the parties to implement BIM for a particular project in the form of a contract agreement."*

Interviewee B agreed that the importance of interest of client and stakeholder should be prioritized. Therefore, the use of a three-dimensional model is used to identify the changes or any clash of the components. He said:

> *"The first step we will take is focused on our experience of identifying any common mistake and common changes in the drawing prior to the use of BIM to identify any clash of items."*

However, a contradict statement is made by interviewee C:

> *"It is time consuming to adopt BIM for the identification of changes, that would cause us to have less time to prepare the tender document and all of the changes can be identified upon the construction work is started."*

He further added that:

> *"Since we are a small firm with limited project, it is unnecessary to obtain the BIM license to manage change."*

4.2.3.4 Notification of Change Event

All interviewees claimed that all notices of changes in construction use a mixed method that are paper-based and IT based process to notify team members. All the interviewee A, B and C said:

> *"Any changes arise, we will call for a prompt meeting with important parties to alert and discuss with parties. Upon completion of the meeting, we will send an official letter through e-mail including variation order and revised drawing to related parties."*

The interviewee A, B and C added:

> *"Some of the sub-contractor or other parties are lazy to open and check their e-mail inbox regularly."*

The interviewee A, B and C further added the difficulty:

> *"Although we are using mixed method process, but there is still a possibility that missing information may be shared."*

4.2.4 Discussion

This section interprets the interview transcripts reassembled in Section 4.2.3. It summarizes the current approaches of change management.

The interviewees acknowledged that a firm able to capture lesson learned from the project would benefit ongoing and future projects. Furthermore, interviewee A, B and C have reached a consensus that capture lesson learned is one of the approaches to manage change (Sun, et al., 2006; Jarratt, et al., 2016). It was noted by interviewee C that the process of lesson learned is more effective if employees capture and share their experience of meeting after the change event with the participation of all construction parties. Interviewee C made it clear that, due to the fragmentation of the construction industry, the employee shall share their experience after the change event rather than the completion of the project, because the staff might turnover or forget the change event after the completion of the project (Ibbs, Wong and Kwak, 2001; Valeh, Osama and Zhu, 2017). In fact, Interviewee A, B and C, who actually share their change event experience after the completion of project. Therefore, all interviewees agreed that capture lesson learned is one of the approaches to manage change.

As had been found in several researches (Ibbs, Wong and Kwak, 2001; Sun, et al., 2006; Motawa, et al., 2007; ORACLE, 2009; Jarratt, et al., 2011; Cho, et al., 2015; Mejlaender-Larsen, 2016), interviewee A and B are grateful for the standard of change procedure that has been developed for employees to deal with any changes. The standard of procedure adopted by the interviewee A is that the technical teams identify the changes required for the work, notify and provide information to cost and contract team. The cost and contract team will identify the cost of the change and follow it by obtaining the client’s approval and then formalise the change instruction issuance. However, interviewee C who has limited project to handle does not develop a standard of procedure for dealing with changes in their firm. This explains why interviewee A and B are able to handle a number of projects in their firm because the changes can be handled in a more systematic approach by providing a common frame for employees to deal with any changes (Change Management Coach, 2017). From the interviews, it can be understood that the reason some respondents do not develop a standard of procedure for dealing with changes because they have found that the standard of procedure is not appropriate for any type of change, since the project is unique and requires a flexible solution.

The interviews uncover that interviewees adopt BIM to identify changes as one of the approaches to manage change, because they believe that the interests of stakeholder should be prioritized for all the projects. In addition, the use of BIM to identify changes to the project at an early stage able to protect the interests of the stakeholders and the reputation of their company. Besides that, it was noted by interviewee A, that some clients realized that the use of BIM could benefit their project and enforce the consultant and contractor to use BIM for acceptance of the project agreement. As mentioned in the literature (Langroodi and Staub-French, 2012), the important aspect is that the change can be identified through BIM, and to derive a better decision during the early phase of a project. However, interviewee C noted that some changes can only be identified upon commencement of the project, thus the use of BIM to identify changes would require a longer period of time and would also be costly to purchase the BIM license for small firm. It can be said that any firm that is able to follow and update themselves continuously is meant to be running aligned with the current track.

According to Karimidorabati, Haas and Gray (2016), there is an approach to improve change management by using an automated work-flow process through web-based. However, there is contradicted statement made by interviewee A, B and C that they only use paper-based and IT-based to notify team members at this stage. From interviews, it can be found that they still rely on paper-based and IT-based work culture, and it has been found that most construction parties are reluctant to open and check their e-mail inbox regularly. Meanwhile, all the interviewees further explained, although using a mixed method to notify the construction parties, there is still a possibility that missing information would have to be shared. In order to manage change smoothly, an automated notification approach should therefore be implemented in their company.

In a nutshell, the analysis identified the current approaches of change management implemented by the interviewees.

4.3 Respondents' Demographic Information

In this research, the questionnaires were mostly distributed through e-survey, such as facebook, e-mail, and linkedin. Approximately three hundred sets of questionnaires were distributed through e-survey to the quantity surveyor within Klang Valley area. Besides that, a total of fourteen sets of questionnaires were distributed through a paper-based survey. There are total of eighty-four sets of responses received by an e-survey and a total of fourteen sets of responses obtained by a paper-based survey. However, an outlier to be excluded due to incomplete data. Therefore, there are total of ninety-seven sets of responses will be used in this research. Table 4.3 summarises the demographic details of respondents in terms of gender, age, academic qualification and working experience in quantity surveying.

This research has adopted the Central Limit Theorem to replace the total sample size of 384 sets. This is due to time constraint and low connection with the construction industry, especially the quantity surveyor from consultant firm. In this survey, more than half of the quantity surveyor respondents are male and only around 29.9% are female respondents who worked as a quantity surveyor.

Moreover, the majority of the respondents came under category of 41 to 50 years old, with the percentage of 32.0. In this main survey, minority of the respondents came under category of above 50 years, with the percentage of 5.2.

Besides that, 64 out of 97 respondents had the highest education level in tertiary education with a percentage of 66.0. Instead, only 9 of the 97 respondents had the highest education level in secondary education with a percentage of 9.3.

Lastly, the majority of the quantity surveyors have 6 to 15 years of working experience in construction industry with a percentage of 36.1. On the other hand, the minority of the quantity surveyors have more than 16 years of working experience in construction industry with a percentage of 30.9.

Table 4.3: Respondents' Demographic Information

Profile	Description	Frequency	Percent	Cumulative Percent
Gender	Male	**68**	**70.1**	**70.1**
	Female	**29**	**29.9**	**100.0**
Age	Below 25 years	**21**	**21.6**	**21.6**
	26 – 30 years	**15**	**15.5**	**37.1**
	31 – 40 years	**25**	**25.8**	**62.8**
	41 – 50 years	**31**	**32.0**	**94.8**
	Above 50 years	**5**	**5.2**	**100.0**
Academic Qualification	Secondary Education	**9**	**9.3**	**9.3**
	Tertiary Education	**64**	**66.0**	**75.3**
	Postgraduate Qualification	**24**	**24.7**	**100.0**
Working Experience	Less than 5 years	**32**	**33.0**	**33.0**
	6 – 15 years	**35**	**36.1**	**69.1**
	More than 16 years	**30**	**30.9**	**100.0**

4.4 Cronbach's Alpha Coefficient Reliability Test

There are total three sections have been conducted with the Cronbach's Alpha Coefficient Reliability Test by using SPSS to determine the nearness relationship between a set of items as a group. All sections have achieved a Cronbach's Alpha value of more than 0.70, therefore it is considered to be reliable data (Devellis, 2012). The computed Cronbach's Alpha value is shown in Table 4.4. Thus, all data collected for this research is considered as acceptable and reliable.

