Investigating the Effectiveness of Adopting Building Information Modelling for Refurbishment of Complex Buildings; Case study of Auckland

A thesis submitted to Auckland University of Technology

in fulfilment of the requirements for the degree of

Doctor of Philosophy

July 2019

Auckland University of Technology

School of Engineering, Computer & Mathematical Science

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Abstract

The adoption of building information modelling (BIM) is relatively new to the refurbishment of existing building projects. As a result, the uptake and delivery have been recently reported to be slow for refurbishment projects. Low adoption of BIM is suggested to be due to fragmented projects, isolation, lack of collaboration information sharing in the construction firms. In addition, the refurbishment projects are risky, and very complex in nature. However, some of these projects had reported substantial project delays, significant cost overruns twice the budget, poor stakeholder engagement, dissatisfaction of project outcome by the refurbishment stakeholders. Consequently, the adoption of BIM for complex refurbishment projects is dependent on the project stakeholders' decisions. Although the project stakeholders have diverse backgrounds and interests, they can be independent to each other but having intricate relationships and interactions. In this regard, analysing and aligning the project stakeholders' interactions can bring about an environment where BIM can be implemented. Since these interactions can constitute the norms, values and perception of stakeholders, the impact and interactions of stakeholders can therefore be analysed from the network perspectives.

Therefore, the study aimed at investigating the effectiveness of BIM adoption decisions for complex refurbishment project in the New Zealand context. The study is thesis by manuscript method, hence, each of the manuscript describes fully the analysis approach. Although, the data collection where divided into 4 stages, these includes the preliminary stage, the interview stage, the survey/questionnaire stage and the focus group stage, each of these stages are reflected on different chapters as contained in the thesis. A case study is adopted during the preliminary studies which allowed a snowball methodology to identify hidden population of the research participants. The participants are mainly from Auckland and involves stakeholders who have participated previously in a refurbishment project which was adopted as the case study. The key findings in the study include the main environmental factors that impact refurbishment project stakeholders to adopt BIM in New Zealand, the risk factors that impact project stakeholders role towards BIM adoption for refurbishment project; identification of refurbishment project attributes; and overall validation of factors and provision of solution (optimisation) for adoption of BIM for refurbishment project. The validation of the findings, including identification of real BIM benefits for refurbishment projects using error management and sensitivity analysis indicates that BIM adoption for refurbishment project is feasible through the healthy interaction of the project stakeholders. The findings revealed that the main influence factor is not the cost, which is in consistent with previous study, but rather indicate that it is about cost perception regarding BIM. Finally, the study offered solutions to improve BIM adoption for refurbishment projects discussed in the focus group meeting chapter. Recommendation are given followed by the conclusion. The study provides knowledge on real benefits of BIM and how to optimise the factors found in this study which can either positively or negatively influence BIM adoption.

Keywords; Complex refurbishment project, Building Information Modelling, Environmental factors, stakeholders' interaction, process optimisation, New Zealand.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person, nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Anthony Ifeanyi Okakpu

July 2019.

Candidate Contribution to Co-Authored Works

20th November 2019

All co-authors on the chapters/papers indicated in the following table have approved these for inclusion in Anthony Ifeanyi Okakpu's doctoral thesis.

Chapter publication reference	Author %
CHAPTER 2: Anthony Okakpu, Ali GhaffarianHoseini, John Tookey, Jarrod Haar, Amirhosein Ghaffarianhoseini, Attiq Rehman. A Proposed Framework to Investigate Effective BIM Adoption for Refurbishment of Building Projects	AO = 85 AG = 5 JT = 2 JH = 5 AM= 2 AR = 1
CHAPTER 3: Anthony Okakpu, Ali GhaffarianHoseini, John Tookey, Jarrod Haar, Amirhosein Ghaffarianhoseini. Exploring the environmental influence on BIM adoption for refurbishment project using structural equation modellin	AO = 80 AG = 9 JT = 1 JH = 9 AM= 1
CHAPTER 4: Anthony Okakpu, Ali GhaffarianHoseini, John Tookey, Jarrod Haar, Amirhosein Ghaffarianhoseini. Risk Factors that Influence Adoption of Building Information Modelling (BIM) for Refurbishment of Complex Building Projects: Stakeholders Perceptions	AO = 85 AG = 10 JT = 1 JH = 3 AM= 1
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CHAPTER 7: Anthony Okakpu, Ali GhaffarianHoseini, John Tookey, Jarrod Haar, Amirhosein Ghaffarianhoseini. Identification of BIM adoption Benefits for refurbishment project stakeholders in New Zealand using Bayesian Network Model	AO = 85 AG = 10 JT = 1 JH = 3 AM= 1
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Acknowledgements

I would like to thank the following people for the contribution they have made, and support they have given, to my PhD thesis.

I would like to thank my parents, Mr & Mrs Anthony and Benedette Okakpu for all their hard work during the time of this PhD most especially my mum who left Nigeria to be with me here in New Zealand while I write my Thesis! – I also would like to thank my son – Ifeanyi Dennis Okakpu for being with me during the struggle to completion of my studies.

I would like to thank my supervisors; Dr Ali GhaffarianHoseini, Professor John Tookey and Professor Jarrod Haar. Dr Ali, your guidance throughout the PhD and your wealth of BIM experience and expertise was of great value. You always made yourself available when needed and gave much appreciated encouragement and advice. We both saw the value in hard work but also shared many laughs which I always appreciated. Prof. Jarrod, your work ethic and dedication to your students is astonishing, even when on sabbatical leave away from the country. Your attention to detail and willingness to give of your time is without peer in my experience and was truly appreciated.

In a special way, I would like to thank Prof Tookey, whom through him I was able to come into AUT and was offered tuition scholarship to complete my research with AUT.

I would like to thank Mr Corrie Cook and his staffs at AUT ESTATES for their participation during the preliminary studies and in the research project, and thanks to all other participants who participated in the research projects.

In addition, I am grateful to Dat Doan, Tongrui, Okey for their inspirations during the period of this study. Thanks also to AUT's School of Engineering, Computer and Mathematical Sciences for providing a solid atmosphere for my research and funding for my research tuition fees and conferences.

Dedication

I dedicate this page to my mum.

Ethical Approval

Ethical approval for this thesis research was granted by the Auckland University of Technology Ethics Committee (AUTEC). The AUTEC references were:

- Ethics application: 17/240. Investigating the effectiveness of adopting building information modelling for refurbishment of complex buildings: case study of Auckland.

Chapter 1 Introduction

1.1 Background

Building Information Modelling (BIM) is an emerging technology and its implementation is expected to lead to improved performance in construction and refurbishment processes throughout the life cycle of an existing building facility. BIM is advocated widely as a platform which enhances information-communication, and reduce the project duration and cost in the construction industry (Hong et al., 2016). Although, a strategic approach to BIM adoption which requires the incorporation of people, process, and technologies on timely bases to enhance capacity buildings and good managerial improvements (Alwan, 2016), people has been the slowest entity to evolve (Gu & London, 2010).

Despite BIM benefits to construction projects (Ghaffarianhoseini, Tookey, et al., 2016), its delivery and uptake has been reported to be slow for existing building projects (Chong et al., 2017). Even though the refurbishment sector is expected to provide value for money for sustainable retrofits and energy conservation in New Zealand, its performance is limited by its inability to adopt new technology successfully to improve its workforce (Ilter & Ergen, 2015). This phenomenon is prevalent in New Zealand environment where a large number of construction industries' BIM adoption level is at a pre-BIM maturity stage (Huber, 2012).

The majority of the New Zealand housing stock existed before the introduction of mandatory policies such as the application of wall and roof insulation in 1978 (Chapman et al., 2009). Improving on BIM adoption and implementation for refurbishment projects would contribute towards optimizing how these features are incorporated into energy refurbishment conservation efforts (Häkkinen & Belloni, 2011), including performance, and productivity improvement. These in turn will assist New Zealand in meeting its energy efficiency targets for maintaining consistent economic growth (SBC, 2014). Despite these growing awareness about BIM, the refurbishment project domain are yet to perceive the benefit of BIM and what it can offer from the design phase to the operation phase based on refurbishment projects (Ali, 2014; Chen, 2011; Suermann, 2009).

Previous research suggest the reasons include fragmentation (Ilter & Ergen, 2015), isolation, lack of collaboration and information sharing within the construction firms (Ali, 2014; Park & Kim, 2014). Besides, the refurbishment projects are risky venture (Liang et al., 2015) and very complex in nature (Ali, 2014; Chong et al., 2017). Therefore, the construction industry still exhibits very low maturity towards BIM use, since there is no significant progress in the traditional business model that accompany the introduction of new tools (Porwal & Hewage, 2013). In addition, there has been relatively little emphasis on the benefits of BIM for the refurbishment of existing buildings due to the lack of its interest in the literature (Chong et al., 2017). Despite the challenges and complexities of most refurbishment projects (Ali, 2014), the benefits of adopting BIM for complex projects as a whole is rarely researched (Hong et al., 2016). In addition, the construction information is becoming specialized and larger in volume; highlighting the need to manage and integrate these information among project stakeholders (Park & Kim, 2014). A previous study affirmed that BIM working environment requires a multidisciplinary collaboration effort of different disciplines against information sharing, building design, construction techniques etc. (Sebastian, 2011), with (Chong et al., 2017) adding that invariably this is due to fear of additional risk and liabilities arising due to procurement of BIM business workflows at this stage against conventional procurement approaches.

Therefore, it can easily be inferred that the number and variety of design and refurbishment stakeholders who participate in existing building refurbishments and construction projects can make effective collaboration difficult (Linderoth, 2010). There is a saying that adoption of BIM goes with collaboration, without this, it is only scratching the surface (Mignone et al., 2016). In addition, adoption of BIM does not always come with favourable attitudes, there may be moderating influences, and hence, the potential adopters are likely to be constrained (Ball et al., 1999). Consequently, there is a need to investigate the culture and collaboration of construction stakeholders to improve BIM adoption (Abdirad, 2016).

Previous literatures investigated the alternative approaches towards motivating the implementation of BIM for refurbishment projects. For example, the benefits of BIM integration in housing refurbishment has been explored (Sheth et al., 2010b), besides investigating and comparing the related features of new building to existing buildings (Redmond et al., 2012; Volk et al., 2014a). Ramanayaka and Venkatachalam (2015) further hinted that one of the major barriers to BIM adoption is that “practitioners’ careful consideration of externalities and subsequent dependence beyond BIM’s internal properties, before acting” This means that stakeholders avoid BIM due to prevailing unfavourable organisational characteristics or procurement. Thus, this suggest a need to investigate how these externalities and internalities in construction firms influence BIM adoption for different projects (Menassa & Baer, 2014; Park & Kim, 2014). In this regard, the need to identify these contextual factors became apparent. These factors are also useful to assessing the needs of stakeholders, managerial risks, and technology adoption plan (Gido & Clements, 2014; Liang et al., 2015). A previous study adopted factor analysis method to classify assessment factors for energy performance contracting for refurbishment of a building hotel in China (Xu et al., 2011). Yang and Zou (2014) investigated the risk factors for sustainable green building projects using social network analysis. Ramanayaka and Venkatachalam (2015) implemented technology adoption model (TAM) to assess how externalities influence industry readiness at pre-maturity. Considering the pace at which IT technology is evolving, little research has investigated how these contextual factors impact on refurbishment stakeholders’ decisions to adopt BIM.

With these notions, therefore the aim of this research is to investigate the effectiveness of BIM adoption decisions for complex refurbishment project in the New Zealand context. In order to do this, the research must take account of a comprehensive frameworks that examine how (1) the "contextual factors" influence stakeholders towards the adoption of BIM for refurbishment projects and (2) the extent on how the interaction of refurbishment project stakeholders influence the adoption of BIM, (3) And investigate how the structure of "interaction" of the stakeholders in the current refurbishment practice can be optimised to improve BIM adoption. Consequently, this study adopted multi-purpose building projects as case study of refurbishing project without BIM and to assess and compare the relative benefits of using BIM for such projects. Through this means, a holistic perspective of contextual impact factors would be derived which allows an empirical analysis of relationships and framework assessment to be formulated.

1.2 Research Problem

BIM has many benefits to offer construction projects (Ghaffarianhoseini et al., 2017). While these benefits are yet be identified by refurbishment project stakeholders, BIM uptake and delivery has been recently reported to be slow for refurbishment projects (Chong et al., 2017). Previous authors suggested that the reason behind decline in uptake is due to fragmentation (Ilter & Ergen, 2015), isolation, lack of collaboration and information sharing in the construction firms (Ali, 2014; Park & Kim, 2014).

In addition, some of these projects also reported substantial project delays, significant cost overruns, such as twice the budget (Mok et al., 2017), poor stakeholder engagement (Ali, 2014), including dissatisfaction of the project outcome by the refurbishment stakeholders (Woronkowicz et al., 2014). Hence, this study believes the adoption of BIM for refurbishment of complex building projects is dependent on the project stakeholders' decisions. This is because, the project stakeholders have diverse backgrounds and interests, not only being independent to each other but having intricate relationships and interactions (Mok et al., 2017). Therefore, these issues portray an inability of stakeholders to hold a common ground and strong collaboration, thereby reducing the flow of information and knowledge sharing within the project. Hence, the current research believes that analysing and aligning the project stakeholders' interactions can bring about an environment where BIM can be implemented. Since these interactions can constitute the norms, values and perception of stakeholders, the impact and interactions of stakeholders can therefore be analysed from a network perspective.

To bridge the gaps identified in this study, the research would extend the factor analysis theory and social network analysis theories to investigate the effectiveness of adoption of BIM for refurbishment projects to complement technology acceptance model (TAM). This investigation will analyse what motivates stakeholders of refurbishment projects, the environmental (contextual) factors that influences their roles and decisions to adoption of BIM. Holistic frameworks are developed in this study to enhance motivation to adopt BIM by refurbishment stakeholders and to enhance their informed decisions towards whether to use BIM or not for their refurbishment project. The feasibility of this approach is justifiable because previous research has demonstrated how external factors influences industries decision to adopt technology, identify risk factors and assessment factors for energy performance for refurbishment projects (Ramanayaka & Venkatachalam, 2015; Xu et al., 2011; Zou et al., 2017). There is still a need to investigate "what" factors influences adoption of BIM for refurbishment project stakeholders. In addition, there are other studies that investigated the feasibility of BIM adoption for refurbishment project (KIM 2014, 2015), but are limited to influencing factors. Thus, findings from this study attempts to reduce the gap between the feasibility of BIM adoption and the influencing and motivating factors to optimisation factors.

Overall, the current study focuses on identifying environmental factors, risk factors and project attributes that impact on refurbishment stakeholders' decisions and how these factors relate to the complexities in refurbishment projects, including the processes to optimise the current state of interaction among refurbishment stakeholders and to compare the benefits between the current systems and the optimised systems. The investigation of these processes will provide opportunities to understanding the factors affecting stakeholders 'decisions in relation to BIM adoption, and consequently provides insights on how to manage the complexities as the emanate in refurbishment projects. A comprehensive framework which can facilitate the identification of influencing factors and as well, pinpoint the promising areas will be developed through the literature. Our proposed BIM framework aims to supplement influencing factors and practical issues for real-world adoption criteria while encompassing broader factors and issues within refurbishment phase across different levels of stakeholders' perspectives.

1.3 Rationale for the Study

The reviews in Sections 1.1 and 1.2 shows the necessity to investigates what impacts refurbishment stakeholders' decisions to adopt BIM. The review investigated five main theoretical and contextual issues on BIM effectiveness for refurbishment projects:

1) First, the influence of environmental factors on organisations and refurbishment stakeholders' decisions to initiate BIM adoption in their refurbishment projects is a concern.
2) Secondly, the examination of the risks that impact on refurbishment stakeholders' role in refurbishment projects in New Zealand.
3) Thirdly, the clear distinction between the benefits in the traditional refurbishment systems to BIM method and compared to optimised interaction structurer of the refurbishment stakeholders.

4) Fourthly, there is a lack of empirical studies that considered the perceptions of refurbishment stakeholders towards implementation of BIM on refurbishment projects
5) Finally, little has been done empirically on interaction of stakeholders being optimised to enhance an environment where BIM can be implemented in New Zealand.

All the identified five theoretical and contextual issues relate to the knowledge-implementation gap that exists within the literature about adoption of BIM for refurbishment projects.

1.4 Research Questions and Observation

To address the research problems as specified in this study, three main research questions are considered:

RQ1: What are the main environmental factors that influence the interaction of the refurbishment project stakeholders in New Zealand?

RQ2: To what extent does the interaction of refurbishment stakeholders influence the adoption of BIM in New Zealand construction industry?

RQ3: In what ways can the interaction of stakeholders be optimised to enhance an environment where BIM can be implemented in New Zealand?

The first research question is a call to inquire the contextual factors that impact on the day to day activities of refurbishment stakeholders towards the performance and productivity improvement of refurbishment projects.

And to investigate the rationale behind their willingness or unwillingness to consider BIM as an improvement methodology. The second research question aims to investigate whether the activities or interactions of project stakeholders for refurbishment projects accepts BIM or causes barrier to BIM implementation while the third questions investigates the benefits for implementing BIM. Answers to these questions will provide vital information for mapping out effective strategies for successful BIM adoption for refurbishment projects.

To address these three research questions specified above, the following research objectives are set out to enable a systematic and empirical investigation of the research problem:

1) The identification of the environmental or contextual factors that impact on refurbishment stakeholders' decision to adopt BIM in New Zealand.
2) The identification of risk factors that influence stakeholders' role in refurbishment projects to adopt BIM in Auckland.
3) Identification of the benefits between the traditional method and the BIM method.
4) To understand the perceptions of refurbishment stakeholders in order to Proposed a solution to enhance early adoption of BIM for refurbishment stakeholders in New Zealand.
5) The optimization of the current project interaction system in refurbishment project in Auckland to enable adoption of BIM
6) The validation of the research findings.

1.5 Overview of Methodology

To achieve the objectives being pursued in this study, this research adopted pragmatism philosophy to investigate stakeholders and organisation's varying factors that influence their decision to adopt BIM for refurbishment of complex projects by considering an in-depth understanding of information flow and interactions among diverse construction professionals in case study refurbishment projects in Auckland. Based on pragmatism philosophy, it is a deconstructive paradigm that advocates the use of mixed methods in research, “sidesteps the contentious issues of truth and reality” (Yvonne Feilzer, 2010). Consequently, the approach to carry out this research can be classified into qualitative, quantitative and mixed method approaches (Creswell, 2013). The Mixed-methods approach can reveal unidentified aspects of current problems, and result in a more holistic understanding of the research topic (Anchin, 2008; Creswell et al., 2004). A case study is adopted in the first qualitative phase. Overall, the research is divided into four stages:

(1). The preliminary studies: this stage involves the identification of project, main stakeholders and their groups/roles, project goals, and project problems. This is the background of the case study project. In this stage, there is also the inquiry about the hypothesis formulated for environmental factors which later saw some of the hypothesis dropped out in the main research namely;

- H1. Policies and regulations influence the decision to adopt BIM for refurbishment projects in New Zealand.
- H2. Client resources and expectation influences the decision to adopt BIM for refurbishment projects in New Zealand.
- H3. Retrofit technologies/tools have impact on the decision to adopt BIM technology in New Zealand.
- H4. Social factors influence the decision to adopt BIM for refurbishment in New Zealand.
- H5. Decision to adopt BIM leads to performance improvement of refurbishment project

(2) In-depth interviews (recording the meeting): this involves deeper investigation to ascertain the level of BIM perception by the stakeholders, the factors that influence refurbishment stakeholders’ decision to adopt BIM, risk factor that affect their roles in the identified project, and the project refurbishment attributes of stakeholders as pursued by objective 2 and 4.

(3) The questionnaire distribution: in this stage, the study determines the perceptions of stakeholders to BIM adoption, the main environmental factors, the stakeholders that hold the central role towards adoption of BIM. The quantitative approach uses questionnaire survey as research strategy to pursue research objectives 1, 3, and 5. This avenue helps to engage with a wider audience. The data gathering stage considers administering the questionnaire to the target populations (see chapter 3, 6 and 7) via the online survey and paper based for interactions and perceptions of the project stakeholder modelling using simulation software as shown in chapter 3, 6 and 7 of this Thesis. The respondents rated the relative levels of importance and concerns for the environmental factors towards BIM perception in New Zealand construction industry. They will also rate their levels of agreement/ disagreement of the identified strengths, weaknesses and areas for improvement to organisation interactions to enhance BIM adoption for refurbishment services.

Although structural equation modelling (SEM) is employed to test the hypotheses about relations among observed and latent variables (Hoyle, 1995), it is also used to represent, estimate, and test a theoretical network, mostly is the linear relations between variables (Rigdon et al., 1998). The data were analysed using Amos statistical software for SEM analysis. The implementation of SEM enables the identification of the main factors that influences refurbishment stakeholders to adopt BIM for their project. The covariance based is preferred to partial least square since the variables has circular relationship, and for the purpose of goodness of fit criterion (Hair et al., 2011).

(4) This involved focus group meetings (observation of the interaction structures and feedback): in this stage, the purpose is to examine if the result portrays the current system, and identify the real cause, and how it may be improved as pursued by objective 6.

Following this, there is a validation and verification of the general research results to investigate the accuracy and robustness of research findings, hence addressing the research objective 1, 2 & 3 pursued in this study. This was possible as the findings were shared with the participants at the end of the meeting after transcribing and analysis of the result through a process called participant validation to confirm that the overall result indicated their views, thereby increasing the credibility of the reported findings (Birt et al., 2016). The table below shows the research questions, objectives and their research methods.

Table 1.1: the research table

Research questions	Research Objects	Method
RQ1: What are the main environmental factors that influence the interaction of refurbishment stakeholders in New Zealand?	Identifying key environmental factors (contextual) that impact project stakeholders, Identifying risk factors and project attributes of refurbishment projects	Questionnaire Interview Stage 1 & 2
RQ2: To what extent does the interaction of refurbishment stakeholders influence the adoption of BIM in New Zealand construction industry?	Identifying the clear benefits between the traditional method and the BIM method.	Simulations & Interview questionnaire Stage 2 & 3
RQ3: In what ways can the interaction of stakeholders be optimised to enhance an environment where BIM can be implemented in New Zealand?	Optimization of the current system in refurbishment execution in Auckland. Validate the resultant model and research findings	Simulations, sensitivity analysis, Focus group meeting Stage 3 & 4

1.6 Research Scope

This research focused on the refurbishment project stakeholders of multipurpose tertiary education facility building in Auckland. The result obtained from this study can be applicable to all upgrades for multipurpose existing buildings in New Zealand tertiary institutions by client organisations, including commercial buildings initially built without BIM management in New Zealand.

1.7 Domain of Investigation

This research focused on stakeholders and client organisations who participate in refurbishment of multipurpose buildings or commercial buildings in New Zealand. Specifically, the stakeholders who are involved in refurbishment of educational facilities are the target as these buildings are generally prone to refurbishment and constructed before the introduction of BIM to New Zealand construction industry. The rationales for the research focus are listed below:

1.7.1 Location of the Commercial Buildings

Many of the subject building are the multi-purpose building found in tertiary institutions within the central business districts (CBD) of many New Zealand cities. The focus is Auckland tertiary institutions. A preliminary investigation carried out regarding the adoption of BIM for refurbishment of these multi-purpose buildings suggest that many of these buildings' projects are fragmented to reduce the complexity of these projects and as well, hence, increases the unlikeliness to adopt BIM for such projects (Okakpu et al, 2018). Consequently, the fragmented nature of these refurbishment projects has rather increased the complexity of these refurbishment projects.