Table 4.4: Reliability Test

Section	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Propose a Framework for Building Change Information Modelling (BCIM)	**0.912**	**0.912**	**9**
Current Approaches of Change Management	**0.912**	**0.915**	**6**
Benefits of Building Information Modelling	**0.890**	**0.893**	**8**

4.4.1 Suggestion for the Framework for Building Change Information Modelling

The survey on the designing criteria of BCIM is carried out subsequently to complement the data findings from interviews. The respondents are required to rate the level of importance in Likert scale from 1 (strongly disagree) to 7 (strongly agree) and each of the criteria are ranked on the basis of the mean generated by SPSS software. Table 4.5 shows total nine criteria to be included in the Building Change Information Modelling (BCIM).

The result from survey showed that there was a general consensus among respondents that BCIM shall be able to synchronize data on a server with mobile device application as the most important feature to be included in the BCIM with a mean of 5.74, as shown in Table 4.5. It seems that the implementation of the mobile application for project management is easier since most respondents have their smartphone.

The findings from survey also revealed that BCIM shall be cloud-based to enhance data interoperability issues as it has been rated as the second important feature to be included in the new system with a mean of 5.42.

Besides that, Table 4.5 summarised from survey shows that the respondents rated the standard of procedure for integration of change management and BIM as the third important feature to be included in the new system of BCIM with a mean of 5.40.

Not surprisingly, the survey data discloses that the BCIM shall remain data confidential by only allowing certain information to be shared as the fourth important feature to be included in the new system of BCIM, as depicted in Table 4.5 with a mean of 5.37.

The finding from survey, Table 4.5 also show that BCIM shall be able to facilitate knowledge capture and share from the BIM model and process with a mean of 5.32. Most importantly, the knowledge capture and sharing feature from the BIM model and process has been rated as the fifth important feature.

Likewise, the respondents of survey have rated the integration of the company database with BCIM as one of the features for designing the BCIM with a mean of 5.25. This important feature has been rated as the sixth important feature to be included in the BCIM framework.

The finding from survey, Table 4.5 shows that there is lack of integration between change management and BIM in construction industry, with a mean of 5.22. Not surprisingly, the lack of integration between change management and BIM has been rated as the seventh important feature.

Similarly, the survey results indicate that the BCIM shall be able to show the variation/ updated components to the original model with the reason of changing as the second last important feature where the mean score of 5.19 is obtained, as shown in Table 4.5.

The feature of comparing two different revisions of model simultaneously has the least favourable the survey respondents, where only the mean of 5.05 is obtained. The respondents might not use it to make a comparison between two revisions of the models simultaneously as respondents might think it would be a waste of time to make a comparison.

In conclusion, the findings of the survey identified the most important to the least important of the criteria to be included in the BCIM framework.

Table 4.5: Mean Ranking for Proposal of Framework for Building Change Information Modelling

Descriptive Statistics				
	N	Mean	SD	Rank
The BCIM shall be able to synchronize data on a server with mobile device application.	**97**	**5.74**	**0.833**	**1**
The BCIM shall be cloud-based to enhance data interoperability issues.	**97**	**5.42**	**1.306**	**2**
A standard of procedure shall be developed for the integration of change management and Building Information Modelling.	**97**	**5.40**	**1.344**	**3**
The BCIM shall remain data confidential by only allowing certain information to be shared.	**97**	**5.37**	**1.379**	**4**
The BCIM shall be able to facilitate knowledge capture and sharing from the BIM model and process.	**97**	**5.32**	**1.255**	**5**
The BCIM shall be able to integrate with the company's database respectively.	**97**	**5.25**	**1.299**	**6**
The construction industry is lack of integration between change management with BIM.	**97**	**5.22**	**1.379**	**7**
The BCIM shall be able to show the variation/ updated components to the original model with the reason of changing.	**97**	**5.19**	**1.083**	**8**
The BCIM shall be able to make comparison between two revisions of models simultaneously.	**97**	**5.05**	**1.334**	**9**

4.4.2 Current Approaches of Change Management

The survey on the current approaches of change management is carried out subsequently to complement the data findings from interviews. The respondents are required to rate the level of adoption in Likert scale from 1 (strongly disagree) to 7 (strongly agree) and each of the current approaches are ranked on the basis of the mean generated by SPSS software. Table 4.6 shows total six current approaches of change management.

The result obtained from survey shows that the respondents have ranked the current approach of change management to capture lessons learned from the BIM model and change process as the most widely adopted, with the highest mean of 5.38. According to Sun, et al. (2006); Jarratt, et al. (2016), capture lessons learned from the BIM model and change process is one of the approaches to manage change.

From the survey result, it is found that the leverage BIM for change management is advocated, where the mean of 5.24 is obtained. In other words, the adoption of BIM for change management to manage project seems to be considered high, as the respondents might consider the BIM for managing a project is beneficial in terms of time and cost, and it also convenient for managing the project (Change Management Coach, 2017).

The findings from survey, Table 4.6 shows that the standard of change process for change management has the highest standard deviation and ranked as the third most adoption approaches with the same mean of 5.24. Similarly, outline the standard of change process is one of the widely implemented approaches for managing change in the construction industry (Ibbs, Wong and Kwak, 2001; Sun, et al., 2006; Motawa, et al., 2007; ORACLE, 2009; Jarratt, et al., 2011; Cho, et al., 2015; Mejlaender-Larsen, 2016).

Likewise, the result from survey showed that there was a general consensus among the respondents and, based on the Table 4.6, the respondents ranked the adoption of BIM to identify changes as the fourth most commonly adopted approach with a mean of 5.08, as the similar study by Langroodi and Staub-French (2012).

The findings from survey also revealed that the adoption of an automated notification to inform the team members of any changes to the projects have the second least adoption with a mean of 5.07. According to Karimidorabati, Haas and Gray (2016), the automated work-flow process is an approach to improve change management.

The survey results also recommend that the BIM tools shall be able to compare the “as-planned” model with the “as-changed” model and to capture those changing components, as the similar study by Valeh, Osama and Zhu (2017). It has been ranked as the least adoption with a mean of 4.97 as shown in Table 4.6. It is also important to note that the Building Information Model based visualization as a change management approach has the least adoption among other approaches.

In conclusion, the findings of the survey identified several current approaches of change management in the construction industry.

Table 4.6: Mean Ranking for Current Approaches of Change Management

Descriptive Statistics				
	N	Mean	SD	Rank
My company used to manage change and capture lesson learned from the BIM model and change process.	**97**	**5.38**	**1.295**	**1**
My company did leverage BIM for change management.	**97**	**5.24**	**1.197**	**2**
My company did outline a standard of change process for change management.	**97**	**5.24**	**1.289**	**3**
My company used to identify the changes in the BIM model and compare the revised model with the original model.	**97**	**5.08**	**1.463**	**4**
My company used to adopt automated notification to inform team members for any changes in the project.	**97**	**5.07**	**1.309**	**5**
My company used to adopt BIM to visualize the differences between the “as-planned” model with the “as-changed” model and capture those changing components.	**97**	**4.97**	**1.150**	**6**

4.5 Benefits of Building Information Modelling (BIM)

This section shows the detailed normality test before the data analysis. Besides that, it explains Kruskal-Wallis test as one of the inferential statistics for the benefits of BIM.

4.5.1 Normality Test

Normality test has been carried out to determine whether the data is normal distribution or non-normal distribution for further data analysis. Considering the Kolmogorov-Smirnov test, the significant value above 0.05 indicates normality, while the significant value below 0.05 indicates non-normality. There are total of three normality test groups with working experience of less than 5 years, 6 to 15 years and more than 16 years, as shown in Table 4.7, Table 4.8 and Table 4.9, respectively. The following tables show the significant value of less than 0.05, thus all the data considered to be significantly deviating from normal distribution, which means a non-normal distribution. Therefore, the following data test and analysis focuses on non-normal distribution.