1.7.2 Multipurpose Building type Projects

These are the buildings found in tertiary institutions. It can also be a physical characterisation of infrastructures of buildings which are designated to serve educational needs including the communities. The selection of this building type is that it is characterised by alteration or refurbishment of the building, creating user spaces for individuals depending on the user intent or functions at frequent time. These buildings can be planned for a variety of construction methods. And therefore, the study considers this building type to benefit from BIM adoption for its refurbishment projects. In addition, the building projects has many influencing contextual factors, and hence, the study investigates how these factors influences the project stakeholders to adopt BIM for refurbishing the multipurpose building.

1.7.3 The Impetus for Refurbishing Buildings

The refurbishment industry still suffers challenges in terms of adopting BIM to improve their workforce. Although, the refurbishment industry is dominated by small-scale enterprises who handles small to big projects, many BIM applications have been on big and complex projects by large construction companies. In addition, most retrofits work are carried out by small and medium scale enterprises in different parts of the world including Australia, UK, New Zealand (Elias, 2008; Howden-Chapman et al., 2009; IEA, 2008; Lewis, 2014; Page; Ryan V et al., 2008), there is a need to investigate what impacts refurbishment stakeholders to adopt BIM.

The ministry of business, innovation and employment predicted an unprecedented workload soon that will be placed on the construction industry, due to Auckland housing and infrastructure and remedial works (MBIE, 2013).

To check the predicted workload, digital technology construction such as BIM can be adopted. This addresses the increasing fragmentation problems and productivity improvement in the construction sector. Although, New Zealand's existing housing stocks is sub-standard, most of these houses require improvement (Cowan et al., 2014).

Nearly, one-third of these houses exist in Auckland region. Hence, the case studies are adopted from Auckland region.

1.8 Unit of Analysis and Observation

This research would be investigated from the perspective of refurbishment stakeholders who were involved in the refurbishment case studies adopted. The main concern is to determine how various contextual or environmental factors affect their decisions to adopt BIM and to formulate a framework for BIM adoption assessment. The stakeholders can be directly or indirectly affected by the project. These stakeholders include client organisation, architects, managers, engineers, valuers, contractors, sub-contractors, house coordinators, space managers, students as users, suppliers for building materials etc. The benefit of BIM adoption can be derived from the simulation of these stakeholders' interactions. Hence, it is essential that these stakeholders are used as the unit of analysis in this study.

1.9 Geographical Coverage

Auckland is the main area for obtaining research information. This is where all the case studies are situated. Auckland is chosen due to that it has the highest number of building crises in New Zealand. In addition, there will be a shift or increase in the number of existing buildings. Secondly, there are earthquake probability in this region and so, the result of this research can easily be manipulated to suit seismic upgrade.

1.10 Significance of the Study

This research contributes to the knowledge by providing the main environmental factors that influence adoption of BIM for refurbishment projects in New Zealand, including understanding how the interaction of the current system of refurbishment project impacts BIM adoption, and offering solutions to optimise BIM adoption for refurbishment project. This approach is inevitable as the previous studies and literatures depend on technical

BIM aspect. Hence, the previous feasibility of BIM for refurbishment project is lack of human factors which constitutes the interaction of stakeholders within a refurbishment project. The research significance is realised by its contribution to technology adoption theories and social network analysis and practice in refurbishment of complex building projects. The research's theoretical and practical significance are discussed below.

1.10.1 Practical Significance

The findings and the recommendations in this study helps to strategies avenues to motivate adoption of BIM for building refurbishment stakeholders, especially in tertiary institution in New Zealand. Therefore, this research is of great significance to the tertiary institutions in New Zealand, client-organisations, multipurpose property owners and government and New Zealand construction industries in addressing the real benefits of adoption of BIM and solutions on how to manage or mitigate those influencing factors paramount in New Zealand.

The main environmental factors that impact on project stakeholders to adopt BIM for refurbishment project were revealed in this study. These environmental factors (contextual factors) provided solid information for optimisation strategies for enhancing effective adoption of BIM and providing a platform for BIM adoption risk mitigation plan for refurbishment projects which are prone to refurbishment as found in tertiary institution. The lack of collaboration is significant in traditional refurbishment. Although, the benefit of adopting BIM were clearly identified with appropriate and effective interaction network exerted by BIM.

The introduction of project designed error could be easily identified and managed effectively with refurbishment projects that demonstrated increased collaboration. The research also outlined potential refurbishment project attributes which should be considered to make refurbishment project a priority just like the new building projects.

The simulations on the stakeholders' interaction showing various magnitude of error propagation signifies the benefits of BIM for uncertainty management which was validated by the sensitivity analysis operation on the main project stakeholders. This study also provided answers aimed at understanding how environmental factors contribute to enabling or inhibiting adoption of innovation diffusion such as BIM for refurbishment project for client organisations despite the poor nature of project interaction.

1.10.2 Theoretical Significance

This study covers the theoretical gaps within the limits of adoption of BIM for refurbishment project by formulating BIM adoption research framework to realise BIM benefits for entire project stakeholders planning to adopt BIM. By recognising the relevance of limited nature of literatures in the context of BIM adoption for refurbishment project, this study adds to the body of knowledge by investigating refurbishment project stakeholders' interaction towards the decision to adopt BIM. This is achieved by integrating the theoretical knowledges using social network analysis and extended technology adoption model using structural equation model to identify the main contextual factors that impact on project stakeholders' decisions. The motivational perspectives explained knowledge on how healthy interaction of project stakeholders identifies error, diffuses error, and can recover from the error based on the levels of the interaction of the project stakeholders. In addition, the proposed research framework offers four dimensions for examining and realising BIM benefits for refurbishment project. These dimensions include environmental factors, project attributes, process optimisation and stakeholders' interaction. These dimensions are used to investigate the effectiveness of adopting BIM for refurbishment of multipurpose building projects found in tertiary institutions. Hence, this research provides insight into the main key factors which influences client organisations and all project stakeholders to adopt BIM, and as well pinpoints the risks towards adoption of BIM and offers risk mitigation process to enable even adoption of BIM.

1.11 Thesis Structure and Publications/outputs

This thesis is by publication and draft format. Therefore, the thesis is structured nine chapters as shown in Fig 1.1. The chapter outlines are provided below.

Chapter 1 provides a general overview of the research by providing the problems to be addressed by the research. It constitutes the preliminary analysis with the initial research questions, objectives formulation and the original contributions are stated. Information from; International Conference on Civil Engineering, Construction Management & Structural Design, NZAAR-CCS-18-49.

Chapter 2 provides the review of the existing theories and gaps within the adoption of BIM for refurbishment project. Also discussed the development of research framework and the development of research questions addressed in the study. Published by Journal of Architectural Science Review 2018.

Chapter 3 presents the quantitative results data. It shows the results of the statistical analysis and validation processes using factor analysis (SPSS) and SEM for overall environmental factors that impact on refurbishment project in New Zealand towards BIM adoption. Published by the Journal of Architectural Engineering and Design Management 2019.

Chapter 4 presents the findings from the qualitative research phase obtained from the case study. The qualitative research findings addressed the research question “what are the main risk factors that impact project stakeholders to adopt BIM? Chapter under review by International Journal of Construction Management.

Chapter 5 presents the second findings from qualitative research phase obtained from the case study. The qualitative research findings addressed the project attributes of refurbishment project. In its fullness, it presents the perceptions of refurbishment project stakeholders towards BIM implementation. Published by CCC conference 2019. Extension under review by Periodica Polytechnica Architectura

Chapter 6 presents the validation of BIM benefits through optimisation of project interaction network and simulations for the refurbishment project stakeholders. Published by Frontiers of Architectural Science Review, 2019.

Chapter 7 presents the validation of BIM benefits using error management and sensitivity analysis on the project interaction network. Published by CCC Conference 2019. Extension currently under review by the Journal of Building Performance Simulation.

Chapter 8 presents lessons and overall validations from the research using focus group meeting. Chapter under review by International Journal of Construction Education and Research.

Chapter 9 presents the discussions of the results from the overall drafts/chapters in this thesis. The implications of the result for refurbishment project stakeholders in New Zealand tertiary institutions, the recommendation for further research is discussed and, outlines the summary and conclusion of the research investigations.

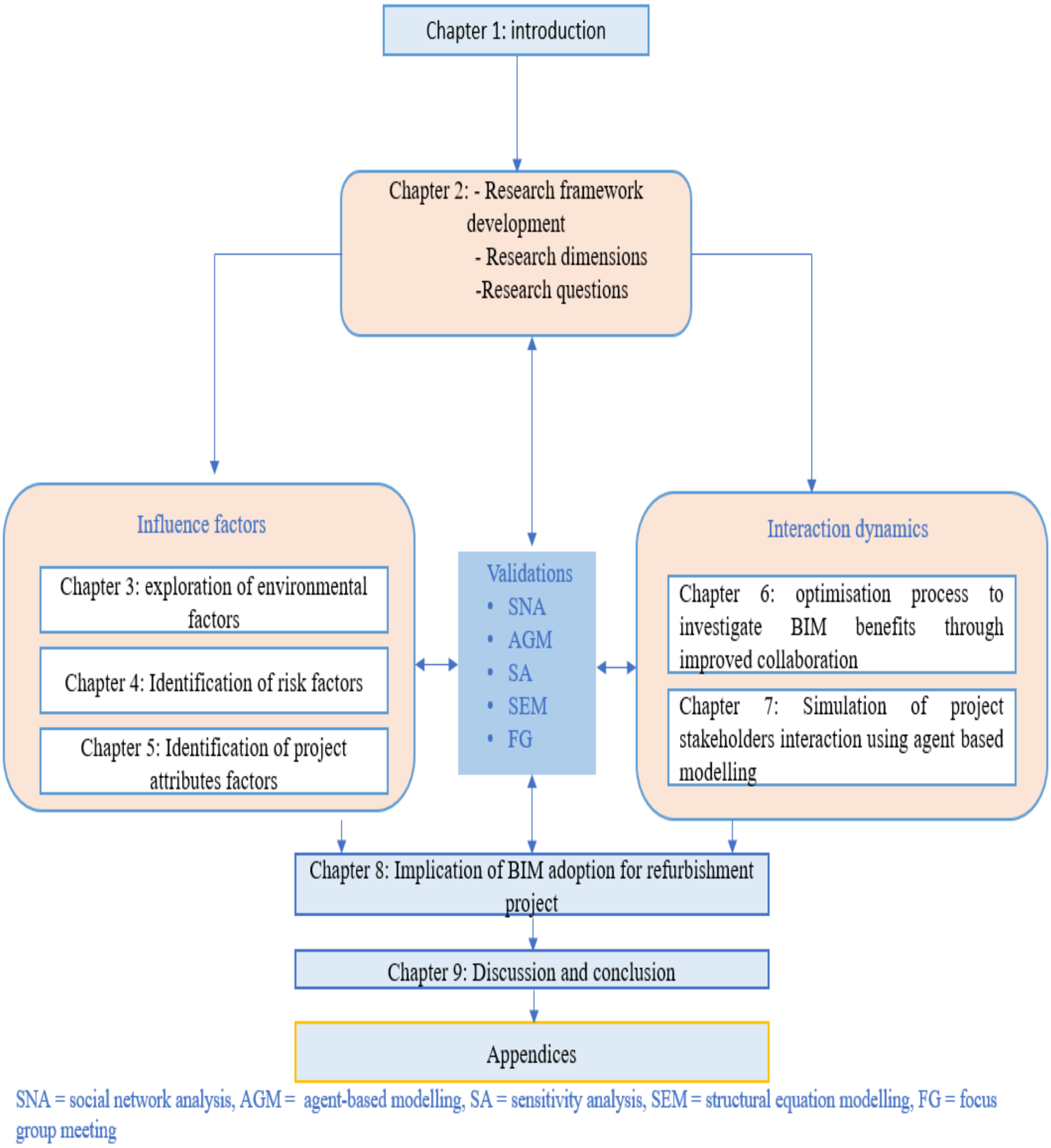

Figure 1.1: Overview of the structure of the thesis

Chapter 2 A Proposed Framework to Investigate Effective BIM Adoption for Refurbishment of Building Projects

2.1 Prelude

The aim of this chapter is to formulate research questions, formulate BIM research framework to address the formulated research questions to solve problems identified through the literatures and during preliminary studies. In this study, building information modelling (BIM) is portrayed as an emerging technology, hence, its application in the refurbishment of building project can significantly improve the construction workflows throughout the project lifecycle. Despite the promising benefits of BIM adoption for the entire Architecture, Engineering, and construction (AEC) industry, this process seems to be ambitious due to the highly fragmented nature of construction practices, resulting in a difficult integration of diverse information throughout the project lifecycle. In the backdrop of recent updated research, Technology Adoption Model (TAM) and thorough examination of Social Network Analysis (SNA), four distinct components comprising refurbishment attributes have been identified in this chapter which includes; environmental influence factors, stakeholders' interaction and structure optimisation to realize BIM on refurbishment projects. Furthermore, it posits a conceptual research framework for detailed investigation of effective BIM adoption on refurbishment project and strongly advocates that the embedded knowledge postulated needs to be actively pursued to improve the maximization of the uncovered BIM research for refurbishment projects through an extended review investigation. The framework is presented as a first step to understand the BIM adoption requirements and the real benefits of BIM for all refurbishment stakeholders planning to adopt BIM.

2.2 Introduction

Building information modelling (BIM) is perceived as one of the most significant developments within the construction industry as it introduces new processes, technologies and healthy interaction into practice (Abdirad, 2016). BIM has been advocated widely as a platform to enhance information communication, and reduce the project duration and cost in the construction industry (Hong et al., 2016). A strategic approach to BIM adoption requires the incorporation of people, process, and technologies on a timely basis, with potential benefits including capacity building through managerial improvements (Alwan, 2016). In addition, BIM has captured the attention of the construction sector based on many recognized benefits for building projects (Bryde et al., 2013; Eastman et al., 2008),including improved productivity, information availability, enhanced decision making, better risk management, competitive advantage, and enhanced market access Cemesova et al. (2015). Other benefits include early identification of errors, reduction of rework and costs, improvement of quality, and fostering of coordination and communication (Bryde et al., 2013). BIM has the potential power to transform the construction industry, bringing fundamental change in the way building**s** are designed, constructed and operated (Holness, 2008 ; Ryan et al., 2013).

Despite the clear benefits of what BIM could offer to construction projects (Ghaffarianhoseini et al., 2017), its uptake and delivery have been recently reported to be slow for the refurbishment of existing building projects (Chong et al. (2017). Suggested reasons include fragmentation (Ilter & Ergen, 2015), isolation, and a lack of collaboration and information sharing within the construction sector (Ali, 2014; Park & Kim, 2014). Besides, refurbishment projects are often a risky venture (Liang et al., 2015) and very complex in nature (Ali, 2014; Chong et al., 2017). Therefore, the construction industry still exhibits very low maturity towards BIM use, since there is no significant progress in the traditional business model that accompanies the introduction of new tools (Porwal &

Hewage, 2013). There has been relatively little emphasis on the benefits of BIM for the refurbishment of existing buildings because it is a new area of interest in the literature (Chong et al., 2017). Despite the challenges and complexities of most refurbishment projects (Ali, 2014), the benefits of adopting BIM for complex projects as a whole is rarely researched (Hong et al., 2016). In addition, construction information is becoming specialized and larger in volume, hence, highlighting the need to manage and integrate this information among project stakeholders (Park & Kim, 2014).

Traditionally, refurbishment projects have reported substantial project delays, significant cost overruns at twice the budget (Mok et al., 2017), poor stakeholder engagement (Ali, 2014), and dissatisfaction of the project outcome by the refurbishment stakeholders (Woronkowicz et al., 2014). As such, adoption of BIM for complex refurbishment projects is dependent on the project stakeholders' decisions. In addition, the project stakeholders have diverse backgrounds and interests, not only being independent of each other but having intricate relationships and interactions (Mok et al., 2017). Therefore, these portray an inability of stakeholders to hold a common ground and healthy collaborations thereby reducing the flow of information and knowledge sharing within the project. The present study argues that analysing and aligning the project stakeholders' interactions can bring about an environment where BIM can be implemented. Since these interactions can constitute the norms, values and perception of stakeholders, the impact and interactions of stakeholders can, therefore, be analysed from the network perspectives for optimised practices. Rogers et al. (2015) asserted that the satisfaction of the specific requirements for BIM adoption may be contingent upon the restructuring of business processes and relationships, and some requirements may as yet be outside of the current capacity and capability of either the technology or human resources. While (Sebastian, 2011) affirms that the BIM working environment requires a more multidisciplinary collaboration effort of different disciplines against information sharing, building design, construction techniques etc, Chong et al. (2017) added that invariably this is due to fear of additional risk and liabilities arising due to procurement of BIM business workflows at this stage against conventional procurement approaches. Therefore, with the diverse approach of technology within the construction world, the integrated workflow can be recommended as a platform for BIM adoption (Rahman et al., 2013). Consequently, to improve the social network of entire refurbishment projects, a strategy is needed as the current practices that involve BIM do not fit into the fragmented nature of conventional project delivery of refurbishment projects.

It can easily be inferred that the number and variety of design and refurbishment stakeholders who participate in existing building refurbishments and construction projects can make effective collaboration difficult (Linderoth, 2010). There is a saying that the adoption of BIM goes with collaboration, without this, it is only scratching the surface (Mignone et al., 2016). In addition, adoption of BIM does not always come with favourable attitudes, there may be moderating influences, and hence, the potential adopters are likely to be constrained (Ball et al., 1999). Consequently, there is a need to investigate the culture and collaboration of construction stakeholders to improve BIM adoption (Abdirad, 2016). With these notions, the present study investigates this research by asking questions: (1) **What** "environmental factors" influence stakeholders towards the adoption of BIM for refurbishment projects, (2) **How** does the structure of "interaction" of the stakeholders in the current refurbishment practice impact on BIM implementation and (3) **To what extent** does the stakeholders interaction impact BIM adoption for complex refurbishment project? Resolving these questions of "environmental factors" and "stakeholders' interactions" hence, it is obvious to refurbishment stakeholders with the view that implementation of BIM is far more complex than ordinary adoption of IT. Therefore, the authors of this article aimed at formulating a research framework for effective adoption of BIM for refurbishment of complex building projects.

2.2.1 The main Objective of the Study

The aim of this chapter is to propose a framework to understand, challenge and extend the existing knowledge management for BIM adoption effectiveness within the limits of refurbishing complex building projects. Therefore, the main objectives of the current study are:

1) To provide a foundation for development of BIM adoption investigation strategy for refurbishment stakeholders.

2) To provide a comprehensive view on dimensions that can impact the failure or success of BIM adoption among refurbishment project stakeholders.

3) To identify the current gap in BIM adoption motivational research studies within the limits of refurbishment projects.

Therefore, the present study critically analyzes the global adoption of BIM and deliberates its practical manifestation in complex refurbishment building projects through an in-depth synthesis of updated research material on the subject. The following sections discuss the methodology of the formulation of the framework, the implication of the framework goals, followed by the conclusion.

2.3 Literature Review

The literature review introduces the definition of BIM and its importance in the construction industry and its related benefits towards refurbishment projects. It further deliberates the characteristics of refurbishment project and the potential for BIM adoption.

2.3.1 Definition of BIM

The international standard defines BIM as "*shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decisions*" (ISO Standard, 2010; Volk et al., 2014a). Although, the benefit of BIM for the construction sector is widely recognised recently (Bryde et al., 2013; Eastman et al., 2008; Gray et al., 2013); Leite et al. (2011), it equally has the potential to transform the construction industry, improving the design and construction operation stages (Holness, 2008 ; Ryan et al., 2013). BIM is also an information technology approach that involves designs, energy efficiency analysis, maintenance, documentation, delivery for different phases of project life cycle. It is also a managed information database coupled with object-based parametric modelling Gerrard et al. (2010). The BIM information approach includes geometric and non-geometric data. The geometric data refers to the 2D drawings, 3D models with spatial relationships and dimensions, while non-geometric data includes the textual data (Gu et al., 2010). BIM provides consistent and coordinated representations of digital models (Chan, 2014) and is now a well-known established collaboration process within all the construction processes (Gholami et al., 2013). The collaboration helps to ensure that information is distributed within the projects since there are multidiscipline stakeholders in construction projects (Murphy, 2014). Despite the great potential of BIM, its advancement is relatively at an infant stage in the construction sector (Cao et al., 2015), and consequently, its actual diffusion rate among industry practitioners worldwide has been lower than expected (NBS, 2014). For instance, the adoption of BIM for refurbishment projects according to literature is just emerging (Ghaffarianhoseini et al., 2017). This shows that a relatively high percentage of construction stakeholders in this venture is "just scratching the surface of how much value BIM can provide" (McGraw-Hill, 2012).

2.3.2 BIM benefits

The benefit of BIM is now a common topic in many countries (CIBER, 2012). For instance, countries like Norway, Germany, France, Finland, UK, Sweden, Australia, and the USA have shown a remarkable progress through some pilot projects (CCI, 2013; Hannele et al., 2012). These projects were found to be successful when implemented with BIM compared to the non-BIM initiatives (Arayici et al., 2009a; Tocoman, 2010). BIM benefits include improved efficiency in retrofitting, optimized energy usage, and reduction of wasted resources (Bynum et al., 2012). In the construction industry, BIM benefits include improved productivity, information availability, enhanced decision making, better risk management, competitive advantage, and a greater market access etc. (Bryde et al., 2013; Chen et al., 2011). Other benefits documented (Building and Costruction Productivity partnership, 2016) include minimized project management, early identification of errors, reduction of rework and costs, improvement of quality, and the fostering of coordination and communication. It enables the creation of new approaches to solve problems with whole life cycle process within the Built Environment (Arayici, 2008a; Suermann, 2009). BIM smoothens the development of detailed information concerning buildings and analysis at the early stages, and this aids the decision making and a decline in downstream changes (Klotz et al., 2007; Manning & Messner, 2008). Figure 1 shows the benefits of adoption of BIM from planning stage to operation and maintenance stage.

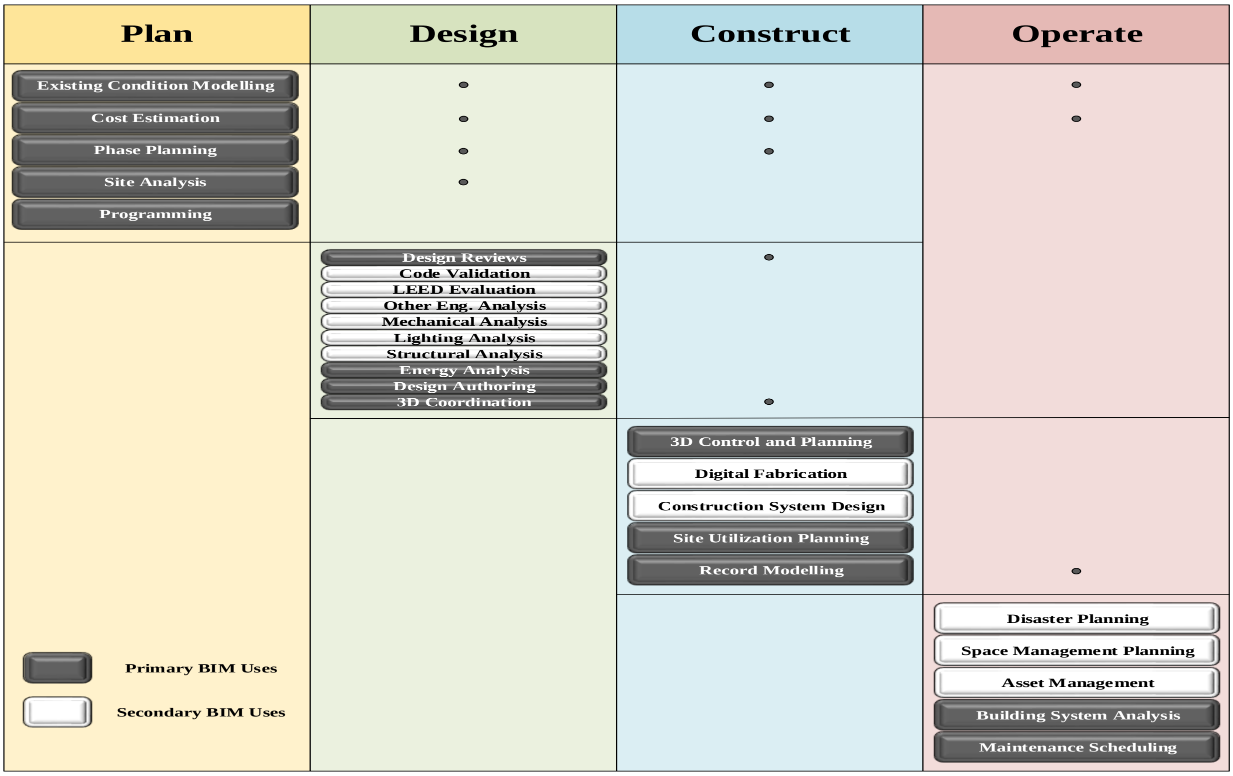

Figure 2.1: BIM uses across building life cycle; adopted from (Kreider & Messner, 2013)

2.3.3 BIM for Refurbishment of Existing Complex Buildings

The refurbishment projects are one of the riskiest, complex and uncertain projects to manage (Liang et al., 2015). This is because the construction sector is fragmented, with less integration of diverse information (Al Hattab & Hamzeh, 2015; Ali, 2014), including lack of collaboration and information sharing (Ali, 2014). Despite the benefits of BIM, researchers and the practitioners have shown less concern for utilizing BIM on the refurbishment of existing building (Ilter & Ergen, 2015). Park and Kim (2014) suggested that the less concern for BIM adoption is attributed to the complicated stakeholder requirements added to the highly fragmented construction sector. Hence, the sector now suffers huge pressure to update existing buildings, such as structural faults including poor insulation (Alwan, 2016). For example, in Europe, the construction sector recorded 40% of energy consumption as 40% of Europe's existing buildings were more than 50 years old (Kylili & Fokaides, 2015). In addition, 35% of existing buildings in the UK predate 1945, and this is likely to remain in use over the next 30 years (Kemmer & Koskela, 2012), causing the high use of energy consumption and high carbon footprint (Alwan, 2016; Park & Kim, 2014). According to a report by Building Research Association New Zealand (BRANZ), the refurbishment projects represented about one-third the total value of the new dwellings with about 33,000 renovation consents (BRANZ, 2008; Manfredini & Leardini, 2014). Hence, improving the performance for the refurbishment of existing buildings in New Zealand suggest that there will be less Auckland housing crisis which is predicted to shift from 1.4 million to 2 million in the next 20 years (Statistics New Zealand, 2013). Therefore, these aforementioned findings suggest a need for a strategic change towards the adoption of BIM for the refurbishment of existing buildings.

2.3.4 Characteristics of Refurbishment Projects

Refurbishment projects are seen to be more complex to new building projects due to the lack of existing building information (Ali et al., 2008), complicated cost-sharing (Miller & Buys, 2011) and large stakeholder interactions (Klotz & Horman, 2009). Complex building refurbishments are fraught with single to multi-level construction, including special purpose user requirements for multi-purpose buildings, complicated nature, challenging in site configuration, multi-organisation participating, multiple stakeholders participating, and larger span (Ali, 2014; Bryde & Schulmeister, 2012; Kemmer & Koskela, 2012). Although, complex projects can contain simple subsets of basic projects, these projects should not be termed simple because of the basic projects (Bakhshi et al., 2016). Hence, complex projects are not always based on their scale, but based on the issue of coordination or specialized expertise required (Glouberman & Zimmerman, 2002). The realisation of a complex architectural project requires a special input for the resolution of structural and technical design components with special purpose provisions, including the collaboration of an experienced professional team for the preparation of project documentation and contract administration (Killip, 2013; Li & Yang, 2014). The procurement of such projects is dependent on an appropriate practice structure and adequate professional and financial resources for its achievement (Choi et al., 2014; Volk et al., 2014a). However, the refurbishment characteristics or attributes need to be clear so that the potential BIM adopter will appropriately align these attributes with the potential features of BIM solution for complex refurbishment projects.

2.3.5 Sustainable Refurbishment and BIM status

Various authors have made an effort to motivate BIM adoption for refurbishment projects, for example, Volk et al. (2014a) focused on the technical problems with BIM implementation which include updating and handling of the uncertainty of data information of BIM in existing buildings. A further study proposed a framework to understand tools and drivers to motivate BIM adoption for refurbishment projects (Gholami et al., 2013; Sheth et al., 2010a), while another focused on the clients as building owners preferences and how it influences BIM adoption for refurbishment projects (Park & Kim, 2014). Essentially, clients' choice is mainly cost-focused against the method of building refurbishment or IT application preferred by contractors. Furthermore, an investigation into barriers hindering BIM adoption for housing refurbishment (Kim & Park, 2013a) found two: (1) clients indicating lack of knowledge about refurbishment technologies, and (2) construction professionals indicating lack of skills and fragmented practices. Park and Kim (2014) asserted that essentially technical barriers, organisational problems, business and legal barriers influences BIM adoption among the refurbishment stakeholders. Other authors such as Alwan et al. (2015) investigated the feasibility of 3D simulation transfer process for environmental assessment of existing building, and the demonstration of producing 3D CAD models and BIM models for existing structures based on designated techniques (Arayici, 2008a), while Alwan (2016) proposed framework for performance was mainly based on utilization of software. Essentially, these studies are built on the technical aspect of BIM adoption. Overall, there are business, legal and organisational barriers that have been identified (Park & Kim, 2014). The present study suggests there is a pressing need for a framework to effectively enhance adoption of BIM for refurbishment projects covering the essential barriers to BIM adoption. This framework should explore the need to enhance fragmented practices, lack of clients' knowledge on refurbishment technologies, professional skills, organisational and business barriers, including legal barriers.

2.3.6 Potential for Adoption of BIM for Refurbishment Project

Many studies depict the need to adopt BIM for refurbishment projects (Ilter & Ergen, 2015; Park & Kim, 2014). While a few of these studies have proposed frameworks for BIM adoption for refurbishment projects (Alwan, 2016; Gholami et al., 2013), these frameworks focus on technical aspect of BIM and do not account for deeper investigation among the refurbishment stakeholders. Table 1 shows the current BIM refurbishment frameworks in the literature. Comprehensive research in the field of information technology shows that introducing a form of a new IT may require a drift away from the goals of organisation and intention within a project (Holmström & Stalder, 2001). The shift from the initial plan or purpose of the organisation based on the adoption of new IT can be seen as an interaction between the disambiguated technology and multi-layered context (Linderoth, 2010; Walsham, 1993), where the knowledge integration and development have a major impact on technology adoption and use (Andersson & Linderoth, 2008). Ultimately, this multi-layered context which is embedded within the IT adoption and implementation can be influenced by industry characteristics, rules and regulations, norms, actors' frames of references and company culture (Linderoth, 2010). Hence, considering BIM as an IT, BIM allows all participants during the design phase to become involved in the evolving goals and solution, to generate solutions and evaluate them Shen et al. (2012).Therefore, a BIM framework should be comprehensive enough to address all relevant BIM issues. In addition, BIM Framework needs to be concise to enable presentation of key issues in a clearer manner.

Table 2.1: The current gap within BIM refurbishment frameworks in the literature

	Environmental factors	Project attribute	Stakeholder interaction	Structure optimization
General study	*	(Volk et al., 2014b)	(Volk et al., 2014a)	*
Organisation	*	*	(Kim & Park, 2013a)	*
Project	(Kasprzak & Dubler, 2015)	*	*	*
LCA	*	(Alwan, 2016; Bhatla & Leite, 2012; Kim, 2015)	*	(Lim et al., 2015)
Energy simulation	(GHOLAMI et al.)	(Cheng & Das, 2014; Wu et al., 2014)	*	(Sheth et al., 2010c)

2.4 Proposed BIM Framework

From general perspectives, the proposed framework is based on research principles (Ashurst et al., 2008; Hallgren & Olhager, 2006; Jung & Joo, 2011; Succar et al., 2007) as a general formulation process. The framework starts by observing the importance of stakeholders interactions as a concern to move BIM adoption. There is also a need to investigate how environmental factors influence organisational adoption tendency and stakeholders' engagement. The environmental factors are those circumstances that impact on the decisions to adopt BIM. Then, the alignment of refurbishment attributes to BIM processes or functionalities became a concern. Volk et al. (2014a) refers to BIM processes as services or capabilities provided as dependent on stakeholder or project requirements. The distinction between previous framework and the proposed framework is that the proposed framework is a research framework that contains a presentation of key issues in a clearer manner including process optimization to enable an improved BIM working environment. This will be useful for comparison of BIM real benefits with conventional practices. The proposed framework is detailed in Figure 2.

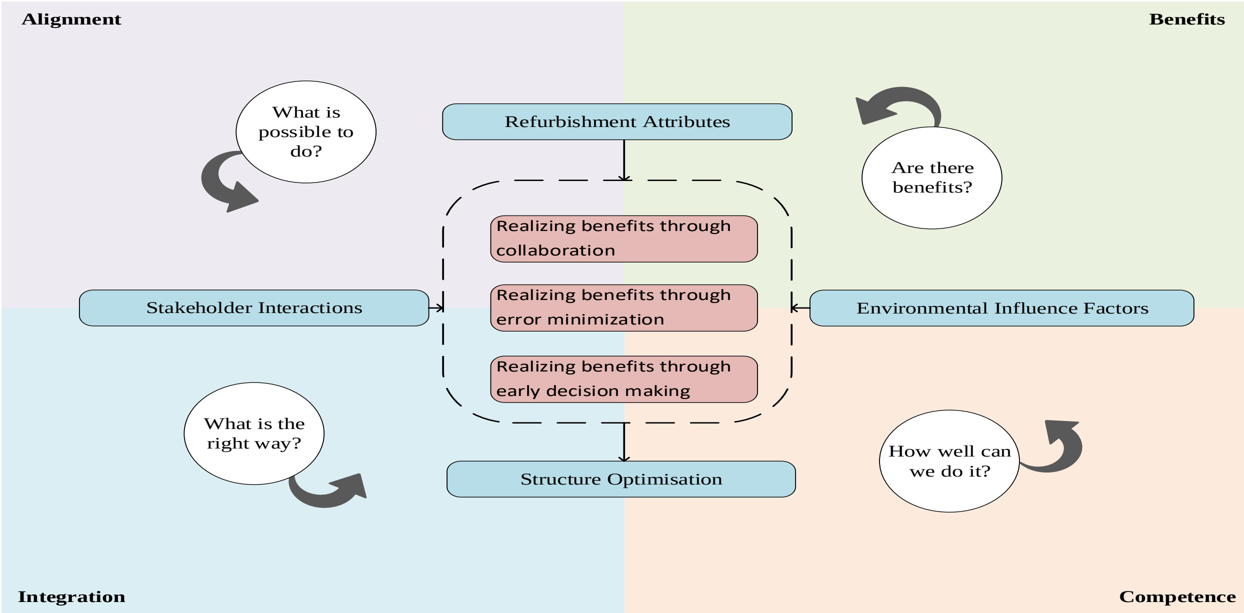

Figure 2.2: Proposed framework for investigating effective BIM adoption for the refurbishment of complex building projects adapted from studies (Cox, 1999; Gu et al., 2007; Peppard et al., 2007; Succar, 2009)

Frameworks are usually developed to guide and assist in the research effort, knowledge sharing, and to improve concepts into descriptive or predictive models (Jung & Joo, 2011). Figure 2.2 illustrates the factors which can have an impact on project stakeholders considering adoption of BIM. Since the adoption of BIM is evenly based on the knowledge, perceptions and interaction of stakeholders (Shin et al., 2015; Succar, 2009), this conceptual framework gives a theoretical foundation for investigating the effectiveness of adopting BIM for the refurbishment of complex buildings. A description of the components as contained in the above framework is presented.

2.4.1 Stakeholder Interaction

Every construction project is a combination of social interaction and project collaboration (Chinowsky et al., 2008). But when the refurbishment stakeholders are isolated and highly fragmented in nature, including the procurement practices (Ali, 2014), it is possible that the three common types of relationships in the construction firm (communication, information exchange, and knowledge exchange) are inefficient (Chinowsky et al., 2008; Pryke, 2004). The refurbishment stakeholders are those actors that have an interest in a particular refurbishment project (Beringer et al., 2013). Accordingly, one characteristic of AEC industry is the unconventional nature of networks of stakeholder interaction which constitute building and construction projects (Linderoth, 2010). This has contributed to the challenges within projects including knowledge transfer in organisations and the diffusion of innovation propensity (Linderoth & Jacobsson, 2008). Therefore, the benefits of BIM adoption can be achieved within an interaction of stakeholders in a project. However, with few studies around the adoption of BIM for refurbishment projects implies that there is little innovation diffusion and uncover of other factors that could hinder interaction of stakeholders. A previous author suggested that there is a need to convince the actors of construction projects to enable adoption of BIM (Linderoth, 2010). Therefore, to improve the social network of entire refurbishment projects, a strategy may be required as the current practices that involve BIM may not fit into the fragmented nature of traditional project delivery of construction projects.

Surprisingly, little research has addressed how the interaction of stakeholders on a refurbishment project could influence adoption of BIM. Within a defined complex refurbishment projects, there are two types of stakeholders: (1) internal and (2) external (Beringer et al., 2013; Harrison & John, 1996). The internal stakeholders are the project owners, design team, clients organisation, contractors, employees, customer user, project management team, sub-contractors etc, while the external stakeholders are the political organisations, social organisations, local communities, the general public, interest groups, real-estate owners, trade and industry members etc. who are mainly the potential stakeholders in construction projects (Olander, 2006). When all these stakeholders are involved in a project it contributes to increasing the complexity of the project (Ali, 2014), and hence would require a modern methodology and innovation to improve collaboration and performance of the projects. The present study suggests that there is a need to investigate how the interaction in the traditional method of executing refurbishment projects as per complex buildings impact on the adoption of BIM despite the uncertainties that occur in refurbishment projects. Hence, these gap is in line with the recommendation of (Freeman & McVea, 2001) to investigate among stakeholders to solve a 'real-world' problem than relying or focusing on theories.

2.4.2 Environmental Influence Factors

There are factors that influence how organisations respond to the adoption of IT innovation for the refurbishment of building projects (Maahsen-Milan & Fabbri, 2013; Manfredini & Leardini, 2014). These factors can be useful in analysing the needs of stakeholders, managerial risks, and project plan (Gido & Clements, 2014; Liang et al., 2015). As such, the need to identify these environmental factors became apparent. A previous study adopted factor analysis method to classify success factors of energy performance contracting for the refurbishment of a building hotel in China (Xu et al., 2011). Yang and Zou (2014) investigated the risk factors of sustainable green building projects using social network analysis. Ramanayaka and Venkatachalam (2015) implemented a Technology Adoption Model (TAM) to assess how externalities influence industry readiness at pre-maturity. These factors include the clients' resources and expectations (Ma et al., 2012), retrofit technologies (Arayici et al., 2011a), policies and regulations (Lloyd et al., 2008), social behavioural factors (Ball et al., 1999; Ma et al., 2012), and the age of working population in organisations (Son et al., 2015). These factors also have tremendous impacts on BIM adoption (Azhar et al., 2009; Biagini et al., 2016; Häkkinen & Kiviniemi, 2008; Miller & Buys, 2011). Guy and Shove (2007) indicated that the main information with respect to these named factors is less interpreted among the AEC (Azhar et al., 2011; Sacks et al., 2010). There are other dimensions such as technical, economic, cultural, ecological, social, and architectural dimensions (Mazzarella, 2014; Vahl et al., 2013). These dimensions have formed an interaction-push towards innovation.

In addition, these environmental influence factors can be classified into many factors such as human factors, building-specific information, retrofit technologies, cultural dimension, economic fields, sociocultural, technical, economics, policy and standard, and lots more (Liang et al., 2015; Ma et al., 2012; Menassa & Baer, 2014; Mickaityte et al., 2008; Rey, 2004). However, there is no consensus among scholars regarding the standard classification of these environmental factors (Liang et al., 2015). One obvious thing is that the evolution of technology has affected the way businesses operate, thereby requiring construction firms to cope with the changes in their business environment (Ongori & Migiro, 2010). Since BIM tool is generic (Abdirad, 2016; Bew & Richards, 2008), we argue that there is need to review the main environmental impact factors, considering the culture and collaborative environment of construction firms, as this will contribute to enhancing adoption of BIM (Abdirad, 2016).

2.4.3 Refurbishment Attributes

The refurbishment attributes carry information about the characteristics of a given project (Ali, 2014). Because refurbishment projects are risky, complex and full of uncertainties within the construction industry (Ali et al., 2008), Miller and Buys (2011) added that refurbishment projects are more complex to a new build due to lack of existing building information (Ali et al., 2008), complicated cost-sharing (Miller & Buys, 2011) and lots of stakeholder interactions (Klotz & Horman, 2009). This makes the design process very complex. In the UK, there is an evidence that design problems show almost 80 % of quality problems in a refurbishment project were contributed by the difficulty of managing design process (Egbu, 1994; Remington & Pollack, 2008). Hence, Ali (2014) deduced that the design process constitutes intense technical and social activities.

Addressing refurbishment projects as complex entities, complex projects can contain simple subsets of simple projects and hence, does not imply that the simplicity of the subsets are simple projects (Bakhshi et al., 2016). Hence, complex projects are not always based on their scale, but based on the issue of coordination or specialized expertise (Glouberman & Zimmerman, 2002). In addition, Remington and Pollack (2008) considered four types of complexity for useful analysis when dealing with complex projects. Although the sources of any project complexity can influence project life cycle, it also has a major impact on procurement method choice and approaches to contract management. These complexities are structural, directional, technical and temporal. The structural complexity occurs in large projects, the directional complexity occurs due to unshared goals, while technical complexity results due to design problems, the temporal complexity is as a result of environmental changes or change in the role of actors. Baccarini (1996) asserted that structural complexity can be decided based on the integrity of communication, coordination and control in the given project.

Conclusively, Ali (2014) emphasized that refurbishment projects have a higher uncertainty due to the structural complexity of its projects. In addition, these uncertainties are seen as the main contributors to poor project performance (Bakhshi et al., 2016). Therefore, adopting BIM as a new collaborative approach and technology can better improve the complexity of these projects (Abdirad & Pishdad-Bozorgi, 2014b). Unfortunately, BIM is yet to have a place in most refurbishment activities (Ilter & Ergen, 2015). Although BIM faces challenges of adoption due to a fragmented construction sector and complicated stakeholder requirements within refurbishment stakeholders (Park & Kim, 2014), we assert that development of quality attributes for complex refurbishment projects will go a long way to set out an environment where BIM can be implemented.

2.4.4 Process Optimization

Every organisation or industry has its way of operating and sharing of information. Some of this aspect is inherited termed as organisational culture such that its effects are identified as a business process, technologies implemented or adopted and peoples' work practices. In addition, the construction industry is highly fragmented among the construction stakeholders, resulting to a high level of complexity of workflows due to a high number of companies participating on the same project and this increases the inefficiency of construction projects (Arayici et al., 2012). With these in mind, organisations can differ based on forms, functionalities, and the way they respond to changes. These forms or functionalities can be conventional standalone disciplines such as project implementation and facilities management, design, procurement, integrated professional services (IPS), executive, non-executive functions and services and other management innovations within a project delivery system. Therefore, these variables can be influenced based on their perceptions of IT technology with the impact of internal and external factors. For example, when the clients and some stakeholders have some incorrect perceptions or lack of understanding of 2D traditional architectural and engineering drawing. Hence, the design team are unable to understand the client's needs as a result of poor communication, due to lack of a collaboration platform among the client and the architect, and hence, resulting to client dissatisfaction (Arayici & Aouad, 2010). Therefore, investigating the effectiveness of BIM adoption and its benefits for refurbishment projects may require a thorough investigation of the entire project stakeholders and the interactions within the project. Previous studies have been centred on a technical aspect of BIM (Arayici et al., 2011b; Park & Kim, 2014; Sheth et al., 2010b). Tulenheimo (2015); (Zheng et al., 2016b) affirmed that technology adoption should involve technical and social activities. therefore, the current authors intend to investigate technical as perceptions and social activities as the interaction of project stakeholders through structural or process optimization. To do this, we recommend undertaking a case study and adopting Social Network Analysis (SNA) to simulate interactions and perceptions based on the role of stakeholders in a given refurbishment case study project versus a virtual BIM implementation for the same project. Figure 3 details the reactive optimisation schedule for traditional refurbishment (A) vs virtual BIM project (B) with respect to environmental factors.

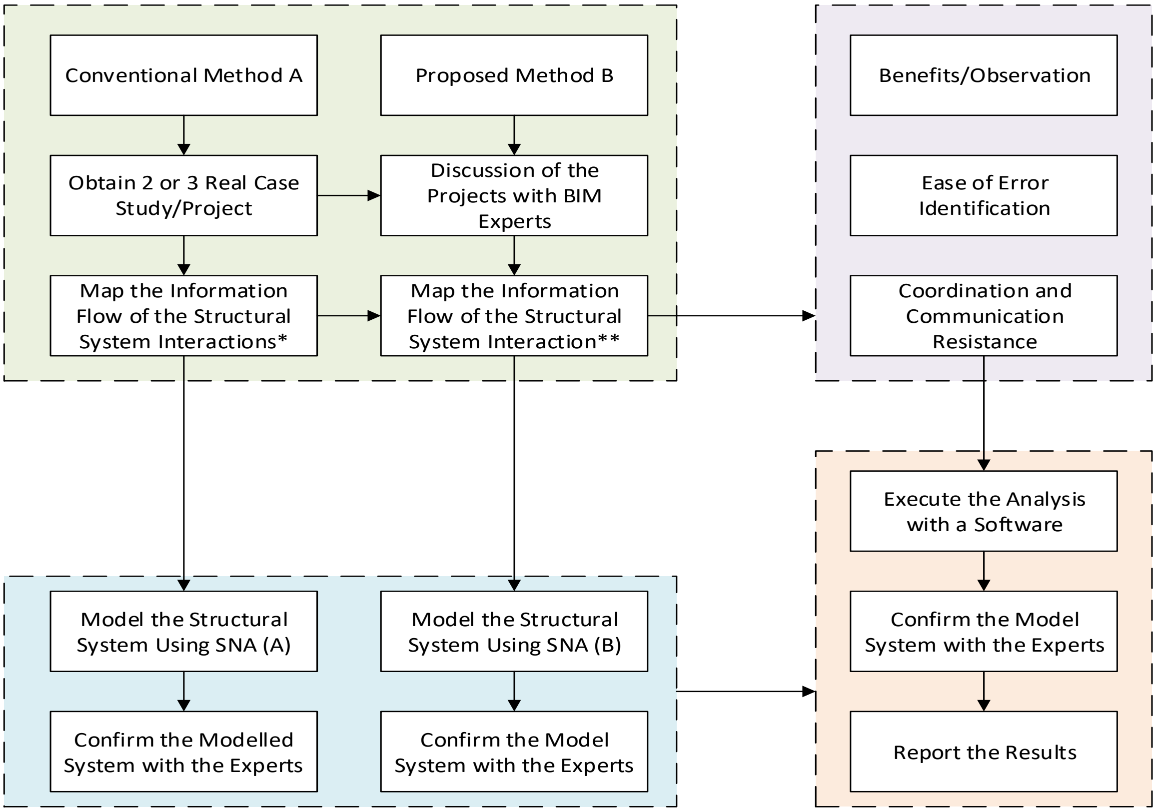

Figure 2.3: Reactive optimisation schedule for traditional refurbishment project vs BIM virtual refurbishment project

As SNA is based on the assumption of the importance of relationships among project stakeholders, its potentials have been identified to encompass theories, models, and including applications which are expressed in terms of relational processes (Hoseini & Ibrahim, 2007). The estaries denotes differences in interaction between the conventional method and the BIM method. In addition, SNA has also been used to showcase how organisations interact with each other showing how the executives connect between individual employees (Chinowsky et al., 2008). Therefore, we posit that this analysis tool can be used to investigate different roles in construction during refurbishment phase, as well as to determine the main central role both in traditional projects and BIM projects. By observing the differences, we believe that there are possibilities for restructuring the current system to enhance adoption of BIM-based on refurbishment projects.