Table 4.7: Tests of Normality for Working Experience Less Than 5 Years

		Kolmogorov-Smirnov
Working Experience	Variable	Sig.
Less than 5 years	Improve information flow	**0.000**
	Better design visualization	**0.002**
	Conflict resolution	**0.000**
	Improve cost estimation	**0.000**
	Maintain control	**0.002**
	Reduce uncertainty	**0.000**
	Reduce overall construction cost	**0.001**
	Reduce project duration	**0.002**

Table 4.8: Tests of Normality for Working Experience 6 – 15 Years

		Kolmogorov-Smirnov
Working Experience	Variable	Sig.
6 – 15 years	Improve information flow	**0.000**
	Better design visualization	**0.000**
	Conflict resolution	**0.002**
	Improve cost estimation	**0.000**
	Maintain control	**0.000**
	Reduce uncertainty	**0.001**
	Reduce overall construction cost	**0.005**
	Reduce project duration	**0.005**

Table 4.9: Tests of Normality for Working Experience More Than 16 Years

		Kolmogorov-Smirnov
Working Experience	Variable	Sig.
More than 16 years	Improve information flow	**0.013**
	Better design visualization	**0.002**
	Conflict resolution	**0.000**
	Improve cost estimation	**0.000**
	Maintain control	**0.000**
	Reduce uncertainty	**0.000**
	Reduce overall construction cost	**0.011**
	Reduce project duration	**0.001**

4.5.2 Kruskal-Wallis Test

Kruskal-Wallis Test was used to test if there are significant differences in view of three group with different working experience towards the continuous variable. There are two hypotheses have generated for the Kruskal-Wallis Test, as shown in the following:

1. Null hypotheses (H_0): There is no significant difference between groups.
2. Alternative hypotheses (H_1): There is significant difference between groups.

The alpha value less than 0.05 indicates that there is a statistically significant differences in the continuous variable across the three groups. Table 4.7, Table 4.8 and Table 4.9 show the normality tests with the significant value of less than 0.05, thus the following data interpretations are based on a non-normal distribution.

The Kruskal-Wallis test was used to compare the views of the three respondent groups on the benefits of BIM. The results reported that among the total of eight benefits of BIM, there is a statistically significant differences in BIM improves information flow throughout the process with an Asymptotic significance value of less than 0.05 as shown in Table 4.10. Therefore, it accepts the alternative hypothesis as there is a difference between the working experience group of less than 5 years, 6 to 15 years and more than 16 years. The contrasted view between the groups of the respondents are likely due to the different working experience is viewed differently that the BIM improves information flow throughout the process. The different respondent groups might have different perceptions of the information flow of the BIM throughout the process.

The result found that the significant difference is the BIM improves information flow in Kruskal-Wallis test was then using follow-up test of Mann-Whitney to evaluate the pairwise differences among the three groups. A total of three different working experience groups will be tested, which are group 1 (less than 5 years compared to 6 – 15 years), group 2 (less than 5 years compared to more than 16 years), and group 3 (6 – 15 years compared to more than 16 years). Table 4.11 shows that the BIM improves information flow throughout the process, indicated a significant difference between the group of less than 5 years and the group of 6 – 15 years with the Asymptotic significance value of less than 0.05. Among these two groups, the group of less than 5 years have the lowest mean rank of 26.99 as shown in Table 4.11. As a result, the less than 5 years working experience group concluded as the significant difference that may be attributed to less working experience in familiarizing with BIM, so that the group of people may not realize that BIM's pros have been able to improve information flow throughout the process. Nevertheless, the higher working experience group of 6 – 15 years might realise the BIM has been able to improve the flow of information, as the parties acknowledged that they are able to receive the up-to-date information (Olatunji, et al., 2010; Boukara and Naamane, 2015).

On the other hand, the result also reported that the remaining seven benefits of BIM, including better design visualization, improve cost estimation, maintain the control, act as conflict resolution, reduce uncertainty, reduce project duration, and reduce overall construction cost, have an Asymptotic significance value of more than 0.05 as shown in Table 4.10. Therefore, the remaining seven benefits of BIM have failed to reject null hypothesis as it failed to prove that there is difference between the group of working experience less than 5 years, 6 to 15 years and more than 16 years. The following discussions explain the consistency of the respondent's perspectives on the remaining benefits of BIM.

First, the Table 4.10 shows that the BIM provides better design visualization through three-dimensional is one of the Asymptotic significance values of more than 0.05. This indicates that the respondents acknowledged that BIM provides better design visualization with an intelligent 3D model-based on project team members to visualize design through a virtual life system in the early stages of the project (Olatunji, et al., 2010; Boukara and Naamane, 2015; Autodesk, 2015; Fountain and angar, 2018).

The respondents of surveys have shown that their perspective on the BIM is able to improve cost estimation towards the project, with an Asymptotic significance value of more than 0.05 as shown in Table 4.10. The respondents realised that the BIM is able to improve cost estimation by using BIM to auto-quantify the materials for any project with an extremely fast and convenient operation (Azhar, Hein and Sketo, 2009; Olatunji, et al., 2010; Boukara and Naamane, 2015; Kjartansdottir, et al., 2017). This is particularly important for the consultant quantity surveyor to provide a cost estimation of the project during feasibility study.

According to Table 4.10, BIM maintains control by auto-saving and retracing the design model with an Asymptotic significance value of more than 0.05. This means that the respondents admitted that the user can less concerned losing data in BIM because the digital model-based of BIM is able to auto-save and retrace the design model in some sense (Autodesk, 2015).

Fourth, the findings from survey also revealed that BIM act as conflict resolution is one of the Asymptotic significance values of more than 0.05 as shown in Table 4.10. This indicates that the respondents agreed the BIM is able to minimize conflict between parties by automating clash detection on potential design conflict (Love, et al., 2011; Boukara and Naamane, 2015; Autodesk, 2015; Agyekum-Kwatiah, 2018). The user is able to detect any clashing items before drafting tender documents and this would ensure the buildability of end product.

Besides that, there is a consistent perspective among the three different working experience groups on the BIM reduces the uncertainty of the project. This shows that the respondents acknowledged that the adoption of BIM for construction project can reduce uncertainty by ensuring reliable information provided in a timely manner to team members (Autodesk, 2015). Besides that, BIM is an intelligent 3D technology to replace the conventional approach that caused uncertainty to project (Underwood and Isikdag, 2010).

According to Table 4.10, BIM reduces project duration with an Asymptotic significance value of more than 0.05. Similarly, the respondents realised that the BIM users are able to visualize the issue or identify issues that will occur before construction phase, thus all the issues and chain consequences can be avoided. In other word, the BIM provides a model-based approach that would useful for better managing project during both pre-contract and post-contract phases (Azhar, Hein and Sketo, 2009; Autodesk, 2015; Boukara and Naamane, 2015; Kjartansdottir, et al., 2017). The BIM consists of detailed information than a paper drawing, in which there is sufficient detail for the BIM user to review and avoid from losing important information.

Lastly, there is a consistent perspective among the three respondent groups on the BIM reduces overall construction cost. The respondents realised that the intelligent 3D model-based provides an accurate quantity to be used in the project rather than a manual measure that reduces the risk of over-quantification of materials (Azhar, Hein and Sketo, 2009; Autodesk, 2015; Boukara and Naamane, 2015; Kjartansdottir, et al., 2017). The reduction in construction time will eventually reduce the overall cost of completing the project. Besides that, the use of BIM is able to reduce unnecessary rework in the preparation of drawing and construction work, which in turn reduces unnecessary costs.