2.5 Results and Discussions

Previous studies on BIM adoption for refurbishment projects are mainly centred on technical adoption of BIM (Alwan, 2016; Bu et al., 2015; Kim & Park, 2013a; Park & Kim, 2014). Although to achieve effective BIM implementation for refurbishment projects there is a need for a comprehensive framework which can facilitate the identification of influencing factors and as well, pinpoint the promising areas. Our proposed BIM framework aims to supplement influencing factors and practical issues for real-world adoption criteria while encompassing broader factors and issues within refurbishment phase across different levels of stakeholders' perspectives.

Considering the stakeholder's interaction in Fig 3 indicates the areas where there is more or less an intense need for an investigation. Since the previous studies previous studies majorly emphasised on technology adoptions and barriers, they are more recent to identifying how and what impacts the stakeholders to adopt BIM and their perceptions for the traditional method vs BIM method.

2.5.1 Realising Benefit through Improved Collaboration

For the benefits to be realized through collaboration, one major characteristic of complex refurbishment projects is the multiple stakeholders and this is one of the causes of difficulties during collaboration or share of project information. Talking about different types of stakeholders in major refurbishment projects namely; internal and external stakeholders (Beringer et al., 2013). The first includes the project owners, design team, clients organisation, contractors, employees, customer user, project management team, sub-contractors etc, while the later includes the political organisation, social organisation, local communities, the general public, interest groups, real estate owners, trade and industry etc. who are mainly the potential stakeholders in construction projects (Olander, 2006). With the different stakeholders and complexities in refurbishment projects, it implies that there is a need to enhance collaboration between these stakeholders and BIM offers collaboration and communication. For example, the use of 4D BIM which has the facility to display animated construction sequences on screen which is mainly used by designers and construction planners to communicate the sequence of project construction Sacks et al. (2009) and further to that, with the high number of stakeholders in a project, the non-native operatives are also increasing requiring provisions of visual models as translators Tutt et al. (2011) are some of examples of benefits for collaboration.

2.5.2 Realising Benefit through Error Minimisation

The error minimisation realisation implies that within an effective BIM implementation, errors within projects or repetition of works or reworks can be minimised. For example, when a refurbishment project is presented in 2D drawings, there is the possibility of presenting these buildings in only one view at a time (Campbell, 2007). This 2D view can cause issues regarding clarity of design information with the traditional approach with insufficient information for project stakeholders (Ashworth, 2012). This, however, can result in requests for information (RFIs) by the contractor. The RFIs can cause project delays, which could result to re-design, and consequently, errors are bound to occur including project cost overrun (Eadie et al., 2013). While there are many issues that can cause an error or rework in refurbishment projects, BIM can have a positive influence on these projects (Barlish & Sullivan, 2012). In addition, when the stakeholders are BIM capable, one of the benefits is that they can produce fast and reasonably accurate estimates of cost implications on these refurbishment projects especially for the unknowns as a starting point for mitigating actions. With the cost of construction works and its realistic sequence through 4D BIM, significant money and time are saved through a reduced rework and delays to programme (Eadie et al., 2013). Similarly, the clash detection can offer savings for about 10% of contract value and as well reduce the project duration by approximately 7% (Azhar et al., 2008). Hence, the error minimised through BIM implementation can help save much cost and energy mandated to be improved for existing buildings giving example as in New Zealand.

2.5.3 Realising Benefits through Early decision Making

The framework realisation effectiveness of BIM adoption can offer many benefits during decision making. For example, the walk-through visualizations BIM models could offer to assist clients during decision-making process offer them the ‘choices’ and then their preference is thus reduced for making changes later on in the contract (Eastman et al., 2011). In addition, there could be contributions from designers, contractors with no geographical restraints during a real-time online platform to suggest changes to the clients visually on screen (Bentley, 2012). As long as the object properties have been loaded into the system, this makes it favourable for designers and other stakeholders to compare and manipulate objects on screen for a change. This entirely gives the clients a realistic sense of 3D on how the facility would look like, operated, and be able to fit into the existing structure as detailed by the designers (Kassem et al., 2015). As the case may be, the contractors and the design managers can be seen as the communicators, advisors, and facilitators in a BIM project (Lock, 2012). Resultantly, the designers, therefore, ensure that the client scope of the build are met with the available budget and when there is any re-work would be minimal and hence satisfies the client’s needs (Emmitt, 2014). These benefits are expected to motivate BIM adoption but the problem is not just the benefit of BIM but what factors has been influencing BIM adoption and how to implement BIM.

From the figure 2.3, the environmental influence factors are assumed to have an impact on how organisation adopt IT technology. These factors are useful in analysing the needs of stakeholders, managerial risks, and project plan (Gido & Clements, 2014; Liang et al., 2015). As such, the need to identify these environmental factors became apparent. Furthermore, the refurbishment attributes have been given little attention. The main considered attributes are usually the larger refurbishment project in terms of cost. There are other attributes that characterise refurbishment projects. These attributes can even be aligned to BIM processes to visualize the nature of attributes and the corresponding BIM processes for innovation solution. Considering that the need to establish BIM relationships with quality attributes of projects to enhance BIM adoption potentials has been highlighted (Abdirad, 2016; Bassioni et al., 2004; Menassa, 2011; Project Management Institute, 2003; Succar, 2013), however, significant BIM assessment processes have different potentials to assess different organizations, projects or individuals (Sebastian & van Berlo, 2010). Besides, these assessment criterions differ and can give different results in different construction environments (Dakhil et al., 2015). Therefore, we propose that further studies should require a thorough literature investigations to identify refurbishment attributes and how BIM processes could be aligned to develop models as a strategy to involve traditional practitioners to understand the benefits of BIM and its implementation values. This can be done through the examination of interactions of stakeholders and how it influences their BIM perception quantitatively. Figure 2.4 shows the inter-play for actors within a given refurbishment project

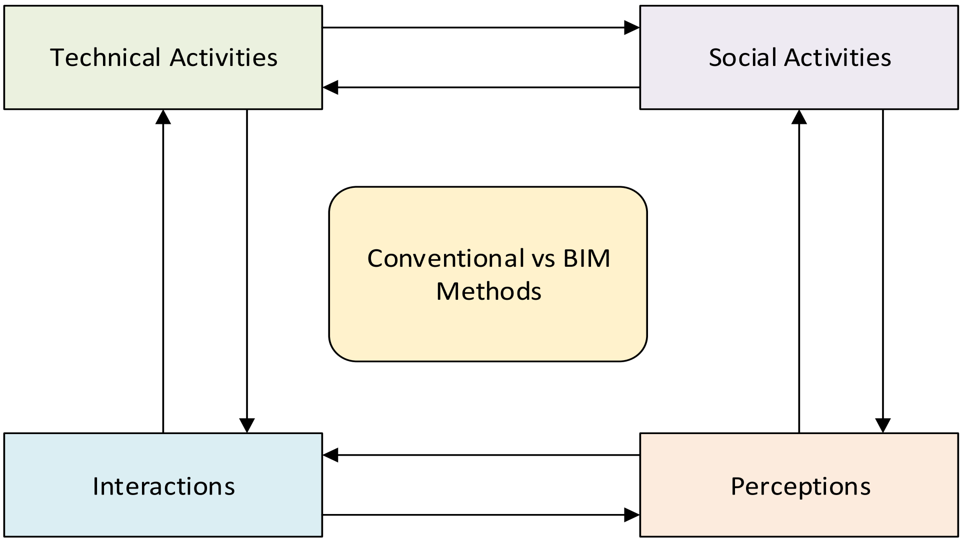

Figure 2.4: Diagrammatic indicative research comparison for conventional vs BIM method in a refurbishment project

Considering a given refurbishment project, to realize the effectiveness of BIM and its adoption possibilities, questions should be raised by these stakeholders which can further lead to other sub-questions to enable assessment of relative positive values of adoption of BIM and its barriers. In order to do this, we adapted the key questions as suggested by (Cox, 1999) to assess whether technology would provide values as contained in figure 2.3:

1 *What is possible to do?* The stakeholders in a given refurbishment project should be able to ask why they want to use BIM, the drivers and what and how to implement BIM. They should be able to know what quality of information they require, and the related complexities of the project. This will help the responsible actors to decide the level of detail for the BIM implementation. In addition, the actors should also investigate who will be responsible to update the model and ensure that every department is able to populate the required information such that the BIM model would not be considered as an unreliable model. Hence, it calls for BIM enabled comprehensive stakeholders' alignment strategy.

2 *What is the right way?* Under this question, there should be an examination of the interaction of refurbishment stakeholders, including how to restructure the organisational structure having effects on adoption of BIM. The construction sector is purportedly fragmented in nature, there are the possibilities that the refurbishment projects may still suffer further fragmented problems, including given refurbishment projects lesser priority among other projects. BIM integration based on its definition has the potentials to transform the construction industry, bringing fundamental change in the way building is designed, constructed and operated (Holness, 2008 ; Ryan et al., 2013). Therefore, the current authors suggest structure optimisation to possibly re-address the fragmented nature of AEC.

3 *How well can we do it?* Depending on the competence of organisations or stakeholders capability, there is a need to investigate the possibilities that the current practices in the organisation are in favour of BIM adoption. Consequently, there is a need to ensure that while optimising the current practices, the real benefits of BIM adoption can be maximized.

4 *Are there benefits?* In this aspect, there is the possibility to examine the real benefits of the conventional methods and the BIM methods. This can be achieved when the interaction of the actors are analysed to trash out issues with the collaboration, the rate of error minimization and decision making within a refurbishment project. Through this channel, the impact of environmental factors on BIM adoption for refurbishment projects can be assessed.

With these questions as shown in figure 3, further investigation will require identifying research sub-questions, such as:

I. What are the environmental factors that influence stakeholders' decisions to adopt BIM for refurbishment of complex building projects?

II. What are the specific risk factors that influence stakeholders' role in refurbishment of complex buildings?

III. What are the clear benefits between the traditional method and the BIM method?

IV. What are the perceptions of BIM adoption by the refurbishment stakeholders?

V. In what ways can the interaction of stakeholders be optimised to enhance a platform where BIM can be implemented?

Therefore, each of these sub-questions should be used efficiently to investigate the effectiveness and usefulness of adopting BIM to increase value and as well as acquiring a competitive advantage for refurbishment projects.

In summary, the present paper strongly recommends that the embedded knowledge within the proposed framework need to be actively developed to improve the maximization of the uncovered BIM research for refurbishment projects through an extended review investigation. The future findings of the extended review of these aforementioned knowledges will be utilized to assess the perceptions and the influence of identified criteria towards BIM adoption capability and implementation strategies. Hence, the proposed framework is important since its products can be used as evaluation criteria towards implementation of BIM, irrespective of the level of complexity of the refurbishment project.

2.6 Conclusion

The importance of BIM adoption for refurbishment projects has been given a considerable debate within the literature. Yet, its use for refurbishment project is just starting. In addition, the refurbishment projects are unique and can be function dependent especially when the existing building are prone to a continues refurbishment exercise such as multi-purpose buildings found in tertiary institutions. The difficulty to adopt BIM for refurbishment project is often due to inappropriate frameworks that lack effective mechanisms to realise real BIM benefits between traditional method and BIM methods. To address these issues, this chapter proposes a research framework for realizing the effectiveness of adopting BIM for the complex refurbishment project. This study is in line with authors (Alwan, 2016; Succar et al., 2007; Volk et al., 2014b) who had investigated BIM adoption framework studies. These studies emphasised mainly the barriers and research directions. However, the current proposed framework differs previous studies through the identification of four dimensions that encompasses the main factors that impacts BIM adoption specific to refurbishment projects and at the same time guides BIM research for future refurbishment studies. Comprehensive variables of the proposed framework have been discussed within four dimensions such as the refurbishment attributes, environmental influence factors, stakeholders' interaction and process optimisation, and as well as embedded questions to uncover the need to adopt BIM for refurbishment projects. We believe that the proposed framework can provide a solid basis for research into practical BIM adoption effectiveness and identify driving factors for BIM implementation. In addition, each of these dimensions as shown in figure 3 plays a pivotal role in enabling a strategic alignment, integration, capability and real benefits between BIM and refurbishment stakeholders. Although, realizing BIM adoption effectiveness may not be static, but rather a dynamic one, as the refurbishment stakeholders are expected to consistently question the usefulness of BIM implementation processes and practice to ensure that the benefits of BIM adoption are realized.

The stakeholder interactions and process optimization are part of the empirical investigation used to assess the impact of the aforementioned dimensions.

The proposed framework is conceptual in nature but at the same time, provides the underlying foundation for the development of investigation strategy for refurbishment stakeholders, and to consider how BIM adoption effectiveness can yield real benefits, creates values and offer a sustainable competitive advantage. BIM research focusing on complex refurbishment projects, real benefits and process optimization network has been under-reported. Hence, the proposed framework provided an avenue for BIM adoption effectiveness for refurbishment projects. It can be adopted for BIM investigation in different construction environment or different countries, thereby, providing an avenue for comparison studies. Therefore, in the following chapters will be discussing in detail the propose variables by answering the research questions posed in chapter 2. The next chapter discusses about the environmental factors that impact project stakeholders to adopt BIM.

Chapter 3 Exploring the Environmental Influence on BIM Adoption for Refurbishment Project using Structural Equation Modelling

3.1 Prelude

This chapter answers the questions posed in chapter 2 for (environmental factors that impact on project stakeholders' decision to adopt BIM). In this chapter, building information modelling is perceived as a remarkable innovation in the built environment sector with a handful of expectations towards refurbishment of existing buildings. Despite the motivations and acceptance of BIM within Architecture, Engineering and Construction (AEC), this promise seems to be hampered by less consideration of environmental factors which might also impact BIM adoption for refurbishment projects. The aim of this chapter is to empirically examine the potential environmental factors that influence refurbishment stakeholders' attitude or decision to adopt BIM by conducting structural equation modelling. It further describes an empirical testing of a structural model of environmental factors that influence decisions to adopt BIM for refurbishment of complex building. The study is based on response of 105 New Zealand construction professional who have participated in refurbishment project and have BIM experience. Several factors were identified and developed, and a final path model was determined that fit the data best. Overall, we find strong support for policies predicting the attitude towards BIM adoption, including having impact on information sharing, retrofit tools, culture of organisation and client expectations. The model provides empirical insights into how environmental factors can positively or negatively impact refurbishment project stakeholders to adopt BIM in the context of New Zealand construction industry.

3.2 Introduction

The international Standard defines BIM as "shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decisions"

(ISO Standard, 2010). BIM is also a construction management tool for managing engineering problems that involves design, energy efficiency analysis, maintenance, documentation, and delivery for all different phases of project life cycle (Venkrbec et al., 2018). It manages this through information database coupled with object-based parametric modelling Gerrard et al. (2010). Recently, BIM has captured the attention of the construction sector due to its widely recognized benefits for building projects (Bryde et al., 2013; Eastman et al., 2008), yet the use of BIM for refurbishment projects is just emerging (Ghaffarianhoseini, Tookey, et al., 2016). Refurbishment project can be carried out on existing building when it involves change in use, change of circumstances, subjective features of the decision maker and even optimisation of economic factors by improving energy efficiency (Aikivuori, 1996). Therefore, the multipurpose complex buildings in tertiary institutions can benefit from such operation. Although, the refurbishment sector is expected to provide value for money for sustainable retrofits and energy conservation, its performance is limited by its inability to adopt new technology successfully to improve its workforce (Ilter & Ergen, 2015). This phenomenon is prevalent in New Zealand environment where a large number of construction industries' BIM adoption level is at a pre-BIM maturity stage (Huber, 2012; Okakpu et al., 2018).

The majority of the New Zealand housing stock existed before the introduction of mandatory policies such as the application of wall and roof insulation in 1978 (Chapman et al., 2009). Improving on BIM adoption and implementation for refurbishment projects would contribute towards optimizing how these features are incorporated into energy refurbishment conservation efforts (Häkkinen & Belloni, 2011), including performance, and productivity improvement. These in turn will assist New Zealand in meeting its energy efficiency targets for maintaining consistent economic growth (SBC, 2014). Considering the question of BIM adoption, there are factors that can influence the adoption of BIM for the success of refurbishment projects (Gido & Clements, 2014).

These factors are also useful to assessing the needs of stakeholders, managerial risks, and technology adoption plan (Gido & Clements, 2014; Liang et al., 2015). As such, the need to identify these environmental factors became apparent.

Previous studies focused mainly on barriers and benefits of BIM for refurbishment project, little has been investigated about what impact the decision towards BIM implementation. Although, there are factors that impact construction organisations to adopt BIM, a previous study measured how factors such as attitudes (Davis, 1989) influences individual or organisation decision making. However, there is less research about those variables that motivate a positive or negative attitude regarding the adoption of BIM. In addition, many authors have investigated environmental factors but either consider only construction culture (Ho & Zeta, 2004; Wu & Issa, 2014), or organisational safety (Lingard & Blismas, 2006), and did not assess its influence on refurbishment project stakeholders when considering BIM innovation. Hence, previous literatures also lack a consideration of contextual factors that inform refurbishment project stakeholders decisions towards BIM adoption. Overall, the main objective of the study is to identify the causal relationships between clients' expectations of their refurbishment projects and how it impacts their decisions to adopt BIM. By doing this, there will be an understanding of what facilitates or inhibits BIM adoption among client organisation for refurbishment of building projects. Table 1 contains the environmental factors identified in previous studies which could have impact on decision towards acceptance of innovation.

Thus, this study aims to cover the gap posed by the following research question (Okakpu et al., 2018):

(1) *What are the potential environmental factors that influences refurbishment project stakeholders' decisions to BIM adoption?*

(2) In what ways can the interaction of refurbishment stakeholders be optimised to enhance a platform where BIM can be implemented?

Table 3.1: environmental factors that impacts refurbishment project stakeholders (adapted: Okakpu et al. (2018))

Pool of environmental factors	References
Policies, Energy efficiency standard, Renovation consents	Project Management Institute (2003); (Sebastian, 2011; Wetzel & Thabet, 2015)
Investment decision, Payback period, Retrofit with energy conservation measures, BIM standard	(Arayici et al., 2011a; Dakhil et al., 2015; Gholami et al., 2013; Miller et al., 2013; Tran et al., 2012)
Economic payback of tool uses, Complicated tool, Ease of tool implementation, Energy saving technologies, Renewable systems use, Energy consumption patterns, Interoperability with BIM software, Compatibility with BIM software	(Ezcan et al., 2013; Harris et al., 2000; Ma et al., 2012; Murphy 2014; Park & Kim, 2014) (Balaras et al., 2005; Castleton et al., 2010; Gursel et al., 2009; Ma et al., 2012; McChesney et al., 2006) (Sepasgozar & Bernold, 2012) (Cetiner & Edis, 2014; CIBSE, 2004; Hardin, 2009; Maahsen-Milan & Fabbri, 2013) (Ma et al., 2012; Tagliabue et al., 2014)
client attitude, Comfort requirement, Access to control, Management, Maintenance, Occupancy regimes, Public awareness, Social safety, Assess to education, Collaboration, Regulations	(Mickaityte et al., 2008) (Eadie et al., 2014; Mickaityte et al., 2008) (CIBSE, 2004; Howden-Chapman et al., 2009; Maahsen-Milan & Fabbri, 2013) (Owens & Wilhite, 1988) (Succar, 2009) (Alaghbandrad et al., 2015; Azhar et al., 2009; Succar, 2010)
Effects of age, Experience, Gender concept	(Enegbuma et al., 2015; Mickaityte et al., 2008; Ottchen, 2009; Son et al., 2015)
Behavioral norms, Cultural heritage, Mission, Adaptability, Consistency, Involvement	(Abdullah et al., 2014; Büschgens et al., 2013; Hogan & Coote, 2014; Kim & Park, 2013b; Menassa & Baer, 2014; Naranjo Valencia et al., 2010; Son et al., 2015)
Fair price, cost effective, Good service, Energy saving reliability, project completion time	(Mickaityte et al., 2008; Mitropoulos & Tatum, 2000; Noorman & Uiterkamp, 2014; Soetanto et al., 2014)
Construction materials management, Energy minimization, Waste minimization, Noise management, Pollution management, Use of land, Health management, Air quality management	(Cetiner & Edis, 2014; K. Ahadzie et al., 2014; Mazzarella, 2014; Mickaityte et al., 2008) (Dixon et al., 2014; Ng et al., 2014)
Type of comfort, Aesthetics, Decoration, Environment purposes, Buildings purposes, Level of detail	(Ankrah & Ahadzie, 2014; Ferrante, 2014; Mickaityte et al., 2008; Porwal & Hewage, 2013; Tagliabue et al., 2014; Wang et al., 2013; Zanni et al., 2013)

3.3 Methodology

This study was carried out by collection of data through online questionnaire survey from many construction experts who have numerous experiences with BIM and have been involved in refurbishment projects in New Zealand. The collected data was subjected to confirmatory factor analysis (CFA) and structural equation modelling (SEM) to obtain the potential environmental factors that impact attitude to adopt BIM.

To achieve the objectives of this study, a conceptual model was designed and was empirically tested using survey data covering the environmental factors that impact refurbishment project stakeholders' decision towards BIM innovation. The questionnaire comprised of items reflecting several environmental factors and is rated by five-point Likert-type scale from 1 (very small concern) to 5 (very large concern). The questionnaire also included the demography of the respondent to ensure that the target professionals and organisations are met. The conceptual model is developed based on the logical assumption that environmental factors influence social behaviour of stakeholders to adopt BIM. This same assumption is in line with most commonly applied model for technology adoption (TAM) and social network analysis (SNA). The empirical evidence suggests that application of TAM to assess user behaviour and intentions has positive effects on organisational performance or ability to move innovation (Son et al., 2015). Many researchers now argue in favour of investigating the environmental variables that can explain the core TAM variables, hence leading to extended TAM in such a way that enhances the ability to better understand the acceptance of new technology. This is in line with building execution plan (BEP) which suggest identification of factors for widely adoption for standardized workflow of strategic BIM implementation (Wu & Issa, 2014). In addition, factors that influence technology adoption tends to vary depending on the usage and the environment (Moon & Kim, 2001), but little has been investigated for the low adoption of BIM for refurbishment project. Considering the empirical validations from TAM studies and reported use of social network theories, we proposed a non-prescriptive conceptual model deemed suitable for this research study.

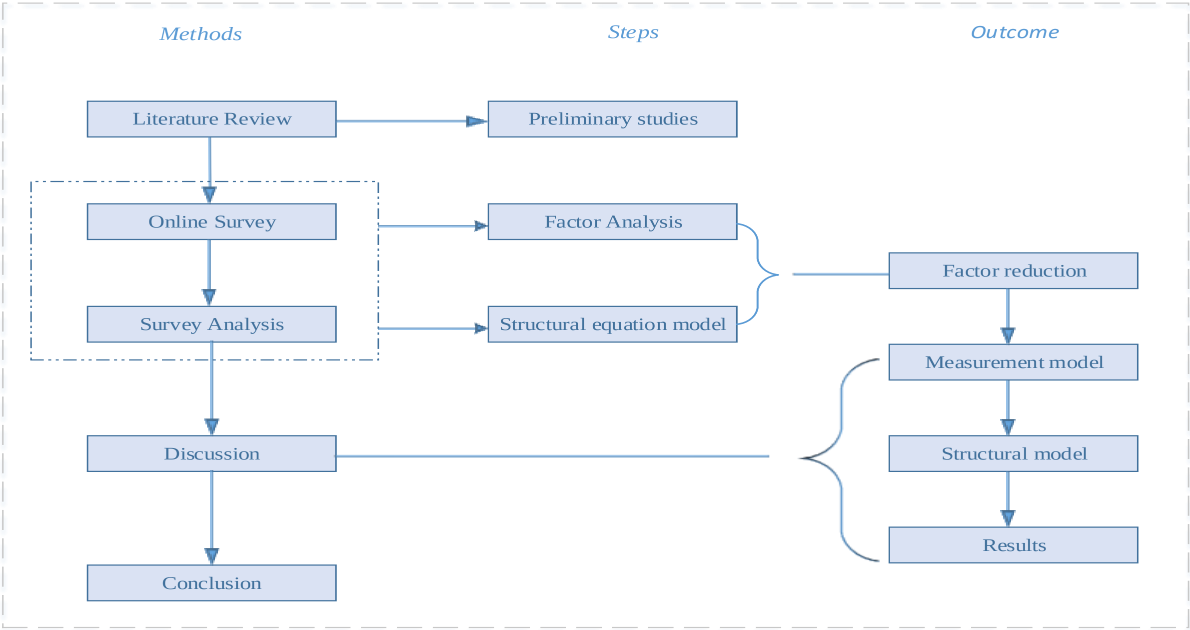

Figure 3.1: Research methodology

Once data was collected, a statistical technique of exploratory factor analysis (EFA) is conducted to investigate the correctness of the proposed latent group variables and then followed by structural equation modelling to ascertain the relationships (via regression analysis) among the variables of the conceptual model. The following sections would provide details of the proposed model.

3.4 The Proposed Model

The proposed model consists of twenty-one variables grouped into five independent variables namely: standards, information sharing, retrofit tools, culture of organisation, clients' expectation, and the dependent variable of attitude towards BIM adoption. The independent variables explain the external and internal conditions that impact stakeholders while the dependent variable is the result of the impact of the independent variables on the organisation intention to adopt BIM.

This study focused on the positive factors that influence social domain which we can call the independent variables. The proposed model is graphically represented in Figure 2 where we assumed that standards, culture of organisation, information sharing, retrofit tools, and client expectation all drives how client visualise the output of refurbishment project (that is BIM adoption). These factors collectively are believed to impact the social domain where we consider stakeholders attitude towards BIM, which have the basic elements to address technology innovation. The details of the associated dependent factors are briefly described below.

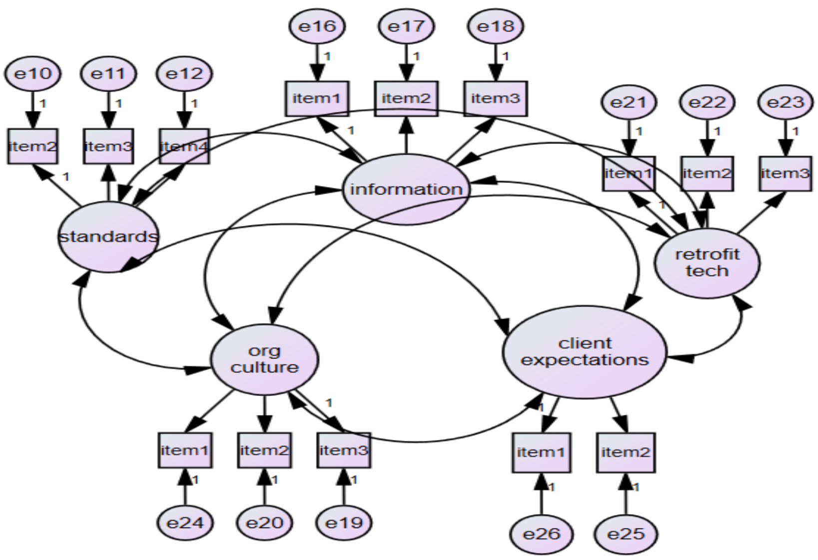

Figure 3.2: The proposed model in CFA

3.4.1 Standards

The standards represent all the policies and regulations that governs refurbishment projects and its execution. This is an important factor of BIM since it can be perceived through the interactions of BIM users or project participants in a different way (Abdirad, 2016). Therefore, it is possible that they can influence how BIM could be used for refurbishment projects. The policy and regulations are the minimum standards that regulate energy efficiency requirements for refurbishment of existing buildings. Although the benefits BIM can offer during sustainable refurbishment are documented (Arayici et al., 2011a; Gholami et al., 2013), one of the reasons why there is slow BIM uptake is the lack of focused initiatives (Tran et al., 2012). This signifies a lack of real appetite on the part of policy makers, despite having an interest in BIM for refurbishment projects (Miller et al., 2013). Dakhil et al. (2015); (Travaglini et al., 2014) identified one aspect of BIM, such as good policies, which can influence stakeholder’s ability to adopt change during refurbishment projects, including enhancing work-life balance within an organisation (Haar et al., 2014). Therefore, Standards are summarised into four independent items: energy efficiency standards, policies in construction, BIM standards, refurbish with energy efficiency measures. These items are the main drivers that empirically impact on refurbishment project stakeholders according to the present study which also supports the empirical evidence and economic theory of a previous studies (Gillingham & Palmer, 2014).

3.4.2 Information sharing

This factor is related to information, skills and knowledge of a specific BIM function. The collaborative effort occasioned by the adoption of BIM can enhance the spread of information regarding the aim of the project (Abdirad, 2016; Matinheikki et al., 2016). The information, such as the ecological domain, involves ecological management for sustainable development. It comprises the construction materials (Mitropoulos & Tatum, 2000), energy, waste, noise, pollution, use of land, health, and air quality (Dixon et al., 2014). The transportation of construction waste incurs extra cost to construction firms. Waste minimization and minimization of energy, in addition to other factors, have positive effects on cost-effectiveness and conservation efforts of construction firms during construction operations (Abdirad & Pishdad-Bozorgi, 2014b; Mickaityte et al., 2008). From the proposed model, the information sharing is supported by the following items: assess to education, public awareness, and collaboration. These factors have positive impacts towards the decisions to adopt BIM for refurbishment project.

3.4.3 Retrofit tools

The technology factors are associated with capabilities for the deployment of tools and software for BIM integration (Alwan et al., 2015). Despite the capabilities of software, 3D modelling technology which is used for new buildings is rarely used for existing buildings, hence less data/information for refurbishment within a BIM environment (Alwan, 2016). Although the retrofit technologies are usually utilized for major refurbishments to achieve maximum energy efficiency, these tools promote sustainability and energy efficiency (Sepasgozar & Bernold, 2012). However, some of these tools do not have the same economic payback and can be quite complicated to use (Maahsen-Milan & Fabbri, 2013).

A successful application of these technologies will encourage changes in energy consumption patterns, control, and renewable systems use, while optimizing technologies for heating and cooling (Ma et al., 2012; Tagliabue et al., 2014). In addition, the use of innovative technologies, energy saving technologies including HVAC technologies, and how it influences general refurbishment efficiency (Mickaityte et al., 2008) can well determine a need for integration and collaborative effort, and hence BIM adoption may be expected to be implemented. Hence, based on the proposed model, this independent variable is made up of items including interoperability of software/tools, coordination of services, and economic payback of tool uses.

3.4.4 Culture of Organisation

The cultural dimension is a factor that portrays the behavioural norms, i.e., the cultural heritage of a society where an organization is situated (Park & Kim, 2014). It has been described as “strong prescription for success” (Martin et al., 2006) and appropriate channel for investigation. Culture is a group with an underlying beliefs and assumptions of its members based on what they share in common, operates and how they relate to environmental constraints (Martins & Terblanche, 2003). Previous research identified factors that critically impact IT innovation which includes organisational commitment, organisational attitude to communication, including investment drive etc (Gajendran et al., 2005), such factors although are analogous to the desired cultural values of an optimised project environment, in a real practical world, there are differences between the levels of BIM integration between stakeholders of different projects (Brewer & Gajendran, 2012). Hence, the way new build project stakeholders perceive BIM would be different from how refurbishment project stakeholders do. This notion is supported by (Mickaityte et al., 2008; Son et al., 2015) whose studies showed that the way these factors impact project stakeholders differ from region to region, project of different kinds, and has some influence on how refurbishment stakeholders manage their operations. For example, there is the possibility that facility mangers of existing buildings scarcely use BIM while their counterparts for new build use BIM (Becerik-Gerber & Rice, 2010a), thus, requiring more access to training for BIM use for existing complex buildings and infrastructure that require refurbishment, and this can happen when the organisation is open to change in practice. Based on the current empirical study, the proposed model comprises an independent variable made up of items including saving time and resources, management and alignment, and regulations and standard mostly impact refurbishment project stakeholders.

3.4.5 Clients' expectations

the expectations of stakeholder requirements based on clients' investment can influence BIM adoption for refurbishment projects. For example, the investment decisions towards energy refurbishment upgrades are still unpredictable (Ma et al., 2012). A previous survey of one hundred firms found the factors that affected the company's decision regarding investments in energy efficiency. One of these factors is the payback period (Harris et al., 2000). Ma et al. (2012) indicated that refurbishing with non-energy conservation measures saved only 6.5 % of a building's annual energy consumption whereas energy conservation measures saved 49.3% of annual energy consumption. As such, there is an indication that consumers may not be aware of differences in degree or level of refurbishment and, therefore, require some virtual concept of BIM implementation at the conceptual stage. In addition, there is an increase and effective adoption of BIM when the building owner (clients) actively wants the project team use BIM (McGraw Hill, 2015). Because external forces from clients and competitors play a large role in BIM adoption (Liu et al., 2010), client-driven BIM mandate programme can enhance the rate of BIM adoption for refurbishment stakeholders.

3.5 Questionnaire survey and Data collection

A questionnaire survey covering environmental factors identified through a review of the literature and tested through the preliminary analysis for correctness was drawn up to operationally define each of the models six construct. Each of the questions was designed to elicit the respondents' opinion on different factors that influences them when considering adoption of BIM for refurbishment projects. Therefore, all the factors were evaluated on the five-point Likert scale with anchors from '1 = very small concern, 5 = very large concern". By doing this, the perceptions of the general participants and their main concerns towards the construct (Table 3.2) are evaluated. An initial sample frame of 320 refurbishment stakeholders across New Zealand was initially considered for this study. Considering that BIM is still at the prematurity level (Huber, 2013; Okakpu et al., 2018), the targeted respondents of 200 were then selected based on the assumption that they have BIM experience and as well, have been involved in many refurbishment projects across New Zealand.

Table 3.2: multi-item scale for the structural model

Standard	1	**We have concern for BIM adoption when dealing with energy efficiency standard**
	2	Policies in construction influences BIM adoption decision
	3	BIM standards is interested in BIM adoption decision for refurbishment project
	4	Refurbish with energy efficiency measures encourages the decision to BIM adoption
Information	1	Assess to education effectively support the decision to BIM adoption
	2	Increased public awareness supports the decision to BIM adoption
	3	Improved Collaboration is in support of the decision for BIM adoption
Retrofit Technology	1	The need for interoperability of software influences the decision to adopt BIM
	2	The need for coordination of services influences BIM
	3	Economic payback of tool uses influences the decision for BIM adoption
Organisational culture	1	To save time and resources influences the decision to BIM adoption
	2	Management & alignment influences the decision to adopt BIM
	3	Regulations & standard in refurbishment projects influences the decision to adopt BIM
Client expectation	1	Pressure to deliver on time positively supports the decision to adopt BIM
	2	Information about payback period of different tools influences the decision to adopt BIM

A total of 200 questionnaires were distributed with 110 responses returned, representing a response rate of 55 percent. Out of all the responses, only five responses were rejected because of incomplete data and were however removed from the data set. Overall, 70 percent of the respondents have more than five years of BIM experience. Majority of the respondent have used BIM before. A *post hoc* analysis reveal that the statistical power was above the threshold of 0.80 which suggested that the sample size was large enough for the current research (Cohen, 2013), and based on the current BIM maturity level in New Zealand. Hence, the 105 retained responses were subjected to SPSS (Version 25) to compute the standard deviation, mean score, and check the correlation of the factors with each other to understand the distribution of the factors considered. Figure 3.3 details the demography of the respondents.

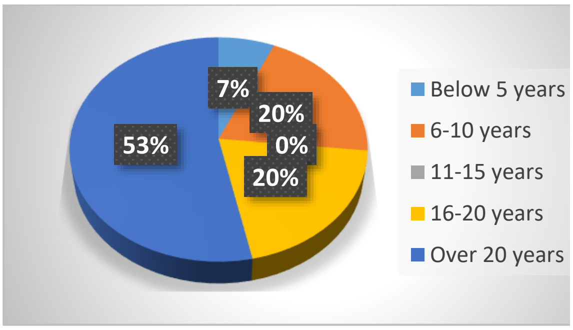

Fig 3a: years of experience of the participants

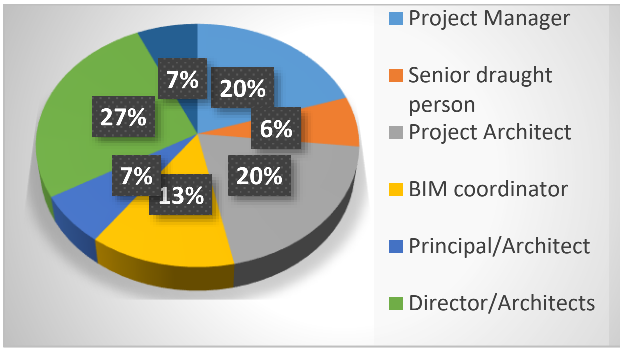

Fig 3b: Job tittle of the participants

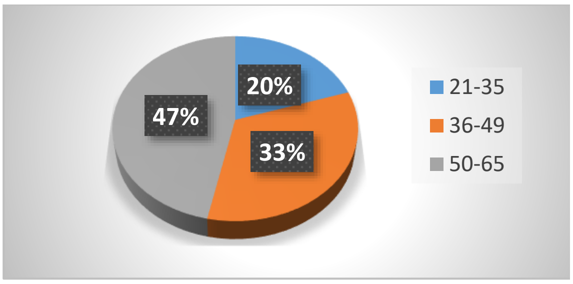

Fig 3.33c: Age differences of the participants

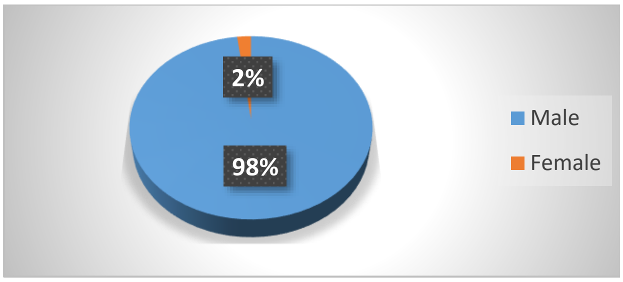

Fig 3.3d: the percentage of gender for the participants

Figure 3.3: The demographic attributes of the respondents

3.6 Results & Analysis

3.6.1 Exploratory Factor Analysis (EFA)

In the present study, three statistical analyses were performed to test the given model: (1) an exploratory factor analysis (EFA), (2) a confirmatory factor analysis and then (3) structural equation modelling. The exploratory factor analysis was carried out to identify the structural model based on the environmental factor responses received from the questionnaire items and as well as for data reduction, thereby confirming the structure of the proposed environmental impact model. The analysis employed principal axis factoring with the varimax rotation method to examine the dimensionality of the environmental factors that influence refurbishment stakeholders and better interpretability of factor loadings. Weaker indicators were removed from the overall factors considering a cut-off factor loading of 0.45 (Hair et al., 1998). Therefore, the items were reduced to fifteen items with five latent variables formulated: exploratory factor analysis (principal components, varimax rotation) which confirmed the items all loaded onto five factor – all with eigenvalues greater than 1, accounting for sizeable amounts of the variance (72.3%) and achieving good reliability. The specific details are shown in Table 3.3.

It is worth noting that the above analysis initially gave 10 factor components. However, the Cronbach's alpha was found to be less than 0.7 with a number of factors, which is the generally accepted minimum (Pallant, 2010). In addition, there are items cross-loading on two factors and having a total variance of 74.288 per cent. For example, fit5 and fit2 initially loaded into two factors. We found it was not suitable for the analysis and these items were removed. After removal of these items, other items started loading onto two factors. Similarly, they were removed. We assumed a cut-off factor loading of 0.45 to remove the weaker loading items. Ultimately, a five-factor loading was finally derived from the factor reduction process. Table 3.3 shows the rotated component matrix[a].

Table 3.3: rotated component matrix

	Rotated component matrix component				
Variables	**Standards**	**Information**	**Retrofit technology**	**Org culture**	**Client expectations**
Energy efficiency standard	.843				
Policies in construction	.823				
BIM standards	.780				
Refurbish with energy efficiency measures	.778				
Assess to education		.904			
Public awareness		.773			
Collaboration		.667			
Interoperability			.877		
Coordination of services			.811		
Economic payback of tool uses			.780		
Time and resources				.922	
Management & alignment				.809	
Regulations & standard				.513	
Pressure to deliver on time					.771
Payback period					.771

Eigenvalues	2.828	2.232	2.153	1.963	1.671
Percentage variance	18.9%	14.9%	14.4%	13.1%	11.1%
Number of items in measures	4-items	3-items	3-items	3-items	2-items
Cronbach's Alpha	.82	.75	.77	.75	.57

Overall, all constructs had good reliability except the fifth factor: client expectations (α = .57) but was included in the analysis since it is approximately equal to the Cronbach's alpha critical value of 0.60 (Chahoud et al., 2017). The reliability of a construct can be due to the number of items (Cortina, 1993; Schmitt, 1996) and with only two items this likely represents that issue. Despite this low score, Schmitt (1996) notes that even coefficient alpha scores of .50 can be reliable. Similarly, Nunnally (1967) suggests reliability scores in the .05-.06 range are acceptable when the research is preliminary research.

3.6.2 Structural Equation Modelling (SEM)

The SEM is a statistical technique that allows the assessment of direct and indirect effects of variables on other variables (Byrne, 2016). This study used Amos version 25 for the investigation of the inter-relationships between the variables as contend in the proposed structural equation hypothesized model. The implementation of SEM on variables inter-dependencies was justified to dis-allow excess multi-collinearity which could occur leading to bias and unstable findings especially when dealing with inter-correlations among influencing factors within a model's constructs. Previous studies have manifested successful use of SEM. For example, Mohamed (2002) investigated the relationship between work safety and work behaviour in a construction environment. More recently, Son et al. (2015) used SEM to examine the factors that impact architects adoption of BIM through an extended technology acceptance model in North Korea. Theoretically, SEM is made of two model types: (1) a measurement model (confirmatory factor analysis) and (2) a structural model. The structural model is concerned with modelling the relationships among the latent factors and also describes the amount of unexplained and explained variance which is similar to regression models (Wong & Cheung, 2005), while measurement model measures indicates how well variables measures the latent factors describing its validity and reliability.

Measurement model

The confirmatory factor analysis was conducted to establish confidence based on the measurement model that posits relations of the observed variables relative to the underlying constructs. CFA is used to assess the fit between observed variables and the latent factors and their relationships (Mueller & Hancock, 2008). The baseline model was analysed using Amos with a number of goodness of fit (GOF) indicators to assess the model (Hu & Bentler, 1998; Williams et al., 2009). We confirmed this was the best fit through trying alternative factors and comparing the models (Hair et al., 2006). In the end, one item (the weakest loading item on the standards factor “Refurbish with energy efficiency measures” was dropped due to high cross-loading.

Table 3.4: Results of Confirmatory Factor Analysis for Study Measures

Model	χ^2	df	CFI	RMSEA	SRMR
1. Hypothesized 5-factor model.	96.7	67	.941	.065	.070
2. Alternative 4-factor model [combining the social factors 2 and 4	155.5	71	.833	.107	.085
3. Alternative 4-factor model [combining the refirb factors 1 and 5]	110.0	71	.923	.073	.077

Overall, the standardised path and the total variance (R^2) for the best fit measurement are presented in Table 3.5. From the table, the entire coefficient is positive and significant at $p < 0.05$, thus would indicate the model is augmented. While the (R^2) of the main observed variables should be greater than 0.50, to indicate a good convergent validity of the model. The Chi-square is 126.471, the degree of freedom is 76 at a probability level of 000, accounting for the sample size (n = 105).

Table 3.5: Standardized path coefficients and square multiple correlations of the observed variables

Regression path	Standardized coefficient	R^2
Policies		
Refirb5	.779	.607
Refirb4	.731	.534
Refirb7		
Refirb3	.848	.719
Information sharing		
Soc9	.777	.604
Soc7	.915	.836
Soc10	.390	.152
Retrofit technology		
Fit13	.881	.776
Fit9	.713	.509
Fit1	.617	.380
Culture of organisation		
Soc5	.723	.522
Soc4	1.008	1.016
Soc11	.377	.142
Client expectation		
Refirb12	.423	.179
Refirb2	.939	.881
Goal		
Attitude to BIM adoption		.581

The correlation table with means and relationships amongst the study variables is shown below.

Table 3.6: Descriptive Statistics and Correlations

Variables	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
1. Standards	3.34	0.89	--					
2. Client expectation	3.42	1.01	0.498**	--				
3. Information	2.91	1.04	0.087	0.131	--			
4. Org culture	3.86	0.90	0.030	0.136	0.491**	--		
5. Retrofit Tools	3.44	0.72	0.684**	0.611**	0.119	0.093	--	
6. Goal	2.96	1.24	0.266**	0.221*	0.513**	0.535**	0.159	--

N=105, *p<.05, **p<.01

There is broad support for the constructs being tested, with four of the constructs significantly correlated to goal (BIM adoption): standards (r= .266, p< .01), client expectations (r= .221, p< .01), information (r= .513, p< .01), and organisational culture (r= .535, p< .01). Only retrofit tools was not significant correlated (r= .159, p= .106).

Structural Model

Structural equation model is used to test or examine the relationships among the latent variables as shown with the pointing arrows to each other. Most importantly is the direction of arrows which describes the type of relationship between variables. Although these arrows show a relationship that the clients' expectation is influenced by policies, resources and retrofit technologies and culture of organisation, and these three latent factors are collectively influencing the level of collaboration which impacts the social factors that determines the decision to adopt BIM.

We follow the approach of (Clissold, 2004) around the directional influence of constructs, and present the best fitting model and the GOF indices in Table 3.4. The final model (Figure 3.4) has all the environmental factors that influence the decisions to adopt BIM for refurbishment project.

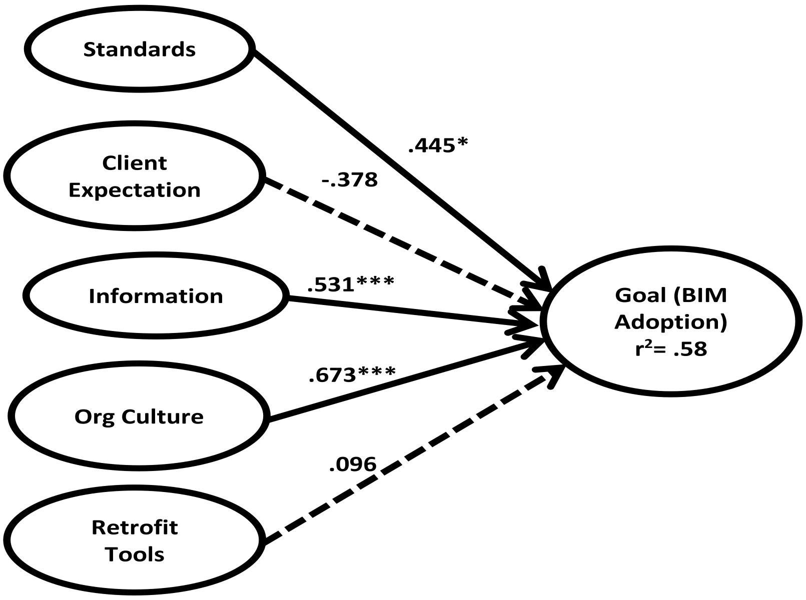

Figure 3.4: Final model of environmental factors that impact decision to adopt BIM

Figure 3.4 shows that most factors are significant predictors of BIM adoption. Org culture has the greatest impact on goal (BIM adoption) with a path coefficient of .673 (p= .000), followed by information (path coefficient of .531, p= .000) and standards (path coefficient of .445, p= .000). Only client expectations (path coefficient of -.378, p= .193) and retrofit tools (path coefficient of .096, p= .301) are non-significant. Overall, the model accounted for a large amount of variance towards goal (attitude to BIM adoption) at 58 percent.