Table 4.10: Kruskal-Wallis Test for Benefits of Building Information Modelling (BIM)

Hypothesis Test Summary			
	N	Asymptotic Significance	Decision
BIM provides better design visualization through three dimensional.	**97**	**0.357**	**Retain the Null Hypothesis**
BIM improves cost estimation towards the project.	**97**	**0.198**	**Retain the Null Hypothesis**
BIM maintains the control by auto-saving and retracing the design model.	**97**	**0.602**	**Retain the Null Hypothesis**
BIM act as conflict resolution.	**97**	**0.589**	**Retain the Null Hypothesis**
BIM improves information flow throughout the process.	**97**	**0.009***	**Reject the Null Hypothesis**
BIM reduces uncertainty due to reliable information provided.	**97**	**0.364**	**Retain the Null Hypothesis**
BIM reduces project duration.	**97**	**0.573**	**Retain the Null Hypothesis**
BIM reduces overall construction cost.	**97**	**0.373**	**Retain the Null Hypothesis**

Note: * indicates the significant value, P ≤ 0.05.

Table 4.11: Pairwise Comparisons of Working Experience

BIM improves information flow throughout the process			
		Mean Rank	Asymptotic Significance
Group 1	Less than 5 years	**26.99**	**0.002***
	Compared to		
	6 – 15 years	**41.23**	
Group 2	Less than 5 years	**29.72**	**0.331**
	Compared to		
	More than 16 years	**34.08**	
Group 3	6 – 15 years	**29.12**	**0.106**
	Compared to		
	More than 16 years	**36.33**	

Note: * indicates the significant value, P ≤ 0.05.

4.6 Overall Concept of Building Change Information Modelling

The Building Change Information Modelling (BCIM) system integrates BIM with change management to improve the performance of project design changes, improve communication with all parties and manage the project efficiently throughout the project lifecycle. Figure 4.1 illustrates the designation of the BCIM framework which tried to address the limitation found in the current approaches to change management and BIM. Besides that, the requirements proposed by the respondents are taken into consideration for the development of BCIM framework. Finally, the overall concept of the Building Change Information Modelling (BCIM) is shown in Figure 4.2.

The BCIM consists of three main modules, namely change management process, knowledge module and BIM. The BCIM system is designed to be web-based in which that the user can log into the system through the World Wide Web (Web) as shown in Figure 4.2.

The BCIM server is proposed to be cloud-based as to enhance data interoperability issue. The concept of centralised cloud-based is that the change management process, knowledge module and BIM are integrated to provide access to each of the module and remove the need of replicating data input. Therefore, the advantages of the cloud-based system are that the three main modules can be accessed and are capable of exchanging information such as data, services and processes despite the geographical location.

The knowledge module act as an intermediate module to provide the function of facilitating communication between BIM and change management, and capture lesson learned in the BIM and change management activities. The proposed knowledge module can connect to BIM model and change management module to facilitate knowledge capture and sharing in the BIM model and change management process. Therefore, any decision made in the change management process and revision made in BIM model will be immediately reflected in the knowledge module. Besides that, the knowledge module also supports knowledge re-use in the project lifecycle for the benefits of construction parties in such that to leverage the knowledge module for the better decision making or problem solving. There will be a real-time synchronisation between cloud-based and knowledge module. Should any new knowledge be shared or updated, an automatic generated notification will be sent to notify the parties. With the synchronised feature, the most updated information and data captured will appear in both three modules.

Next, the change management module is designed to support efficient change processing, with functionality to control, report and follow-up project changes to achieve changes in projects. The change management in the BCIM system is associated to the on-going projects in which the related information can be notified to different users via an automated work-flow process. In addition, the change management module is interlinked with both the knowledge module and BIM model. Should any changes have made to BIM model, a list of change is saved in the change management module. The knowledge stored in the knowledge module can be referred when making changes. Figure 4.3 illustrates the development of a flowchart that visualizes the change management process.

The BIM is one of the core modules of this system that leverage the digitalised construction site, comprising detailed project information. It is in the form of a 3D model-based process that provides 3D model visualization for architectural, engineering and construction professionals as tools for speedy project design.

One of the unique features of this BCIM system is that it can be incorporated with company's database if needed upon the request by the users. This is to allow the team members can have a real-time view of the data performance which can only be located from company server. In other words, the users who use BCIM are able to capture certain data from company database and use it in the BCIM. In fact, there is a need to protect certain important information to be shared among project team members. This can be accomplished by sending a request and permission is granted to the person who is permitted to do so. In addition, a file encryption is also proposed in the database to store and secure certain important data in the database that enable certain users to access and review the database. Therefore, unauthorized data sharing by project team members may also be avoided and can remain confidential.

The BCIM system is different from other system is such that, the user can open two different models at the same time for comparison purposes. The system will show the changes made to the BIM model and depict the differences of two models.

The BCIM system will outline the updated components in a list with the related details such as, the rationale of change, the user who modified, the date of change and the approval person. By doing this, the next user to use the modified model would know what has been done on the revised model.

Another feature associated with the BCIM system is that the synchronization data on a server with mobile device application. This user-friendly mobile device application provides user convenience so that construction projects can be accessed anytime at anywhere without the need for printed spreadsheet or drawings. The digitalisation construction is evolving from manual work and paper-based processes towards real-time sharing of information and automated process. In fact, when the information is updated from either of the modules, the users can be easily notified and contacted. As to keep record, every update is also be copied to email.

In conclusion, the integrated framework of BCIM is a centralised cloud-based that enables a comprehensive building information modelling, related knowledge, and change management method to facilitate project management and team collaboration. The management of building digital models and changes in a single process will greatly increase working efficiency and productivity.

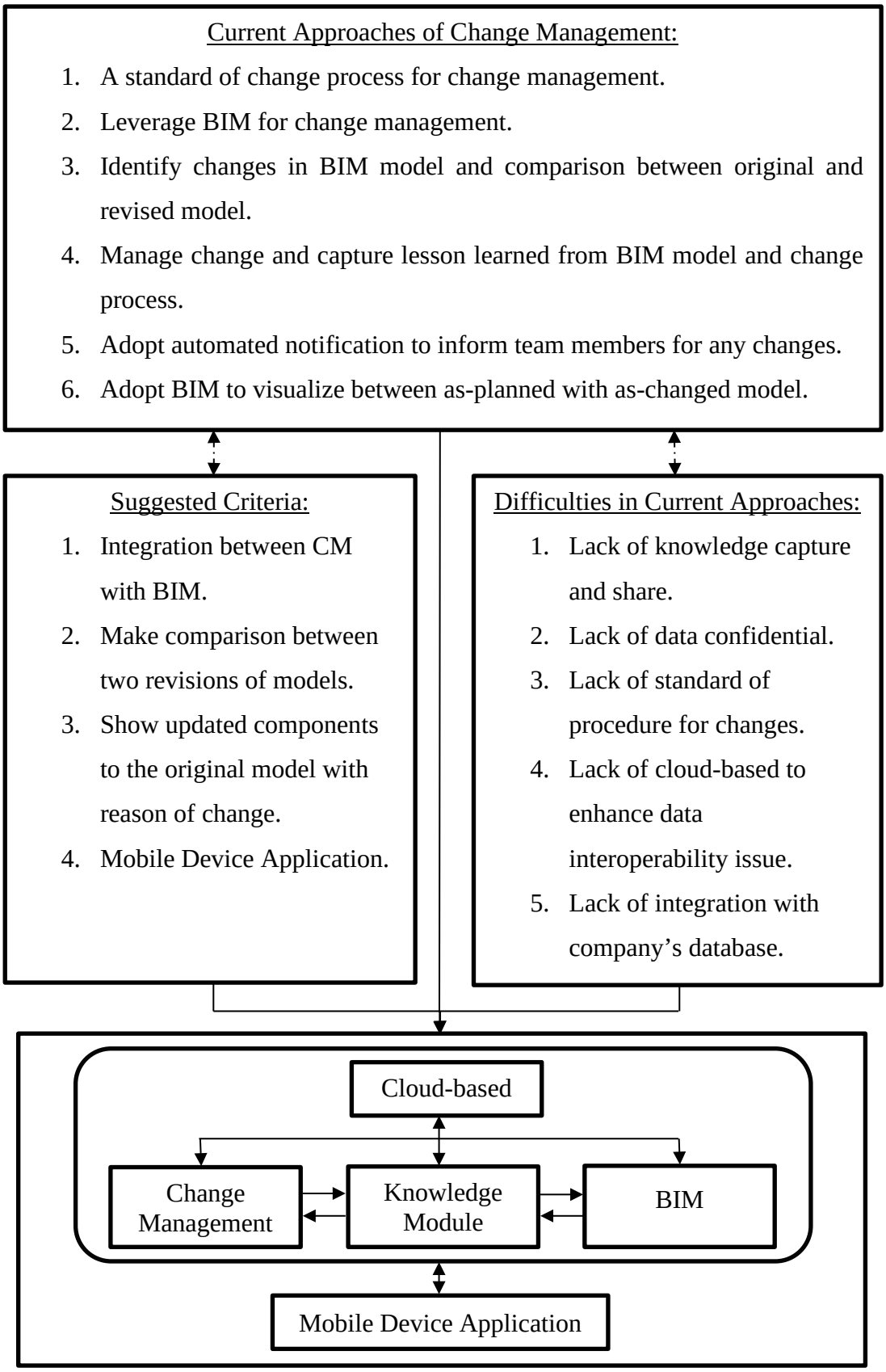

Figure 4.1: Designation of BCIM Framework

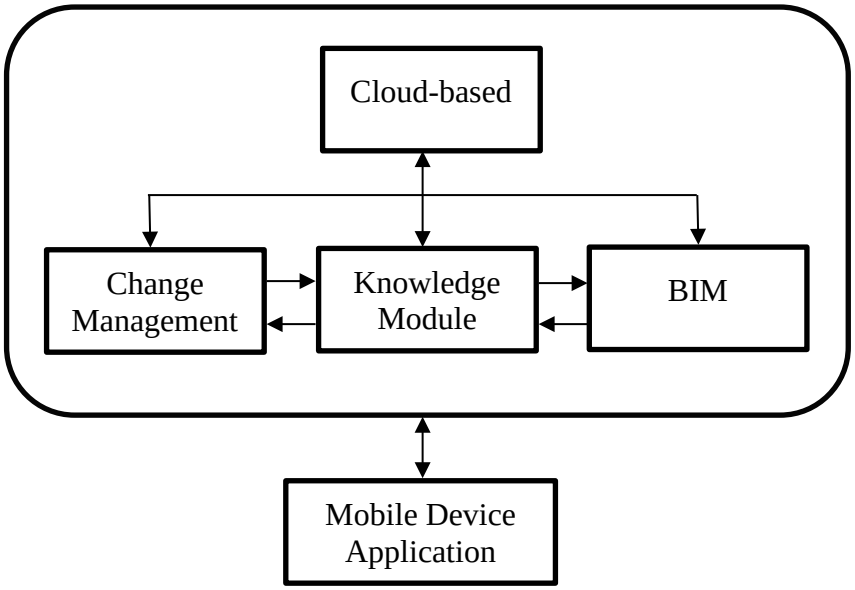

Figure 4.2: Overall Concept of Building Change Information Modelling

4.7 Standard Change Management Process

Figure 4.3 shows the recommended standard change management process. This process is not standalone whereby it can be aided with BCIM system. Put it simply, when a change request is made by a party to the BCIM system, they can refer to the knowledge module to make the best decision. It will be captured and saved to the database when decision is made albeit the proposal is rejected. With the automated function of BCIM, the relevant parties are kept up-to-date and informed of any changes, update happens to model or new knowledge shared. The standard change management process consists of four phases, namely general project execution phase, filtration and assessment phase, approval and implementation phase, and control strategy phase.

General Project Execution Phase

The first step to proceed with the change is for the team members to focus on the communication process and to identify the contract condition for the project in terms of its scope (ORACLE, 2009). Identifying the contract provision is very necessary before continuing with the changes, as the disagreement between the parties will easily occur in the future. Once the contract has been identified, the project team members will be able to manage the change more effectively.

Filtration and Assessment Phase

The purpose of filtration is to identify the possible changes that might occur when the new changes item has been implemented (Ibbs, Wong and Kwak, 2001; Motawa, et al., 2007). This identification is important to be carried out before a chain consequence may arise as a result of the proposed change.

When the potential change has been identified through the use of the BCIM system, the project team will decide whether the proposed change will be accepted or rejected. The BCIM is applied to assess which and what changes are affected, as the affected components will be highlighted as a signal to the team members to consider the issue. At the same time, the knowledge module will also provide a previous decision on a similar case as a reference for the decision-maker. Usually, the decision to make the changes are based on the profit that the changes will generate and the effects of the changes, schedule, quality and etc (Ibbs, Wong and Kwak, 2001; ORACLE, 2009; Jarratt, et al., 2011; Mejlaender-Larsen, 2016).

A Proposal Change Order (PCO) is created via the BCIM when the change has been evaluated. PCO is created to track easily the changes made by the team members, with specific details of the changes and the risk identified (ORACLE, 2009). The benefit of using BCIM for the PCO creation is that the impact to the project could be determined by referring to the BIM model. In addition, the list of PCO for the project can be kept track easily by minimising the loss of printed spreadsheet.

Approval and Implementation Phase

The approval step is the most important step in change management, as it is the final decision of the client to proceed with the change. Although the upper management approved the proposed change and created the PCO. Final approval from the client is required, as the upper management has gone through most of the financial and technical aspect to make it easier for the client to make a decision.

As soon as the change has been approved by the client, and the decision has been updated to the system. The system shall immediately notify all parties involved and they are responsible for having a timely meeting with the respective members in order to re-arrange the schedule in the best possible way.

Control Strategy Phase

Although all decisions made and all other necessary information in the PCO would be knowledge captured and stored in the company's database, but the team members will still be responsible for ensuring that all the data is completely stored without the absence of any information because the dispute might arise in the future (ORACLE, 2009).

Once the documentation has been completed, the project team members will be discussed openly about the mistakes that cause the changes. It is beneficial for team members to recognize the root causes of change and to prevent them from making similar mistakes in the future (Ibbs, Wong and Kwak, 2001; Jarratt, et al., 2011). The knowledge module plays an important role in ensuring that knowledge captures all information in the process.

In conclusion, this change management process provides a standardized mechanism for users to deal with all the construction changes. Besides that, this process is an automated workflow process that operates within the BCIM system and may reduce human involvement intensively.