3.7 Discussions

This study examined the key environmental factors that influence BIM adoption among the refurbishment project stakeholders in New Zealand. The findings of this research are in consistent with recent BIM adoption studies (Bin Zakaria et al., 2013; Hong et al., 2006; Marcoulides & Heck, 1993; Succar & Kassem, 2015), where policies, culture of organisation, client expectation were found to impact attitude to adopt BIM. In the present study, our model showed that standard have sparingly relationship with culture of organisation but strong relationship with client expectation. This is in line with (Wright et al., 1999) whose studies indicated that effective standards improve innovation processes. The result also shows that culture of organisation is related to the type of retrofit tools to implement and influences client's expectation simultaneously.

These relationship studies are in consistent with others (Cooke & Rousseau, 1988; Legris et al., 2003) who investigated the importance of culture of organisation to impact clients expectation during innovation processes. In addition, the retrofit tools were found to be strongly related to client expectation. A closer look at BIM adoption characteristics is important considering previous TAM studies which had examined the relationship between new technology and stakeholders' skills or time to familiarize their usage (driving factors), and thus was considered an important predictor of BIM adoption decision.

Interestingly, information sharing in this study strongly relates to culture of organisation but does not have a strong relationship to retrofit tools. At the same time, culture of organisation impacts retrofit tools. One explanation to this could be that the type of tools implemented for refurbishment project is not dependent on the level of information sharing or coordination of services, but rather based on the culture of the organisation handling refurbishment project. Here, the culture of organisation is highly portrayed as a factor or mediator between information sharing and retrofit tools. Considering previous studies, top management which can be viewed as part of culture of an organisation has a positive impact on perceived usefulness (Son et al., 2015). The perceived usefulness is defined as the degree of which IT users believe that adopting BIM will improve the work performance (Venkatesh & Davis, 2000). Hence, organisational culture has a strong link with information sharing and retrofit tools and therefore will impact the decision to adopt BIM. In addition, the client expectation tends to depend on other variables. Perhaps, it is related to other variables and does not impact any of the latent variables. This could be explained that client depend on the information they receive, and only influenced by such variables which would impact their decisions to adopt BIM for refurbishment projects.

Although the five latent variables have various degree of impact on the dependent variable of attitude towards BIM adoption, in Table 3.5, standard is seen to be the very influential to impact BIM adoption for refurbishment projects. Overall, these direct effects corroborate well with (Blayse & Manley, 2004), who predicted that policies in form of regulations and standards impact IT innovation in construction industries. Hence, we present a BIM adoption assessment model for refurbishment project stakeholders (Figure 3.5) based on the validation from the empirical study.

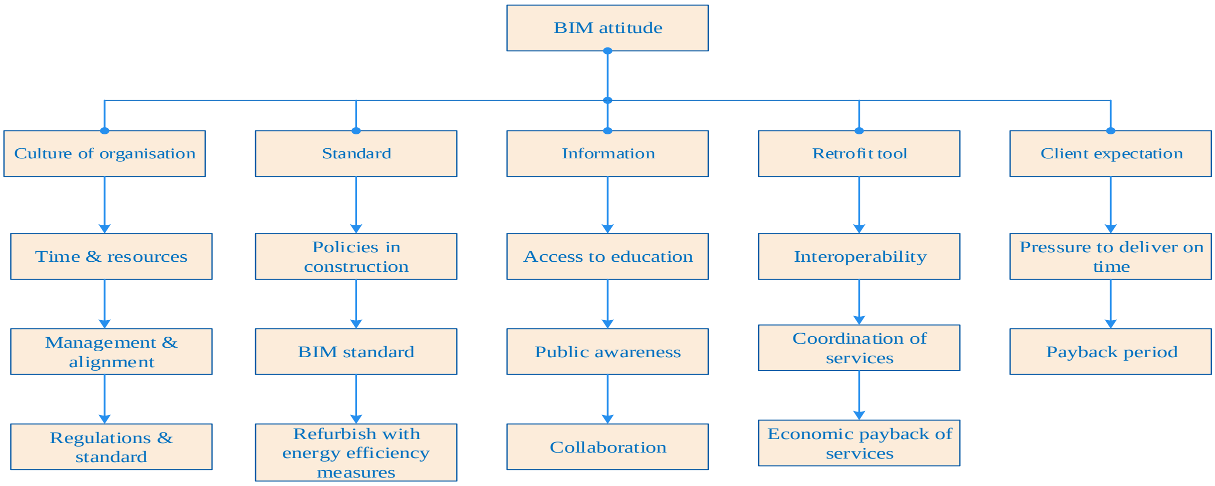

Figure 3.5: An environmental decision assessment framework for refurbishment project BIM adoption effectiveness

There are no other factors that had direct influence on policies which invariably would impact the attitude to adopt BIM for refurbishment project.

3.8 Conclusion

BIM adoption for refurbishment projects has been given considerable debate in the literature. Despite this attention, there is little investigation on environmental factors that impact refurbishment stakeholders' decision to adopt BIM for refurbishment projects. To address this issue, the present study investigated the environmental factors that influence refurbishment stakeholders' decisions towards BIM adoption. We used structural equation modelling to empirically test and validate casual relationships of environmental factors towards the goal of attitudes towards BIM adoption, using data and information gathered through a questionnaire of New Zealand experts. Our result showcases the causal relationships and helps determines the main environmental factors for which refurbishment project stakeholders need to pay more attention to achieve maximum innovation diffusion such as BIM adoption.

In this study, it was found that Standards strongly have correlation with Client expectation, followed by Retrofit tools, Information sharing and sparingly influences Culture of organisation. Thus, Policies within refurbishment projects should be given considerable attention to promoting human behaviours, skills, communication within refurbishment projects, especially when it concerns multipurpose buildings designated to client organisations such as tertiary institutions and this policy should be communicated throughout refurbishment project stakeholders. Even though Policies is one of the main drivers of BIM adoption for refurbishment project in New Zealand, well reformed policy towards BIM for refurbishment projects is crucial in promoting BIM.

Additionally, information sharing has high correlation with Culture of organisation and Client expectation but sparingly influences Retrofit tools. This critically shows the social domain of stakeholders, and how the performance of business process could be determined by the level of coordination of services in their refurbishment projects. This therefore reflects the need for improvement in coordination of services by adopting appropriate tools.

It can also be seen that culture of organisation influences client expectation leading to a favourable attitude to adopt BIM as well as influencing retrofit tools. Although, there are indirect influence from the retrofit tools and client expectation towards culture of organisation, here, we mostly measured the direct impact. Hence, culture of organisation also plays important role after policies and information sharing towards enabling maximization of software use to various level of details and what client expect from refurbishment project as future benefits. Surprisingly, from the study, retrofit tools correlated with client expectation towards the attitude to adopt BIM. Therefore, it can be postulated that an effective use of software such as BIM to manage refurbishment project would be useful contribution towards the visualisation of the project lifecycle, and hence, clients are able to ascertain or visualise project benefits at the conceptual level of the refurbishment project.

The result of this study has some implications. Firstly, from the social point of view, to increase the level of BIM adoption for refurbishment project among project stakeholders, BIM should be developed to target changes in the current standards and policies around refurbishment projects. In addition, the level of information sharing, the culture of organisation to enable BIM implementation, and the type of retrofit tools to use perhaps must be compatible to BIM. In doing so, the stakeholders' perception of BIM will be maximised to realise BIM.

From the technical point of view, the result suggests that culture of organisation is a major factor that informs how organisations or project stakeholders' perceptions about retrofit tools as well as BIM. This invariably would impact how clients would visualise the BIM benefit. Therefore, when the culture of an organisation favours BIM adoption, it also improves the expectation of clients-organisations. This is also related to Retrofit tools having influence on Client expectations. A thorough consideration of these factors would offer optimisation opportunities towards BIM adoption capability and motivation for refurbishment projects in New Zealand.

The next chapter (chapter 4) will discusses the risk factors that impact project stakeholders to adoption of BIM considering the adopted case study project in the next chapter which is part of the research question posed in chapter 2

Chapter 4 Risk Factors that Influence Adoption of Building Information Modelling (BIM) for Refurbishment of Complex Building Projects: Stakeholders Perceptions.

4.1 Prelude

This chapter addresses one of the research questions as posed in chapter 2. It attempts to identify the risks factors in refurbishment projects that has negative setback towards BIM adoption. While the construction projects continue increase in complexity, comprising varying activities and processes, requiring input from different disciplines, adoption of BIM cannot be undermined. BIM adoption is believed to improve project performance, collaboration and information sharing. Despite the promising benefits of adoption of BIM for the entire AEC, adopting BIM for refurbishment of existing complex buildings seems to be challenging due to the highly fragmented nature of construction practice, which invariably instigates a difficult integration of diverse information throughout the project life cycle. To this end, this study investigates the main risks factors that influence refurbishment of complex building projects stakeholders towards adoption of BIM. A case study of tertiary education multipurpose facility project is adopted. Semi-structured interviews were conducted with informed project stakeholders and BIM experts in New Zealand with the aim to (i) identify specific risk factors that impact refurbishment project stakeholders' role towards acceptance of BIM, (ii) to suggest solution to BIM adoption for refurbishment project stakeholders in New Zealand. The findings revealed several risks factors that can impact stakeholders' interaction and the nudge to adopt BIM. Thus, two distinct type of risks; the project type which is the BIM enablers and the organisation risk that hinders BIM. The manifestation of these risks to BIM adoption is highly driven by financial and socio-cultural risks.

4.2 Introduction

Building Information Modelling (BIM) is an emerging technology and its implementation is expected to lead to improved performance in construction processes throughout the life cycle of an existing building facility. BIM is advocated widely as a platform which enhances information-communication, and reduce the project duration and cost in the construction industry (Hong et al., 2016). Although, a strategic approach to BIM adoption requires the incorporation of people, process, and technologies on timely bases, it also leads to capacity buildings and good managerial improvements (Alwan, 2016).

Despite that BIM adoption for refurbishment project is emerging (Ghaffarianhoseini, Tookey, et al., 2016), its delivery and uptake has been reported to be slow for existing building projects (Chong et al., 2017). Anecdotal evidence reveal that the decline in uptake is due to project fragmentation (Ilter & Ergen, 2015), isolation, lack of collaboration and information sharing within the construction firms (Ali, 2014; Park & Kim, 2014). Besides, the refurbishment projects are of risky essence (Liang et al., 2015), and very complex in nature (Ali, 2014; Chong et al., 2017). Although, the traditional practice has little or no significant changes which enables the adoption of BIM as a new technology and therefore portrays a low BIM maturity level. Previous studies conducted in US have proved that BIM improves competitiveness, efficiency, and collaboration in construction industry (Matarneh & Hamed, 2017). While other country such as New Zealand as a whole, is said to show lack of BIM focus initiative due to many risk factors (Tran et al., 2012) which are ultimately centered around the fragmented nature of her construction industry, thereby suggesting for a need to shift from the current workflow (Harrison & Thurnell, 2015).

In addition, there are BIM guidelines and standards established to guide the functions of each stakeholder in dealing with BIM use, yet the collaboration problems remain existing within the AEC (Chong et al., 2017). Secondly, there is also fear of additional risk and liabilities arising when procuring a BIM model as many organisations and construction industries still prefer adopting the conventional procurement approach (Chew & Riley, 2013).

While previous literature reveals that such decision to implement BIM relies on the effort of multidisciplinary collaboration of different disciplines against information sharing, building design, and construction techniques (Backlund et al., 2015; Ghosh, 2015; Rizal, 2011), hence, these efforts are also required to extended to BIM adoption investigation for refurbishment project. Although to adopt BIM can be influenced by emergence of new threats or risks (Tomek & Matějka, 2014), understanding these risks could help to build argument to adopt BIM since these risks has the potential to decrease the chances and opportunities to adopt BIM specific to refurbishment project. In this regard, the current study aims to answer the following research question (Okakpu et al., 2018);

I. What are the risks factors that influences adoption of BIM for refurbishment of complex buildings?

To achieve the main aim, this study starts with the background of the study on BIM adoption for refurbishment projects. This is followed by the research method, then the result and discussion, then followed by conclusion. A descriptive interpretative research was conducted using semi-structured interviews. This approach is suitable to allow the investigator to disallow presuppositions regarding the phenomenon in search of the true meanings and to have deeper understanding of the phenomenon as experienced by the experts.

4.3 Background of The Study

This describes the importance of refurbishment project and the benefits of BIM for the entire architecture, engineering and construction.

4.3.1 The need for BIM Adoption for Refurbishment Projects

Although BIM benefits are well known, researchers and practitioners show less concern towards this venture (Ilter & Ergen, 2015). Considering the complicated stakeholder requirements added to the highly fragmented construction sector (Park & Kim, 2014), hence, the sector is in great pressure to updating an existing buildings with structural faults, including poor insulation Alwan (2016). For example, in Europe, the construction sector recorded 40% of energy consumption as 40 % of Europe's existing buildings were more than 50 years old (Kylili & Fokaides, 2015). In addition, 35% of existing buildings in UK predates 1945, and this is likely to remain in use over the next 30 years (Kemmer & Koskela, 2012), causing high use of energy consumption and high carbon footprint (Alwan, 2016; Park & Kim, 2014). According to a report by Building Research Association New Zealand (BRANZ), the refurbishment projects represented about one-third the total value of the new dwellings with about 33,000 renovation consents (BRANZ, 2008; Manfredini & Leardini, 2014). Hence, improving the performance of existing buildings in New Zealand suggest that there will be less Auckland housing crisis, which was earlier predicted to shift from 1.4 million to 2 million in the next 20 years (Statistics New Zealand, 2013). Therefore, these suggests a need for a strategic change towards adoption of BIM for refurbishment of existing buildings, particularly in New Zealand.

4.3.2 BIM benefits

In the construction industry, the benefits of BIM includes improved productivity, information availability, enhanced decision making, better risk management, competitive advantage, gain of market access, etc. (Bryde et al., 2013; Chen et al., 2011). Other benefits includes minimised project management, early identification of errors, reduction of rework, reduction of costs, improvement of quality, and the fostering of co-ordination and communication (Building and Costruction Productivity partnership, 2016). It enables the creation of new approaches to solving problems with whole life cycle process within the Built Environment (Arayici, 2008b; Suermann, 2009). BIM smoothens the development of detailed information concerning buildings and analysis at the early stages, and this aids the decision making and a decline in downstream changes (Klotz et al., 2007; Manning & Messner, 2008). Consequently, countries like Norway, Germany, France, Finland, UK, Sweden, Australia, and the USA have started seeing these benefits through the projects when implemented with BIM than the non-BIM initiatives (Arayici et al., 2009a; Tocoman, 2010). The table 2 shows further BIM benefits and the extent of impacts on construction projects.

Table 4.1: BIM benefits

Benefits	**Impact stages**	**Degree of impact**		
		Short-term	Mid-term	Long-term
Improved design (Azhar et al., 2008)	Design	x		
Improved customer service (Gholami et al., 2013)	Design-FM	x	x	x
Speedy evaluation (Manning & Messner, 2008)	Design-FM	x	x	x
Automated assembly (Lambrecht et al., 2016)	Design & Construction	x	x	
Cost savings (Bryde et al., 2013)	Conceptual-End of life-Refurbishment	x	x	x
Improved communication (Lewis, 2014)	Conceptual-End of life-Refurbishment	x	x	x
Time savings (Bryde et al., 2013)	Conceptual-End of life-Refurbishment	x	x	x
Improved coordination (Alwan et al., 2015; Bryde et al., 2013)	Conceptual-End of life-Refurbishment	x	x	x
Whole life cost and environmental control (Chaves et al., 2015)	Conceptual-End of life-Refurbishment	x	x	x

4.3.3 Cost control

Another benefit of BIM is that with the pressure from clients, including the internal organisations in order to increase the return on investment (ROI) in projects, the state of the art technological came up in order to minimise project costs, and increase project control (Eastman et al., 2008). In order to reduce cost, BIM does not necessarily minimise the work load but enhances a lot of decisions at the early design phase where the cost and risk of change is lower (Eastman et al., 2011). Hence, this portrays a need for specified skills to be included in the project during the early stages. The traditional design process which is contrary to the preferred BIM approach has the highest workload when the construction documentation is made and, in this point, changes cannot be made without considerable negative impact on the costs as shown in figure 4.1.

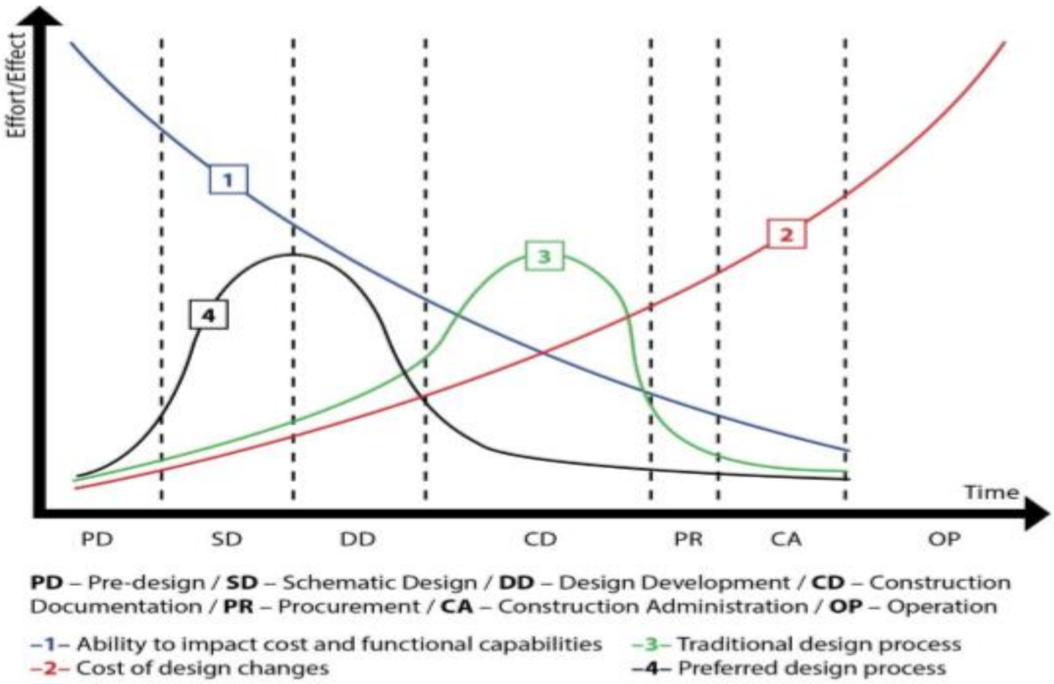

Figure 4.1: Added value, cost of changes and current compensation distribution for design service (adopted: (Construction Users Roundtable (CURT), 2004)

4.4 Methodology

This study adopted a semi-structured interview by allowing the respondent to actively engage them to sharing their views using their own terms (Cohen & Crabtree, 2006). The respondents are the experts in construction industries in New Zealand. Considering the limited nature of expert in refurbishment project execution and with BIM experience, a case study refurbishment project and snowball approach was adapted. The first approach was to identify a refurbishment project case study whereby its previous operation contains a number of stakeholders that were involved in its execution. The second approach was to identify the potential stakeholders with deeper knowledge in refurbishment project execution in tertiary institutions in New Zealand. The refurbishment project case study is a multi-purpose building facility in a tertiary institution in Auckland. This project was selected based on the difficulties and challenges during its execution. Although, the project was fast tracked, there were many loses and uncertainties during the project execution. Request for interview participations was sent out, the initial interviewers suggested potential participants. In total, 14 people were interviewed that accepted our interview request. This sample size is considered appropriate for the sample size as (Galvin, 2015) affirmed that 12 interviews are sufficed to achieve saturation. Therefore, this study employs a descriptive interpretative research to identify the risks factors that impact on refurbishment stakeholders' decisions to adopt BIM for refurbishment projects. According to Creswell (2013), a descriptive interpretative methodology seeks to extract meaning from the experiences of several refurbishment professionals. This process allows a deeper understanding of individuals experience about refurbishment barriers and setbacks to BIM adoption. This is because poorly conceptions can be prevented when the researcher is in active inquiry with the participants (Long & Johnson, 2000). The research participants were interviewed according to their individual preferences for example is by the use of face-to-face interview, and online communication tool platform through Skype. The interviews were held in Auckland, New Zealand. Before conducting the qualitative interview, approval was sought from the (Auckland University of Technology ethics, 2018). This was to protect the safety, privacy, health, welfare and social sensitivities of the various participants involved in the provision of research data. Table 1 details the demographic representation of the research participants

The interviews have been recorded with recording device both for face-to-face interview and the skype interviews. The transcription of the audio interview into text write up was done manually by the researcher. The interview transcripts were categorized based on the simple themes and analyzed using a pattern coding technique.

Table 4.2: overview of the participant demographic information

CODE	Categories of participants	Role type	No of experts	Years of experience
PM1, PM2	Project Managers	Facility management	2	5 – 12
MC	Main Contractor	Technical and design manager	2	8 – 15
SB1, SB2	Sub-contractors	Mechanical services, electrical services, builders	2	10 – 16
M1, M2, M2	BIM Managers	Design	4	4 – 8
C1, C2	Consultants	Mechanical and electrical design engineer	2	10 – 22
AR1, AR2	Architects	Design	2	8 – 15
CR	Client representative	Director of space allocation	1	8 – 12
SU	Space Users	Information technologist	3	6 – 10
Total			18	

The demographics of the participants reveal different levels of experience, and the categories of participants majorly from client organisation (tertiary institution). This could enhance the transferability of the results to readers for their applications, and this can promote the validity and reliability of findings (Merriam & Tisdell, 2015). Adequate care was put in place in order to avoid mistakes during the transcript transcribing stage Creswell and Creswell (2017).