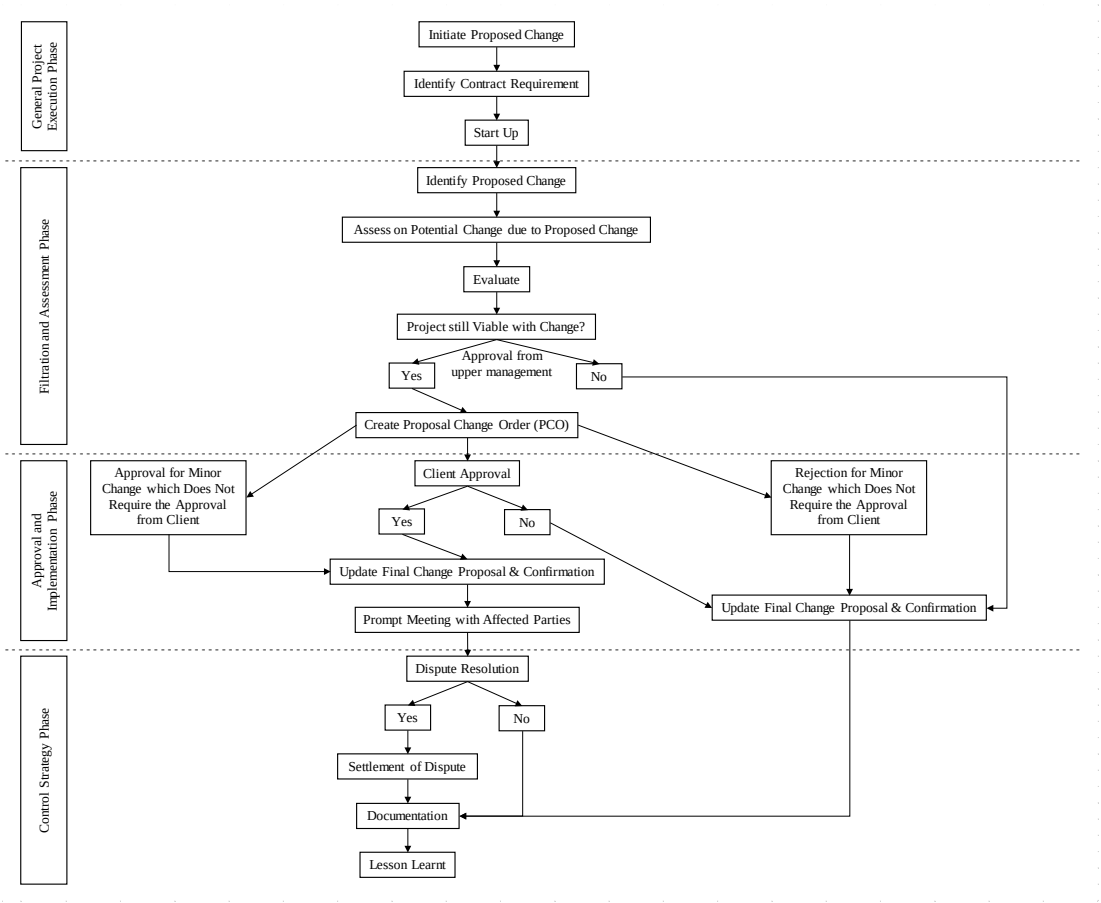

Figure 4.3: Change Management Process

4.8 Summary

The chapter detailed the background of the interviewees and the theme and sub-theme of the interview. It also detailed the background of the respondents, followed by a test of the reliability of the data collected. Next, the data collected from qualitative approach was discussed based on narrative analysis and the surveys have been used for supplementing the interview discussion. The data collected from quantitative approach was tested through Kruskal-Wallis test and the follow-up test by using Mann-Whitney for all the benefits of BIM. Finally, the overall concept of BCIM and standard of change management process are illustrated in Figure 4.2 and Figure 4.3, respectively.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

It summarizes the overall findings of this research. It also covers the research implications. The subsequent section details the limitation of this research. Lastly, it discussed the recommendations for improving this research.

5.2 Research Findings

Construction is one of the most fragmented industries as project participants, such as the client, architect, contractor and so on, may be the ones seeking for changes after the start of the project. Construction change is a significant aspect of the project, as changes frequently result in time delays, cost overruns, quality defects, negative impacts and often lead to disputes. Related to this, many initiatives have been proposed to mitigate the impact of the changes. One of the methods is the leverage of digitalised construction such as BIM. BIM helps to improve the construction project to certain extent as it provides sufficient data to different user needs due to rich data storage, and an intelligent modelling tool. Reviewing the literature, the existing researches have often focused mainly on leverage BIM for visualization purpose without fully integrating with change mangement to effectively manage changes. In addition, it is found that extensive personal experience is required to manage changes manually and the lack of standard procedure for dealing with changes. Therefore, this research was carried out to improve the management of changes in the construction project with the aim of developing a Building Change Information Modelling (BCIM). The objectives outlined early in this research were to discuss the benefits of Building Information Modelling (BIM), to explore the current approaches of change management, and to propose a framework for Building Change Information Modelling (BCIM). In view of developing an integrated framework to effectively manage construction changes, the mixed method research adopted to explore the current practices of change management and BIM. In this research, the Central Limit Theorem was adopted. A total of 97 sets of questionnaire responses were used in this research and a total of 3 out of 5 interviewees were successfully interviewed who working as a quantity surveyor in a consultancy firm within the Klang Valley district.

Reviewing of the literature has explored that it is not uncommon for there to be any changes in the construction industry, and changes may take place at any of the three stages, which is the inception stage, design stage and construction stage. Besides that, the literature review found that the researcher has adopted BIM to identify changes in the model and to compare the revised model with the original model. Furthermore, the automated workflow-based change management process is one of the approaches to change management. In more details, it is designed to improve compliance, improve accuracy information and improve traceability of requests for changes through WEB. Moreover, the researchers use building-information-model-based visualization to visualize the “as-planned” building information model with the “as-changed” model to track and highlight the change sequence as one of the change management approaches. It is found that various of change management procedure has been developed by different researchers to handle change.

In fact, this research findings revealed the nine criteria to be included in the BCIM system based on the difficulties found in the current approaches to change management and the criteria suggested by the respondents for the development of BCIM. The nine criteria for the development of BCIM system are integration of BIM and change management, comparison between two revisions of models, show updated components to the original model with reason of changing, synchronize data on a serve with mobile device application, facilitate knowledge capture and share from BIM model and process, remain data confidential, develop a standard change procedure, cloud-based to enhance data interoperability, and integration of company’s database with the proposed system.

In more details, the consultant quantity surveyor perceived the integration of change management with BIM would allow project team members to manage change efficiency in a single software. Besides that, this research has identified the need to provide a comparison feature between two revisions of models that would allow users to easily distinguish between the two different models. The feature of showing updated components to the original model with the reason of changing is suggested for tacking purpose and also helps users to be clearly aware of the updated components. Furthermore, majority of the consultant quantity surveyor recommended the synchronization of data on a server with mobile device application to allow users to access the project anytime at anywhere, especially for an international project.

It is found that majority of the respondents manually capture lesson learned, as a result of unreliable information due to human mistake. However, the system facilitates knowledge capture and share lesson learned in a systematic approach would eliminate human involvement intensively and, as a result, improve information accurately and precisely. In addition, the result of survey revealed that all the data shall remain confidential to protect important information and allow certain information to be shared. Although, majority of the firms have their own standard change procedure as a common frame for employees to follow, but some respondents viewed it differently that the standard of change procedure shall be developed into the system for all users to follow the standardized process throughout the construction project. Furthermore, respondents highlighted that the system shall able to enhance data interoperability by incorporating with cloud-based to allow multiple types of users to operate concurrently under the same document. It is noticed that the company’s database must be integrated with the system to improve accessibility.

The benefits of BIM obtained from literature include improve information flow, better design visualization, conflict resolution, improve cost estimation, maintain control, reduce uncertainty, reduce overall construction cost, and reduce project duration. In more details, the research findings disclosed that there was a significant difference in the perception between the different working experience groups on the BIM improves information flow. A follow-up test discovered the significant difference between the working experience group of less than 5 years and the working experience group of 6 – 15 years. By comparison, the less than 5 years working experience group was the significant difference that may be attributed to less working experience in familiarizing with the BIM, so that the group of people might not realize that BIM's pros have been able to improve information flow throughout the process.

In conclusion, the proposed BCIM framework is therefore designed to be a centralised cloud-based that manage digital models and changes in a single process. It also revealed the working experience group of less than 5 years is the category explored, that has significant differences in the perceptions of the BIM that has been able to improve information flow.

5.3 Research Implications

There are several contributions in this research. Firstly, this research used qualitative and quantitative methods that specifically examine the current approaches of change management and BIM. It also helps to gain a deeper understanding on the current approaches of change management and BIM in order to develop an integrated framework to manage construction project efficiently. In addition, the difficulties of change management found during interview session, eventually alert the firm to take action to strengthen it. Besides that, existing strategies often provide valuable information for a new established firm to refer as a guideline for handling changes.

Furthermore, most of the limitations on current change management and criteria for developing a software/ system have been identified in this research, which highlights the importance of viewpoints in this research. This provided a valuable guidance for the current researcher who is undergoing research on the development of a comprehensive software/ system.

This research is beneficial because it increases the awareness of BIM as well as the benefits of BIM that brought to the construction industry. This information pertaining to the benefits of BIM provides details information for company considering the implementation of BIM.

5.4 Research Limitations

There were several limitations have been identified in this research. The limitation of the research included the insufficient sample size to be collected, however it has replaced by the Central Limit Theorem due to time constraint and weak relationship in this industry field. Besides that, interview saturation has not reached in this research due to extremely weak relationship with construction industry, especially in consultant quantity surveyor.

Moreover, the data obtained from samples were viewed as unbalanced perception by different groups of personnel such as academic qualification and groups of age. In this research, only the groups of working experience have reached the thirty sample in each of the group that can be used for data analysing. Therefore, the other groups of personnel cannot be used for data analysing due to insufficient of thirty sample in each of the group.

In addition, this research study was limited to consultant quantity surveyor, while the perception of the technical expert in BIM has overlooked. Since this research focuses on the development of framework for BCIM, it will be good if the involvement of BIM's technical expert could furnish with different useful information for the research in the future.

Lastly, the Information and Communications Technology (ICT) development is too fast to be keeping up-to-date. The new development of ICT may introduce some additional feature or criteria to the BIM which this research is not able to foresee.

5.5 Research Recommendations

First, any organization that has reported its difficulties in handling change should not only recommend a solution, but should also take action to address it. In order to manage project effectively, the company shall take prompt action to address the issues within the company. In this research, most of the interviewees acknowledged their problem and even suggested some solution during interview session, but no further action was taken.

Throughout the interview session, the acceptance of BIM in Klang Valley area is not considered high. A total of three people from different companies participated in the interview session and there is one company that does not use BIM for their project, which is a small consultant firm that does not realize the benefit of using BIM. Therefore, a reward incentive policy can be implemented by giving free trial to complete a project, so that they can completely understand the benefits of BIM from pre-contract to post-contract.

Moreover, the new development of framework for Building Change Information Modelling needs further study to validate the concept of the system's function in supporting key project operations and also to examine its effectiveness to manage and track changes throughout the design and construction process, which will be the focus of the next phase of this research.

Lastly, this research deals with changes via BCIM for construction project. Further research is recommended to incorporate with claim management, in order to fully leverage on the detailed information and knowledge captured. As a result, any changes have been approved and knowledge captured, the system can somehow continue to prepare claim and track the status of claims.

5.6 Summary

This chapter detailed the overall findings of this research. The aim and objectives of this research, as established early in the research, are fulfilled and justified by the research findings as defined in Section 5.2. The importance of research implication is highlighted in this chapter in order to indicate the importance of this research. Limitations have been identified throughout the research. Finally, it also covered the details of the recommendations for this research.

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APPENDICES

APPENDIX A: Questionnaire Survey Sample

DEVELOPMENT OF FRAMEWORK FOR BUILDING CHANGE INFORMATION MODELLING (BCIM)

TO WHOM IT MAY CONCERN

Dear Sir/ Madam,

I am a student who is currently undertaking the Bachelor of Quantity Surveying (Hons.) from University Tunku Abdul Rahman (UTAR) Sungai Long.

The purpose of the research is to develop a framework of Building Change Information Modelling (BCIM) for construction industry with the following objectives:
i. To discuss the benefits of Building Information Modelling.
ii. To explore the current approaches of change management in Building Information Modelling (BIM).
iii. To propose a framework of Building Change Information Modelling (BCIM).

This questionnaire consists of FOUR (4) sections, which will take approximately 10 minutes to complete. Your participation will greatly contribute to the success of the survey. I deeply appreciate your help in participating in this survey, and your responses will be remained confidential and will be used strictly for academic purpose only.

Thank you for taking the time to complete this questionnaire. If you have any queries please do not hesitate to contact Leong Kar Kang at 014-9240989 or email to ryanleongkk@1utar.my.

Section 1: Demographic Information

1. What is your gender?
    - Male
    - Female

2. What is your age?
    - Below 25
    - 26 – 30
    - 31 – 40
    - 41 – 50
    - Above 50

3. What is your highest level of academic qualification?
    - Primary Education
    - Secondary Education
    - Tertiary Education
    - Postgraduate Qualification
    - Other
        i. Please specify:…….

4. How long have you been working in the construction industry?
    - Less than 5 years
    - 6 – 15 years
    - More than 16 years

Section 2: Proposal of Framework for Building Change Information Modelling (BCIM)

To what extent you agree the following statement, where: 1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Neither Agree nor Disagree, 5 = Somewhat Agree, 6 = Agree, 7 = Strongly Agree

Statements	1	2	3	4	5	6	7
The construction industry is lack of integration between change management with BIM.	O	O	O	O	O	O	O
The BCIM shall be able to make comparison between two revisions of models simultaneously.	O	O	O	O	O	O	O
The BCIM shall be able to show the variation/ updated components to the original model with the reason of changing.	O	O	O	O	O	O	O
The BCIM shall be able to facilitate knowledge capture and sharing from the BIM model and process.	O	O	O	O	O	O	O
A standard of procedure shall be developed for the integration of change management and Building Information Modelling.	O	O	O	O	O	O	O
The BCIM shall remain data confidential by only allowing certain information to be shared.	O	O	O	O	O	O	O
The BCIM shall be cloud-based to enhance data interoperability issues.	O	O	O	O	O	O	O
The BCIM shall be able to synchronize data on a server with mobile device application.	O	O	O	O	O	O	O
The BCIM shall be able to integrate with the company's database respectively.	O	O	O	O	O	O	O

Section 3: The Current Approaches of Change Management

To what extent you agree the following statement, where: 1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Neither Agree nor Disagree, 5 = Somewhat Agree, 6 = Agree, 7 = Strongly Agree

Statements	1	2	3	4	5	6	7
My company did outline a standard of change process for change management.	O	O	O	O	O	O	O
My company did leverage BIM for change management.	O	O	O	O	O	O	O
My company used to identify the changes in the BIM model and compare the revised model with the original model.	O	O	O	O	O	O	O
My company used to manage change and capture lesson learned from the BIM model and change process.	O	O	O	O	O	O	O
My company used to adopt automated notification to inform team members for any changes in the project.	O	O	O	O	O	O	O
My company used to adopt BIM to visualize the differences between the “as-planned” model with the “as-changed” model and capture those changing components.	O	O	O	O	O	O	O

Section 4: The Pros of Building Information Modelling (BIM)

To what extent you agree the following statement, where: 1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Neither Agree nor Disagree, 5 = Somewhat Agree, 6 = Agree, 7 = Strongly Agree

Statements	1	2	3	4	5	6	7
BIM improves information flow throughout the process.	O	O	O	O	O	O	O
BIM provides better design visualization through three dimensional.	O	O	O	O	O	O	O
BIM act as conflict resolution.	O	O	O	O	O	O	O
BIM improves cost estimating towards the project.	O	O	O	O	O	O	O
BIM maintains the control by auto-saving and retracing the design model.	O	O	O	O	O	O	O
BIM reduces uncertainty due to reliable information provided.	O	O	O	O	O	O	O
BIM reduces overall construction cost.	O	O	O	O	O	O	O
BIM reduces project duration.	O	O	O	O	O	O	O

APPENDIX B: Interview Guide Sample

Interview Question

1. **Current Practice of Building Information Modelling (BIM).**
   a. What is the BIM software that your company using?
   b. Why the software being chosen?

2. **Advantages of BIM.**
   a. To what extent you think BIM would benefit your project and why do you think it is beneficial?

3. **Problem of the Company's Current Practice.**
   a. What are the difficulties you have encountered?

4. **Solution for the Company's Current Practice.**
   a. How are you going to solve the difficulty?

5. **Criteria for Building Change Information Modelling (BCIM).**
   a. What are the criteria to be included in the new system?

6. **Current Practice of Change Management.**
   a. How did the current change management process being implemented in your company?
   b. What is the approach that used to deliver message to parties?
   c. Did BIM being implemented for managing changes?
   d. Did a change event being capture?