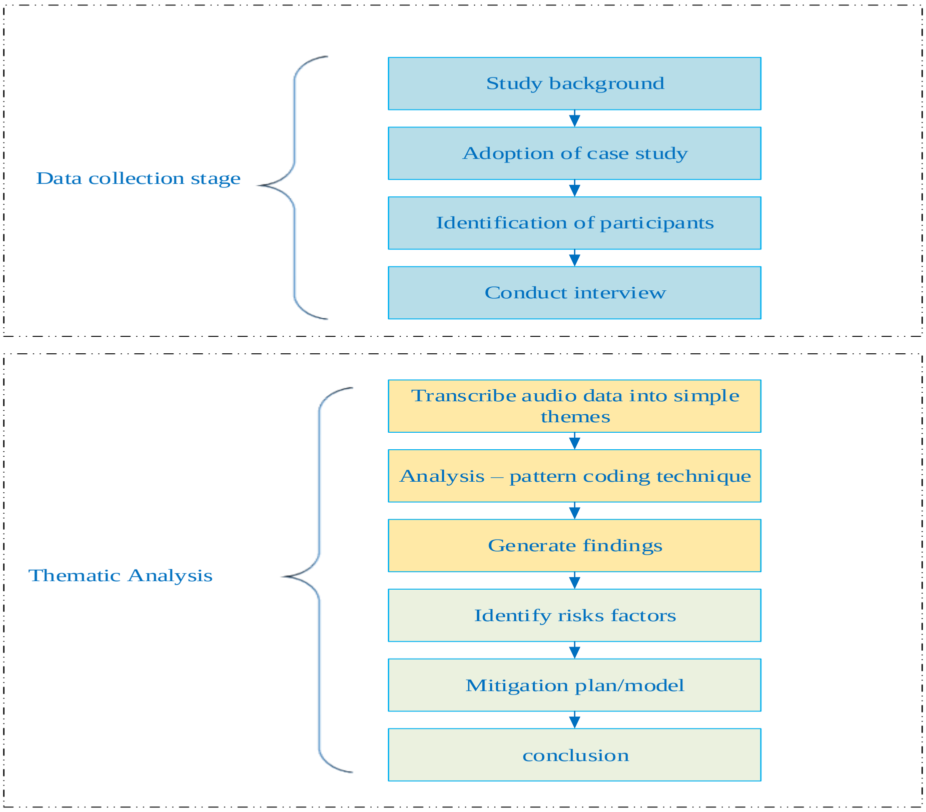

Figure 4.2: Methodological flow chat

4.4.1 Case study

A case study project was chosen in line with the aim to investigate the risks factors that impact project stakeholders towards adoption of BIM. The selected case project (figure 3) is a multipurpose commercial complex building situated in Auckland. This building is used for lecturer offices, student classroom, and lecture classes. Multipurpose building has many characteristics such as large-scale, functional cooperation, multi-functions. It involved multiple participants. The main reason to adopt the case study was to extract the project stakeholders who had participated in the recently completed refurbishment project. Overall, the project was proposed to last for 3 months between November 2016 to January 2017. It however lasted for 5 months. The total cost of the project is approximately $5 M. However, because of the short time stipulated to the project, the budget as well as the project was fragmented into having different level of the storey refurbishment at different project time. This resulted to interdependence and newness of functions and the different stakeholders involved ranging from client organisation, designer/Architect, general contractor, subcontractors, consultants, suppliers, house managers, project manager, client representatives, IT, etc.

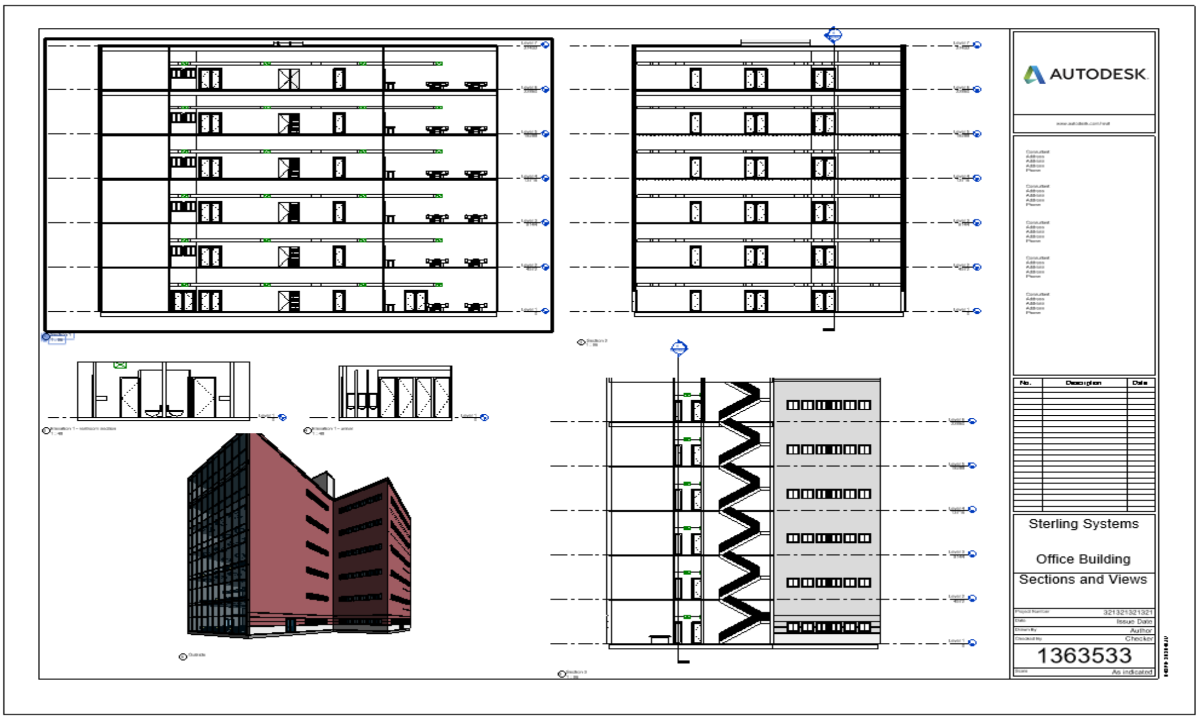

Figure 4.3: Case study multipurpose building refurbishment project. (Revit Autodesk 2019)

The following sections describes the results and analysis.

4.5 Results & Discussions

For a descriptive interpretative research, the analyses are semi-structured, and therefore the qualitative interview starts with open questions that allow the opportunity for the interviewer to explore themes or responses further (Oates, 2005). However, thematic analysis was carried out with suitable coding scheme to identify units of meaning from the main statements and are classified into recurring themes. In this section, three reoccurring themes were analysed: The risks of refurbishment projects towards acceptance of BIM; the risks of refurbishment project towards rejection of BIM; the solution to adopt BIM to solve refurbishment project problems.

4.5.1 The Risks in Refurbishment Project towards Acceptance of BIM

All the interviewees were asked to briefly describe the risks of refurbishment projects which necessitates the BIM adoption. About one-third of the participants stated that the main risks are related to project uncertainties. For example: "The main thing is uncovering the unexpected […] Also, few other participants mentioned that "the important thing is having broad understanding of what the expectations are […] "I think, another risk is especially for these old buildings is you uncover things that you did not expect to find. I think this is a huge risk […] potentially, the opinions of the participants are in line with (Atkinson et al., 2006) who affirmed the need for a sophisticated efforts to manage important sources of uncertainty in refurbishment projects. Further to this, majority of the participants stressed the lack of communication and collaboration problems. For example: "So, I think the communication is the biggest thing, I guess. That is what I am saying. So, that, clarify things because when you think you made things clear, other people might not really get you or understand […] "Sometimes, the information is not clear, we can send wrong products and these products can be returned when they are not the correctly specified materials […] another participants stated that: "The main risk was the unavailability of the information (as-built) records at hand […] while another participant suggested that: "A lot is about the reliability and lack of collaboration environment […] in this view, another participant asserted that: "The better information given for the project, the less the risk will be. So, because everything is existing, so you only know what you know […] The participant indicated that there is need for improvement in collaboration and this can be achieved with BIM. This view was supported by another participant who highlighted that: "This is where BIM is coming in, to produce an as-built to build a central model and how well it is updated became very important for such refurbishment projects […] This is in line with a previous study which affirmed that creating a collaborative environment encourages "shared risks and rewards" philosophy, which also improves performance and harmony among project stakeholders (Eadie et al., 2013).

The short time frame of refurbishment project is a major concern: majority of the participants mentioned that: “The quality of the project might be poor, so pushing the design envelope too hard to fast […] “Due to short time frame, we are not getting enough dialogue with the users […] “Therefore, we do have robust process reviewing the tender [...] “Therefore, there will be pressure to deliver […] “Contractors usually bear the most risk in the traditional method […] “However, the contingency may not cover the entire project or trade specific and may not cover all risks for the entire project stakeholders […] These findings expanded the previous knowledge in literature, (Ali, 2014; Volk et al., 2014b) about some barriers in BIM adoption. BIM adoption is estimated to eliminate unbudgeted change by 40%, project duration by 7% and time to generate project cost by 80% (Azhar, 2011).

The efficient service coordination will ensure health and safety to the building users. A participant mentioned that: “In addition to the risks, health and safety was a significant risk based on how we operate the facility for the safety of the users […] This believe was shared by another participant who agreed that: “The main risk is the coordination of services. If we are to put in a new pipe into an existing ceiling space, but we don’t know what is up there, potentially, it causes delays in having things re-made to actually fit in there […] Few other participants indicated: “Traditionally everyone puts head to each other. A lot is about the reliability and lack of collaborative environment […] As a BIM manager, “One risk is having an incomplete schedule […] This shows similarities with (Park & Kim, 2014) whose studies indicated that BIM improves the coordination of services of different contractors and reduces clashing of different project operations.

4.5.2 The Risks that Hinder BIM Adoption for Refurbishment Project?

To gain deeper understanding and distinction on the nature of risks that impact on refurbishment stakeholders towards BIM adoption, the participants were asked which risks prevent them from adopting BIM for their refurbishment project.

Majority of the participants affirmed that the way project procurement handled is a disadvantage to BIM adoption. A participant mentioned that: “The current system of procurement for refurbishment project might be of risk to adoption of BIM. For example, a lot of contractors go for tendering of projects and has a 20 – 30 % chances to win the project. Although, there are cost related to tendering for a project, yet the projects are not always accepted. Since the construction industry in New Zealand is very robust, many contractors are reluctant to go for tendering due to the cost involved and the chances of getting the project is very slim. Therefore, “an easy eye process” is preferred where by a builder who is able to provide the cost of the materials is selected […] however, this opposes the procurement time for new build with higher project duration (Alhusban et al., 2017).

There is problem of budget overrun which does not match with timeframe of the project. A participant stated that: “Refurbishment project is always prone to budget overrun. Things take longer, cost more, especially in New Zealand at the moment, and the availability of appropriate labour. And, also across New Zealand, the time we do refurbish our facilities is during summer – a very short period of time. I think, it is a kind of culture for schools to refurbish during the summer when student have gone on holiday. This is because we want to reduce noise and disturbance as much as possible [...]

The cultural way of refurbishment in terms of duration is a disadvantage. As a contractor: “We need more time to price, more time to tender etc. these will increase the cost, as it will make the organisation to bring the fund forward based on the consultants’ work […]

The time factor has a tremendous impact on the performance of refurbishment project. Hence majority of the respondent agreed that there is a substantial risk towards BIM adoption relative with project time. This is in line with the findings of (Hong et al., 2016) argument about time factor against BIM adoption. Another participant added that: “Sometimes, there may be fear of change to inhibit BIM adoption. I think, many stakeholders may require examples of projects with BIM and its benefits […] Hence, the risks and its inhibitors can be summarised in the figure below.

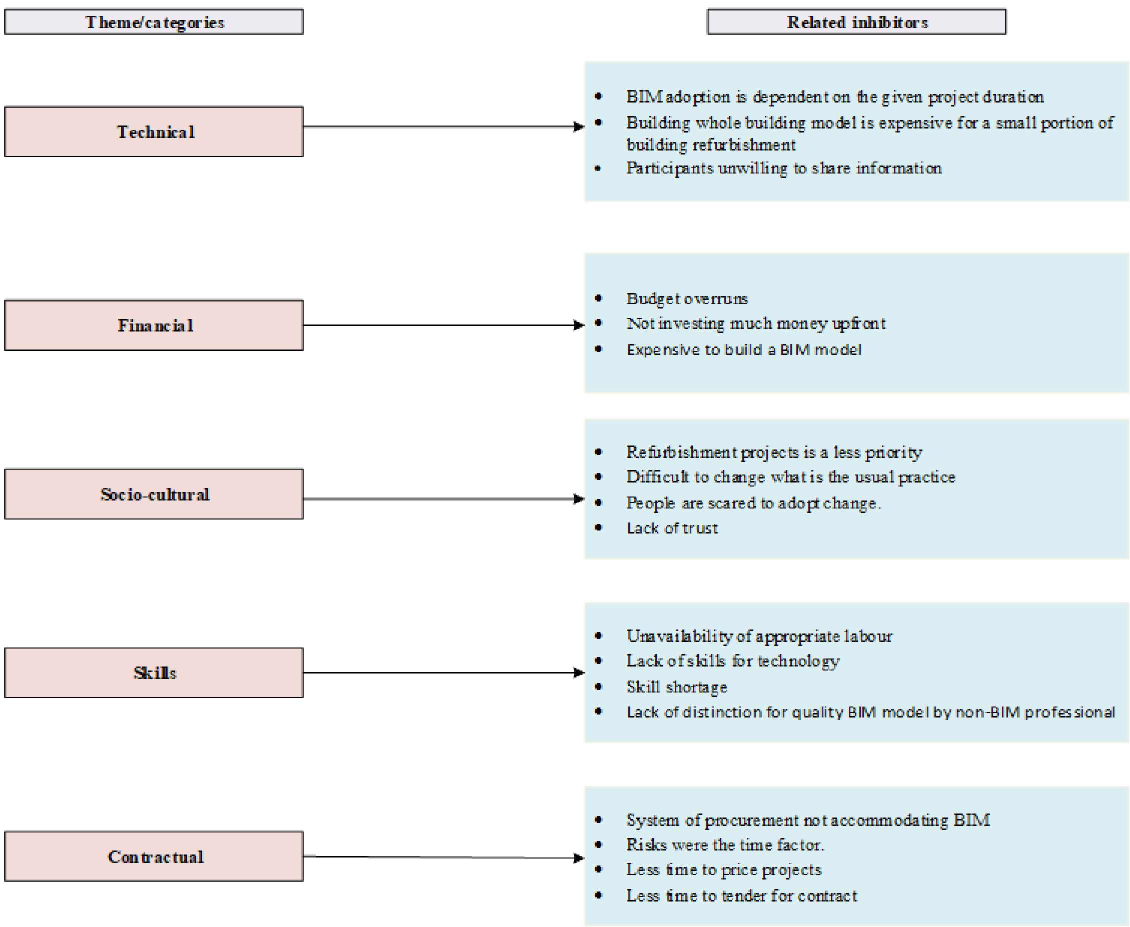

Figure 4.4: The risk factors that impact refurbishment project for BIM adoption

4.5.3 The Solutions to Adopt BIM to Solve Refurbishment Project Problems

After reviewing the risks that impact BIM adoption for refurbishment projects, the participants offered solutions which could be considered for multipurpose existing complex refurbishment.

Starting from the project level requires development of performance assessment criteria. Majority of the participant affirmed that "At the start of every project, there should be something called the BIM execution plan. Where this is not set up at the early stage can be a huge risk […] "Establish a program, list a set of milestones to adopt BIM for the project and set up an assessment to check each stage […]

Another point raised by the research participants was to adopt tools for collaboration. Few participants mentioned that: "During the pre-design phase, a laser scanner can be used to pick points inside the ceiling. This would be more efficient than when the whole ceiling is turned apart for manual measuring […] "The main thing is uncovering the unexpected. Physically, we try to mitigate that by ensuring that the point cloud is done. In this way, the main users can trash so much about those issues about coordination and ensuring that the proposed signs does align with the physical building that exist on the site and the way to mitigate that is modelling the existing building and the point cloud carries the information about the existing building […]

Majority of the participant emphasised about having team culture: "I think, you need good team people, a positive culture. You also need to have good document to reduce the risks […] "The first thing is – I guess is about the leadership of the project. So, the key players need to have good communication [...] "I think about creating a good culture of communication and perhaps addressing these things at the beginning of the project that these are the way we work, meeting times etc. I think it's all about planning, making sure things are going to happen the way it should […]

There is need to improved project time frame: Instead of minor capital work done yearly, we can run it on two-year bases. So, when we are pricing the project, we do that for two years' time bases, hence, we can give room for a lot of consideration. This will help to get the outcome before the project starts […] "We need to understand time frames […] As a BIM manager, "I know that in the past, a whole building model is done for a whole existing building, these are not necessary, it increases the cost of BIM, and makes the model to lack focus at that moment [...] "BIM should be implemented for that particular level of the building, where the refurbishment is to be taken place. This helps the stakeholders to produce a better-quality model, and with less cost. The laser scanner can merge these parts refurbishments point clouds capture to become one full building model […]

BIM should be mandated. Majority of participant: "I also think for educational institution facility, it is really important to use this as a new technology, to share it, you know, a kind of obligation for the students […] "Council people can also incorporate BIM as a regulatory factor during the consent […] "To improve the level of adoption for BIM, there should be a legislature to mandate BIM into law […] This finding is in line with (Alreshidi et al., 2017) whose study recommended factors to govern BIM adoption.

In summary, the participants pointed out the following steps to enhance BIM adoption: develop a programme, adopt tools for information sharing/collaboration, have a positive culture, re-address project timeframe, focus on the required space for refurbishment, and establish policies to motivate BIM adoption.

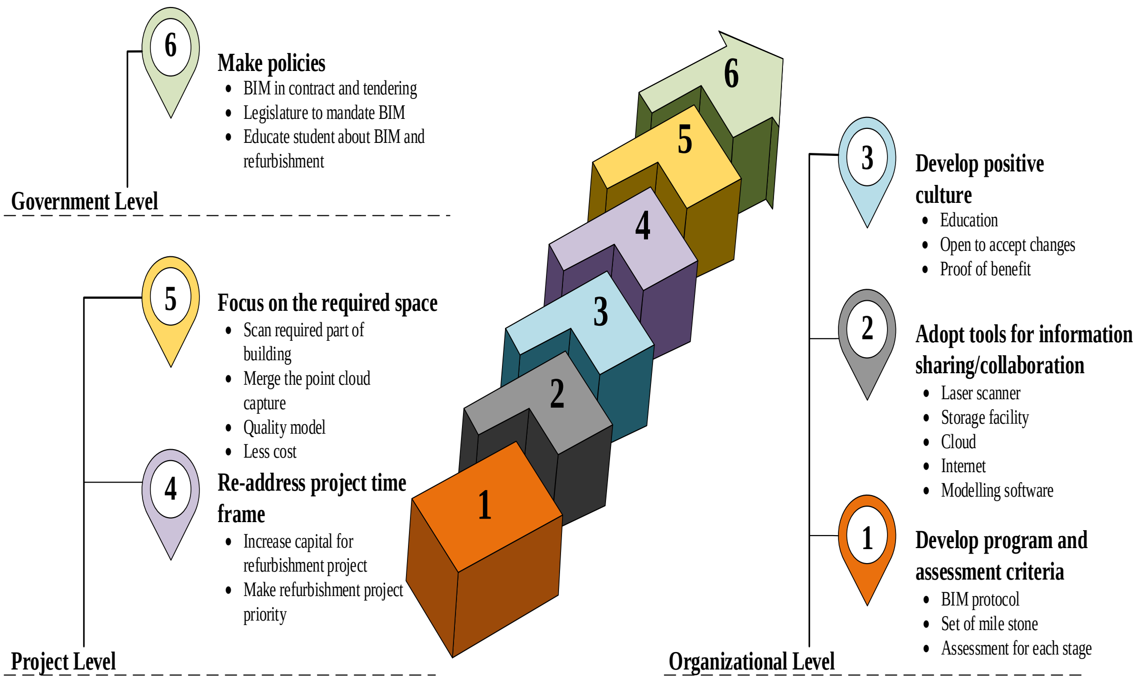

Figure 4.5: Solution steps for BIM adoption for refurbishment project

4.6 Conclusion

It is evident that notwithstanding the benefits derived from adoption of BIM, its use is rare to complex refurbishment projects unlike the new building projects. Refurbishment projects accounts for over 50 percent of cost of the project throughout the life cycle of an existing facility. This shows that a more sustainable platform is required to improve existing buildings that require refurbishment. Many researchers and practitioners are now aware of the benefits of BIM, however, there are still risks that impact stakeholders' decisions to adopt BIM. Based on the foregoing, this study investigated the risks factors that influence stakeholders' decisions to adopt BIM for complex refurbishment project. This is because, the refurbishment stakeholders hold the common ground to make efficient decisions to adopt BIM within a favourable construction environment.

To this end, this article adopts the research question posed by an existing literature Okakpu et al. (2018) and discusses how refurbishment risks factors could influence adoption of BIM. In order to achieve the main objectives of the study, an explorative interpretative methodological framework is adopted to extract information from the experience of the experts and how it could address the current phenomenon under study.

Therefore, after conducting interviews with stakeholders through the adopted refurbishment case study and the BIM experts, the findings reveal key BIM adoption risks that impact on stakeholders' decisions to adopt BIM. These includes; (1) Technical risks, (2) Financial risks, (3) Socio-cultural risks, (4) Skill risks, and (5) Contractual risks.

This was identified as BIM enabler for refurbishment projects. The main enablers are; (1) Project uncertainties, (2) Lack of collaboration and communication, and (3) Coordination of services.

This study also offered a solution towards the cost of BIM adoption for refurbishment projects and hence, fills the limitation of (Alwan, 2016) against whole housing refurbishment.

Besides, expanding on the refurbishment project risks to BIM adoption, the semi-structured interview findings on the participants revealed BIM adoption risks mitigation plan. These includes; (1) Develop a programme and assessment criteria, (2) Adopt tools for information sharing/collaboration, (3) Develop a positive culture, (4) Re-address project timeframe, (5) Focus the laser scanner survey on the required space for refurbishment, and (6) Make new policies for BIM adoption motivation

This study has a significant contribution to BIM and refurbishment research and industrial practices.

Therefore, the authors of this chapter are of the view that greater consultations and input are needed to improve collaboration among project stakeholders since collaboration can reduce the effects of risk. Adoption of BIM offers improved collaboration. The client organisation who are the main owners of tertiary facilities are typically mediocre to BIM process for existing buildings. This need to change in order for the mitigation plan to become effective and inclusive. These could be as a result of their perceptions about refurbishment project attribute. Before this research, no study has investigated how refurbishment project attributes influences stakeholders towards BIM adoption. This will be discussed fully in the next chapter.

Chapter 5 Rethinking the Complex Refurbishment Project Attributes for Building Information Modelling (BIM) Adoption

5.1 Prelude

This chapter distinguishes the risks in BIM uptake for refurbishment project compared to any other type of construction project. It further interprets how the refurbishment project stakeholders perceive technology acceptance such as BIM, and therefore attempts to answer the research question 4 which is the perceptions factors posed in chapter 2. Although, the uptake of Building Information Modelling (BIM) for complex refurbishment projects can be seen as an essential resolution which will possibly increase the BIM adoption rate and eventually play a major role in transforming the construction industry, this anticipation is primarily based on the success of BIM with regards to complex construction operations, management, performance and productivity improvement. Various architecture, engineering and construction (AEC) key players have promoted the adoption of BIM and highlighted its significance in enhancing project delivery. Despite these efforts, many stakeholders including small and medium enterprises (SME) are still reluctant towards BIM. Though the incorporation of BIM in the New Zealand context is also similarly expected to move the construction industry forward, little has been reported in the literature to address the impact of refurbishment project attributes towards BIM adoption. To cover this gap, a semi-structured interview is conducted with informed project stakeholders and BIM experts in New Zealand with the aim to identify refurbishment projects attributes among other BIM barriers in order to distinguish and prioritise adoption of BIM for refurbishment project at the same level as adoption of BIM for a new build. This study contributes to leveraging traditional refurbishment practices towards BIM methodology, and thus provides BIM adoption solution for refurbishment project key players.