Interviewee's Background

1. What is your Gender?
    a. Male
    b. Female

2. What is your age?
    a. Below 25
    b. 26 – 30
    c. 31 – 40
    d. 41 – 50
    e. Above 50

3. What is your highest level of academic qualification?
    a. Primary Education
    b. Secondary Education
    c. Tertiary Education
    d. Postgraduate Qualification
    e. Other: _____

4. How long have you been working in the construction industry?
    a. Less than 5 years
    b. 6 – 15 years
    c. More than 16 years

APPENDIX C: Interview Transcript Sample

Interviewee: A

Transcribed: 21st February 2020

Interviewer: Did you aware of Building Information Modelling (BIM)?

Interviewee: Sure, BIM is just a noun and actually consist of lot of different software.

Interviewer: You are right.

Interviewer: May I know any BIM software being implementing in your company?

Interviewee: Autodesk Revit, AutoCAD.

Interviewer: Great. Could you explain why two of this software being chosen in your company?

Interviewee: First of all, the purpose of using BIM is to follow the current technology track. Secondly, the BIM definitely easy all the job we had and also fasten our job scope.

Interviewer: Oh, this is the reason BIM being implemented in your company?

Interviewee: Yes.

Interviewer: To what extent you think BIM would benefit your project.

Interviewee: It able to clash detection of different trades e.g. services or building structure at early stage before construction stage, which is helpful in avoid abortive works.

Interviewee: Let me provide u one more example. In the case that I need to draw a 3D model, I can easily use pictures that I can find in a catalogue or on the internet and insert into the software. So, why would I try and re-draw something when I can find something that was already done?

Interviewer: Great. First time I heard something like this.

Interviewee: Actually, my company was used Cubicost software but due to decision from upper management to stop using this software and …. thus we just follow not to use.

Interviewer: Oh. Do you agree that this is one of the difficulties in your company?

Interviewee: I do not consider this as difficulty la, this is just a decision from upper management.

Interviewer: Okay. So, currently any difficulties that you have encountered with?

Interviewee: There is a communication issues exist in our company because our company does not consolidate input of information from all parties involved in which it causes lot of discrepancies in the final product.

Interviewer: Basically, this issue still existing and any solution to this issue?

Interviewee: It is good to consolidate the information and BIM modelling into cloud and allow all relevant parties to access and edit on it.

Interviewee: Basically, this is one of the solutions and this solution not decide by me. It is by upper management.

Interviewer: Oh. So, the problem mentioned earlier is solved?

Interviewee: No. It is a suggested solution and still under pending process. As I know, this decision involved lot of parties to decide.

Interviewer: Oh. Other than that, is there any difficulty?

Interviewee: Ermmmm…. Most properly is no.

Interviewer: How about your company system and etc.

Interviewee: Actually, this is what I realized that all the software in our firm is not connecting to our company's database thus causing a lot of separate drawing that store in database, so it takes some time for other users to search for it when we want to reuse the building model from a previous project.

Interviewer: Is mean that if a software that is connecting to your database, other user who open the software can search the model easily instead of searching through database which is platform that storing all files?

Interviewee: Ya. Is about that. This issue I think is not a big issue to some people, I guess.

Interviewer: Is there any solution to this issue?

Interviewee: Ensure the connection of all the software to database, but somehow it is too technical problem.

Interviewer: Ya. Some kind of very IT job scope. Besides that, any difficulty?

Interviewee: I think no.

Interviewer: Great. Now, I am going to ask some opinion from you if there is a new software/ system, what feature you think must be included?

Interviewee: This software/ system is using for what purpose?

Interviewer: For better managing construction project with easily operate.

Interviewee: If you mention about easily operate. My first thought is doing mobile application. Since all the people also have their smart phone and they also can check project information anytime at anywhere.

Interviewer: You mean make it mobile device application?

Interviewee: Indeed. Mobile application could convenient to a firm that involved international project because they can always monitor the status of the project from other country with the mobile application.

Interviewer: So, do you agree that the use of mobile application can manage change effectively?

Interviewee: Sure. Then the parties involved are getting more and more convenience to manage changes.

Interviewer: Great. Any feature that you wish to include?

Interviewee: I suggest that the new system/ software shall able to compare two different revisions of model for a project.

Interviewer: Could you explain more?

Interviewee: This will easy for user who want to find any differences between the two models and also provide a visualization for user to visualise the two different models at the same time.

Interviewer: Oh. Any feature that you wish to include?

Interviewee: Most properly no.

Interviewer: Let me give you some example. How about knowledge capture and share, data confidential, make comparison between two revisions of models at the same time.

Interviewee: I think data confidential shall include for the purpose of remain certain company's data confidentially, so important data will not spread out easily.

Interviewer: Could you explain more?

Interviewee: Just to ensure data remain confidential to secure client.

Interviewer: Alright. Great. Besides that, I would like to know more on your company in terms of change management.

Interviewee: Sure, no problem.

Interviewer: Can you explain how did the current change management process being implemented in your company?

Interviewee: Technical team identified changes required for the works, notify & provide information to cost & contract team with details information. Cost & contract team roughly come out with a cost estimation of the change and followed by getting approval from client and then formalise the change instruction issuance.

Interviewee: So far, our firm has well-developed our own standard procedure for change and the process will review with upper management every two years.

Interviewee: One more thing to add. Our technical team also play an important role in the early stage of project because they have to identify changes on the pre-tender estimate stage to eliminate the changes before tender has been awarded.

Interviewer: Great. Such a well organize system. Besides that, I would like to know what is the approach that used to deliver message to parties especially for change event?

Interviewee: Usually, we verbally discuss changes during meeting.

Interviewer: I mean how your company officially inform the contractor or other parties for the changes of the project?

Interviewee: Oh, first of all, we will discuss change during prompt meeting when there is a change arise. After the discussion, we will back office and send an official letter to related parties.

Interviewer: How about the use of hardcopy?

Interviewee: Sometime we will be using hardcopy as well. As we can observe that some of the sub-contractor or some people are lazy to open and check their mailbox regularly.

Interviewer: Okay. Mean sometime the sub-contractor does not know the change event?

Interviewee: It never happen in my project until now. Usually, we will have a meeting every week, therefore more or less they also will know. However, sometime will also miss out someone to be sent when doing e-mail.

Interviewer: Oh, how do you ensure this problem will not happen again?

Interviewee: That’s why meeting to be conducted every week is important. Our site normally will allocate a Resident Engineering to monitor the progress.

Interviewer: Oh. Besides that, since you were using BIM for all the project. Did u use BIM for managing changes?

Interviewee: As I mentioned early, the software we were using is able to detect clash which also one of the ways for managing changes. Actually, we have to use of BIM for all the project because we have to meet one of our mission and vision in our company is to protect the interest of client and stakeholder.

Interviewee: Not only that, it is common to use BIM to identify and we insist to use in all the project is to make project right and this will increase my company's reputation. For example, we are mostly handling big project, normally the infrastructure project such as railway, roadwork and drainage have the high possibility of clashing items.

Interviewer: Ya, by doing this way, your company will have better reputation as your company think customer ahead.

Interviewee: Nowadays, some of the client enforces the parties to the adoption of BIM for the particular project in the form of contract agreement.

Interviewer: Oh. I did not know.

Interviewee: Because now market started aware the goods fact of BIM.

Interviewer: Oh. By the way, how about capturing change event?

Interviewee: Ya. We do capture and share lesson from every change event.

Interviewer: How this process beneficial to your project?

Interviewee: It benefits to all my ongoing project and also future project when changes being captured and shared.

Interviewer: How do you share along the project?

Interviewee: We share the change event after completion of project because every meeting was busy with other discussion and left it end of the project.

Interviewer: Wow. I learnt a lot from you. I think that's all from me. Thank you for the time.

Interviewee: No worries.