5.2 Introduction

Building Information Modelling (BIM) is an emerging technology and its implementation is expected to lead to improved performance in construction processes throughout the life cycle of an existing building facility. Despite the BIM benefits to construction projects (Ghaffarianhoseini et al., 2017), its delivery and uptake has been reported to be slow for existing building projects (Chong et al., 2017). Anecdotal evidence reveal that the decline in uptake is due to project fragmentation (Ilter & Ergen, 2015), isolation, lack of collaboration and information sharing within the construction firms (Ali, 2014; Park & Kim, 2014). Besides, the refurbishment projects are of risky essence (Liang et al., 2015), and very complex in nature (Ali, 2014; Chong et al., 2017). In addition, the U.K government, as part of enhancing adoption of BIM in the public sector earlier in 2016, targeted minimizing life cycle cost by 20% and 80% reduction in carbon by 2050 (BuildingSmart Newsletter, 2011). Similarly in Netherlands, BIM is now a mandatory requirement for governmental projects towards energy refurbishment, while in Denmark, the government requirement for BIM implementation since 2007 has influenced its use for energy efficiency target (Rahman et al., 2013). Considering New Zealand construction environment, a previous survey regarding BIM adoption affirmed that within construction organizations, 38 % used BIM for most projects, 20 % used BIM for few projects, while 42 % of organizations did not respond indicating low level of engagement in projects models among project stakeholders (Huber, 2013). Although the need to investigate BIM relationships with attributes of projects to enhance BIM adoption potentials has been highlighted by (Abdirad, 2016; Bassioni et al., 2004; Menassa, 2011; Project Management Institute, 2003; Succar, 2013), significantly, the project attributes can have different perceptions to different organizations, projects or individuals (Sebastian & van Berlo, 2010). In addition, the project attributes can be perceived differently by different construction environment (Dakhil et al., 2015). Hence, as BIM tool is generic (Abdirad, 2016; Bew & Richards, 2008; Dakhil et al., 2015), the adoption of BIM can be influenced on how the project attributes is perceived for effective BIM adoption (Abdirad, 2016). Hence, the current authors believe that identifying the refurbishment project attributes in a given environment can be useful to understanding how to motivate adoption of BIM. Therefore, this portrays the need to investigate refurbishment projects attributes to maximise BIM adoption (Okakpu et al., 2018). Hence, the study aimed at identifying the refurbishment project attributes managed by client-organisations such as in tertiary institutions to address the potentials of BIM adoption for the multipurpose existing buildings in New Zealand. To achieve these objectives, this study starts with literature review of previous existing studies on BIM adoption for refurbishment projects and the discussion about how the lack of consideration of project attributes has been given little consideration. Thus, a descriptive interpretative research is conducted by using semi-structured interviews. This approach is suitable to allow the investigator to disallow presuppositions regarding the phenomenon in search of the true meanings and to have deeper understanding of the phenomenon as experienced by the experts.

5.3 Background of the study

The potentials of BIM adoption is to improve the refurbishment work flows so as to mitigate cost overrun, critical decision and save time by project stakeholders (Chong et al., 2017). There are authors that have contributed to BIM adoption study for refurbishment project. Volk et al. (2014a) focused on the technical problems related to BIM implementation. This includes updating and handling of uncertainty of data information of BIM in existing buildings. Also, a study proposed a framework to understand tools and drivers that motivate BIM adoption for refurbishment projects (Gholami et al., 2013; Sheth et al., 2010b). In addition, another study also focused on the clients as homeowners preferences and how it influences BIM adoption for refurbishment projects (Park & Kim, 2014). Essentially, homeowners' choice is mainly "cost" against the method of refurbishment as “thermal performance” preferred by contractors. Furthermore, there is an investigation for the essential barriers to hinder BIM adoption for housing refurbishment (Kim & Park, 2013a). The barriers are twofold; the first is from the clients indicating lack of knowledge about refurbishment technologies, while the second is the construction professionals indicating lack of skills, and fragmented practices. Therefore, these construction professionals may underestimate the real BIM benefit for refurbishment projects. Although one benefit of BIM for refurbishment project is that it enables life cycle data management (figure 5.1) which facility managers (FM) can use to maintain an existing facility (Ilter & Ergen, 2015), Volk et al. (2014a) suggested that there are hindrances to adoption of BIM for existing buildings considering the lack of research to investigate the bottleneck barriers for refurbishment stakeholders and facility managers (FM) in adopting BIM for existing building facilities.

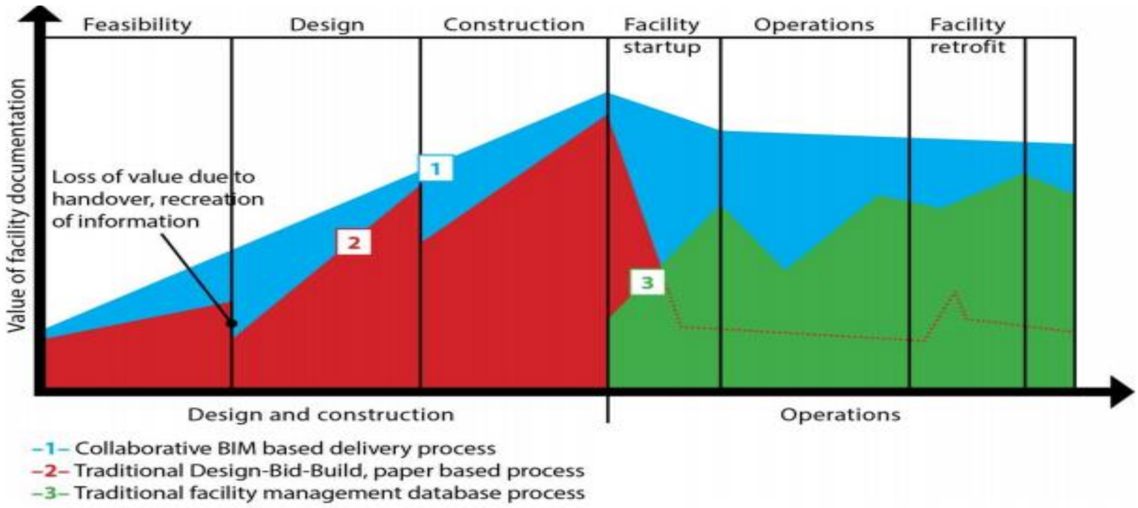

Figure 5.1: Life cycle management of an existing facility. Adopted: (Eastman et al., 2008)

While a previous study is of the view that the bottleneck barriers is due to low participations of FM and refurbishment stakeholders towards the development of strategies to adopt BIM for refurbishment projects (Becerik-Gerber & Rice, 2010b), other authors suggest that the main barriers relies on the ability to identify project attributes on different construction projects in order to align BIM for project performance (Abdirad, 2016; Bassioni et al., 2004; Menassa, 2011; Project Management Institute, 2003; Succar, 2013).

5.3.1 Complexities in Construction Project

(Remington & Pollack, 2008) identified project attributes as complex entities. While managing complex projects show some difficulties, for project managers to succeed requires learning the past pattern of success and failure while they focus on the complexity of projects Bakhshi et al. (2016). Therefore, knowledge including expertise appears to be an essential tool to learn complicated projects which allows for proper practices to overcome its problems (Snowden & Boone, 2007). Besides, complex projects can contain simple subsets of simple projects but should not be reducible to them (Bakhshi et al., 2016). Hence, complex projects are not always based on their scale, but based on the issue of coordination or specialized expertise (Glouberman & Zimmerman, 2002). Consequently, the complexity of refurbishment project can occur from any angles and invariably cannot be measured only by the size of the project.

To further understand complexities as project attributes, a project complexity can be defined in two ways; while the first emphasises differentiation and connectivity, the second shows complexity as a subjective concept based on the difficulties to understand its goals (Baccarini, 1996; Bakhshi et al., 2016). Baccarini (1996) asserted complexities can be decided based on the integrity of communication, coordination and control. (Nudurupati et al., 2007) added that the unpredictability of objectives and methods of achieving project outcomes can increase project complexity. The project management Institute (PMI) affirmed that the two main key characteristics to project complexity is the multiple stakeholders and ambiguity (PMI, 2013). Hence, from the view of PMI reports, a presentation of general characteristics of complex projects is detailed in the Figure 5.2.

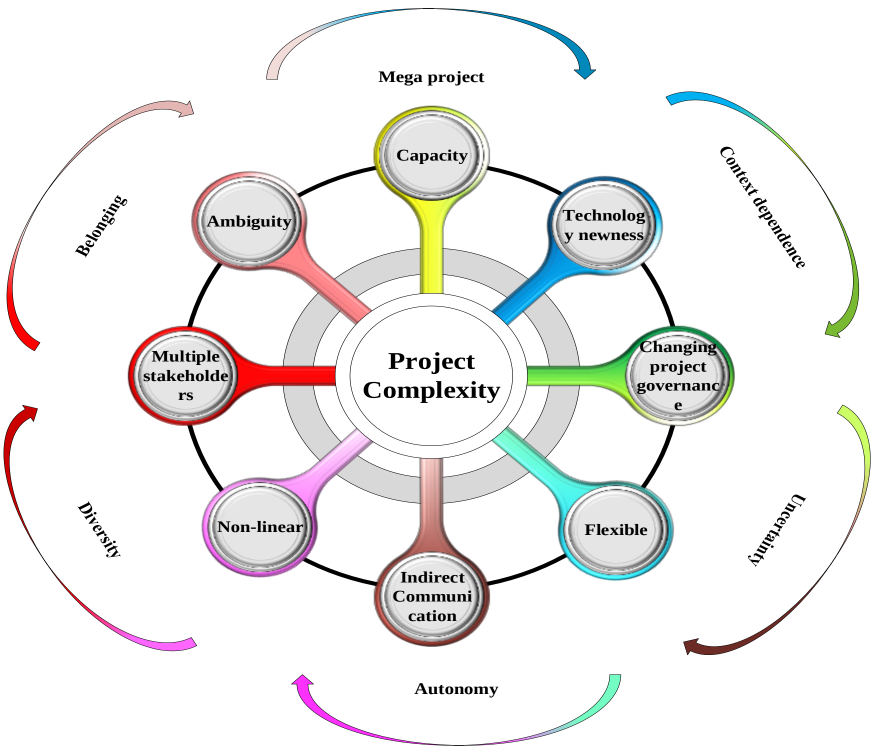

Figure 5.2: The project attributes for construction projects

Figure 5.2 shows a typical project attributes with complexities. The mega project entails the project size having objectives, activities, project durations and how companies share information (Qureshi & Kang, 2015). Context dependence entails the environmental factors which could influence the project such as laws and policies, changing technologies, cultural configuration, organisational risks etc. (Xia & Chan, 2012). The uncertainty explains the emergence of circumstances on the project such as market, information and technical uncertainties including when clients have unrealistic goals (Ahern et al., 2014). The autonomy involves all the type of relationships with the stakeholders, amount of interactions and environmental dependence (Lessard et al., 2014). Belonging portrays the type of trust, capability of stakeholders including quality requirements, training, responsibility and accountability (Qureshi & Kang, 2015; Xia & Chan, 2012). Diversities shows differences existing in the project, for example, diversity of tasks, cultural variety, multiple suppliers, varieties of technologies used, variety of financial resources, staff, organisational skills needed etc. (Lessard et al., 2014; Ramasesh & Browning, 2014). A previous study has shown that projects as those in construction have lower degree of uncertainty but those projects that demand innovation such as IT have higher degree of uncertainty (Shenhar, 2001). However, (Ali, 2014) emphasized that refurbishment projects have a higher uncertainty mainly due to the structural complexity of its projects. It was further established that this uncertainty is seen as one of the contributions to poor project performance(Bakhshi et al., 2016). Adopting BIM as a new collaborative approach and technology can better improve on the complexity of projects (Abdirad & Pishdad-Bozorgi, 2014b). Even though BIM is yet to be effectively implemented for refurbishment activities (Ilter & Ergen, 2015), BIM is said to face challenges of adoption due to a fragmented construction sector and complicated stakeholder requirements within refurbishment firms (Park & Kim, 2014). Therefore, the current authors assert that identifying the main attributes for complex refurbishment projects will help to understand the current perceptions of refurbishment project stakeholders about BIM and to offer solutions based on the identified attributes.

5.4 Methodology

This study adopted a semi-structured interview by allowing the respondent to actively engage them to sharing their views using their own terms (Cohen & Crabtree, 2006). The respondents are the experts in construction industries in New Zealand. Considering the limited nature of expert in refurbishment project execution and with BIM experience, a case study refurbishment project and snowball approach was adapted. The first approach was to identify a refurbishment project case study whereby its previous operation contains a number of stakeholders that were involved in its execution. The second approach was to identify the potential stakeholders with deeper knowledge in refurbishment project execution in tertiary institutions in New Zealand. The refurbishment project case study is a multi-purpose building facility in a tertiary institution in New Zealand. This project was selected based on the difficulties and challenges during its execution. Although, the project was fast tracked, there were many loses and uncertainties during the project execution. Request for interview participations was sent out, the initial interviewers suggested potential participants. In total, 14 people were interviewed that accepted our interview request. This sample size is considered appropriate for the sample size as (Galvin, 2015) affirmed that 12 interviews are sufficed to achieve saturation. Therefore, this study employs a descriptive interpretative research to understand the project attributes of refurbishment project and to formulate mitigation plan to enhance BIM adoption. According to (Creswell, 2013), a descriptive interpretative methodology seeks to extract meaning from the experiences of several refurbishment professionals. This process allows a deeper understanding of individuals experience about refurbishment barriers and setbacks to BIM adoption. This is because poorly conceptions can be prevented when the researcher is in active inquiry with the participants (Long & Johnson, 2000). The research participants were interviewed according to their individual preferences for example is by the use of face-to-face interview, and online communication tool platform through Skype. The interviews were held in Auckland, New Zealand. Before conducting the qualitative interview, approval was sought from the (Auckland University of Technology ethics, 2018). This was to protect the safety, privacy, health, welfare and social sensitivities of the various participants involved in the provision of research data. Table 1 details the demographic representation of the research participants The interviews have been recorded with recording device both for face-to-face interview and the skype interviews. The transcription of the audio interview into text write up was done manually by the researcher. The interview transcripts were categorized based on the simple themes and analyzed using a pattern coding technique.

Table 5.1: overview of the participant demographic information

	Categories of participants	Role type	No of experts	Years of experience
PM1, PM2	Project Managers	Facility management	2	5 – 12
MC	Main Contractor	Technical and design manager	2	8 – 15
SB1, SB2	Sub-contractors	Mechanical services, electrical services, builders	2	10 – 16
M1, M2, M2	BIM Managers	Design	4	4 – 8
C1, C2	Consultants	Mechanical and electrical design engineer	2	10 – 22
AR1, AR2	Architects	Design	2	8 – 15
CR	Client representative	Director of space allocation	1	8 – 12
SU	Space Users	Information technologist	3	6 – 10
Total			18	

The demographics of the participants reveal different levels of experience, and the categories of participants majorly from client organisation (tertiary institution). This could enhance the transferability of the results to readers for their applications, and hence can promote the validity and reliability of findings (Merriam & Tisdell, 2015). Adequate care was put in place in order to avoid mistakes during the transcript transcribing stage (Creswell & Creswell, 2017).

5.5 Results and Discussion

For a descriptive interpretative research, the analyses are semi-structured, and therefore the qualitative interview starts with open questions that allow the opportunity for the interviewer to explore themes or responses further (Oates, 2005). However, thematic analysis was carried out with suitable coding scheme to identify units of meaning from the main statements and are classified into recurring themes. In this section, three reoccurring themes were analysed: The nature of refurbishment projects in tertiary institution in New Zealand; The challenges of refurbishment project to motivate BIM adoption; the solution to adopt BIM to solve refurbishment project problems.

5.5.1 The Characteristics of Refurbishment Projects

All the interviewees were asked to briefly describe the nature of refurbishment projects they have participated for organisations such as in tertiary institution. Almost all the respondents stated that most of the existing buildings are multipurpose building and can be refurbished annually due to several demands by clients or organisation and government. For example: "Many tertiary institutions would want to meet up with the international learning standards. So, there is the tendency that such organisations will embrace modern methods changes and teaching methods, and as well, try to embrace a collaborative modern and open learning method between different groups and learners […]

A similar number of participants noted that during the periodic refurbishments, there are several risks in these projects that need proper management. "there are lot of stakeholders and user involvement to determine a particular layout […] "There is lack of ability to communicate new layout to who will be occupying these spaces […] "There are lots of refurbishment project which are starting with poor building information […] "There are lots of uncertainties to encounter which affects some stakeholders like the contractors who mainly bears the risks during the construction stage […] "It has thoroughly unknown factors […]

Other identified characteristics includes avoiding BIM adoption for such due to fear of the cost for BIM. "A lot of things come back to old buildings. Existing buildings in the past 15 years are not done with BIM. There may be design document that are not suitable for design activities for refurbishment project. Old tradition is not very efficient especially when it involves manual measure. These days, it is prone to error. Now a lot of refurbishment project are starting with poor information […] One of the typical natures of these refurbishment project is the assumptions and most significant in New Zealand is the typical project duration for refurbishment project.

5.5.2 The Challenges of Refurbishment Project that Motivates BIM Adoption

To gain deeper understanding on the nature of the refurbishment projects as found in tertiary institutions, interviewees were asked how the nature of complex refurbishment projects in tertiary institutions can be aligned to BIM processes.

One of the participants believe that improved collaboration is very significant in this venture. According to a participant: "It is about working with good team. When all get on to a common goal, it is easier to manage these unknowns. As long as you have positive approach and people you work with have the same positive attitude in a rewarding environment is what matters. If not, the unknowns will create huge problems for the stakeholders […] While another participant: "I do think that the personality and experience of the people involved brings out a good outcome […] Another participant emphasized that: "if you bring a really rigid attitude to it, and you are a perfectionist, you are going to be really upset about that, but if you are flexible, adaptable and you understand, and you think quickly and carefully what alternatives are, you definitely get a good outcome […] Meanwhile, few participants emphasized there are still skill shortages to manage refurbishment projects and these impacts on accepting new technology for maximum project performance: "Restructuring older houses with older technique to a new technique can be very challenging […] Hence, most of the document produced in a traditional method lacks complete as-built documentation. Another interviewee who supported in view stated that: "Most old buildings have not been done with BIM especially in the past 15 years. Starting with documentation, most of these documentations are not suitable for refurbishment project execution […] in addition, another participant is of the view that: "there are lot of refurbishment project which are starting with poor building information. Which means BIM is a significant requirement for upfront investment in acquisition of building information […] In addition, the technicality of refurbishment operations is not encouraging. This opinion was emphasised that: “The way New Zealand handles information about the existing building is currently immature” the ability to survey is quite very hard, and to discover what is the unknowns for example within the ceilings […] Another participant added that: “In the conventional method, management is always tedious as updated maintenance is not recorded after refurbishment. Sometimes, you have to demolish part of the building to understand what is in the project […] Another participant added that :“One thing we care for is having a complete information for all the stakeholders but when the information is unavailable, there will be delay in execution of projects […] Consequently, the participants believed that when this information is not properly managed, it results to project difficulties. For example, an interviewee stated that: “There are a lot of assumptions, or incomplete records of buildings. There is incomplete information most times, and it takes time to obtain this information […] Nevertheless, the lack of information and management may have effect on the integrity of project outcome from the view of few participants: “When a program is drawn, and there is lack of information, this will cause delays […] “Based on the provided traditional building information, the contractor makes assumption based on the uncertainties and when these does not go as expected, the contractor will start to lose money […] Another participant observed that: Most contractors may not be honest to the cost of the project and therefore they tend to cut down the cost of the project to ensure that the project is awarded to them […] Another participants supported by saying that:

“The cut down cost impact on the finishing trades and interior trades, so they try to recover some of their lost time and the programmes are quite regularly cut […]

About one-third of the participant believed that adoption of BIM for refurbishment project should be relied on the nature and scope of the refurbishment project. For instance: “It depends on the type of building to be refurbished and also by case by case and quality of building […] “It all depend on the nature of scope of the refurbishment project entails […] “It depends on the nature of the building that is being refurbished, I think some are risky than others, and older building might have hidden secrets and problems within them and with poor infrastructure, like rewiring that you submit for needs doing or foundation extra works, compared to a new building where it might be what one could call a “lacking of promise of paid jobs and a better of do-ups […] This indeed opposes the notion that construction projects can contain simple subsets of simple projects but should not be reducible to them (Bakhshi et al., 2016). Therefore, such projects as refurbishment projects are not always based on their scale, but based on the issue of coordination or specialized expertise (Glouberman & Zimmerman, 2002).

Hence, the perception of the scope of refurbishment projects seems to portray a high barrier towards the adoption of BIM. Hence, the findings clearly support the need for refurbishment project improvement by adopting BIM and this needs to be considered among client organisation. Figure 5.3 details the refurbishment project attribute and how it contributes to BIM barriers.

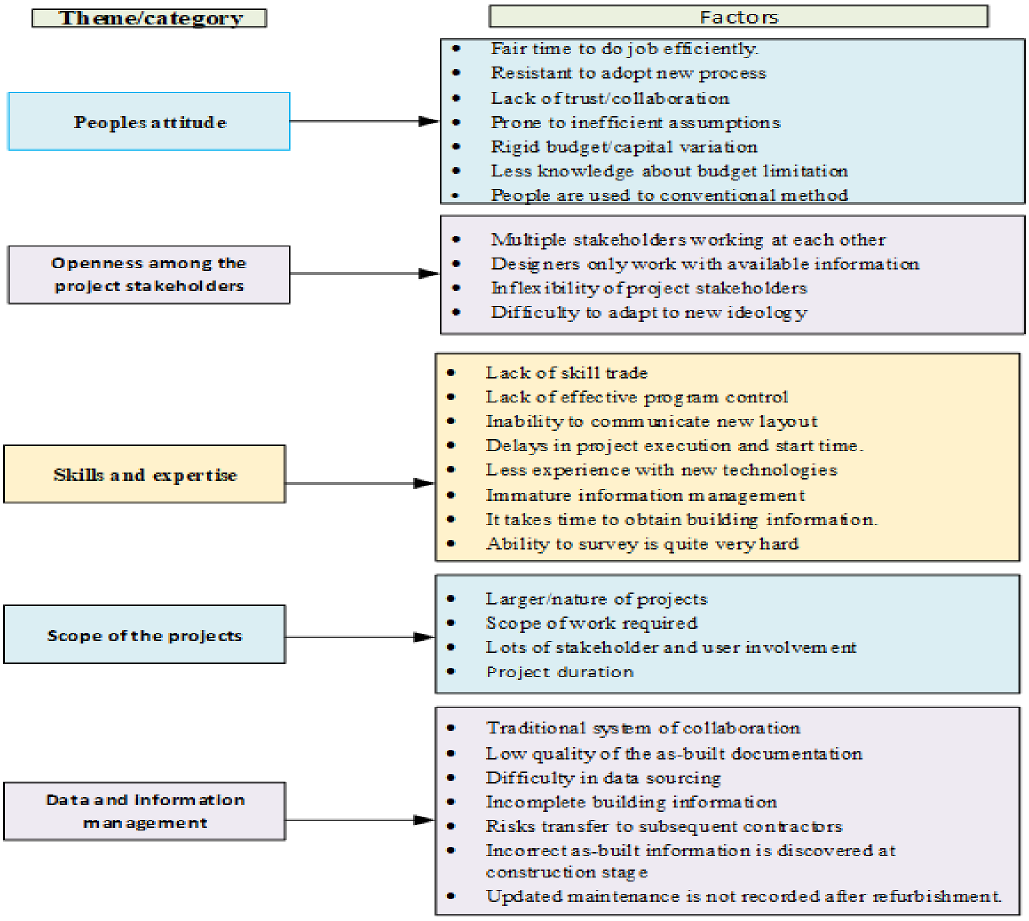

Figure 5.3: Refurbishment project attributes in the case study multipurpose building

5.5.3 The Solutions towards Adoption of BIM for Refurbishment Projects

After investigating the characteristics of typical refurbishment project attributes that may necessitate BIM adoption for performance improvement of refurbishment projects, the participants offered several solutions to align BIM adoption specific to refurbishment project. One-third of the participant were of the view that there is a need to develop program and assessment criteria to check each stage. For instance: “At the start of every project, there should be something called the BIM execution plan. Where this is not set up at the early stage can be a huge risk […] “Establish a program, list a set of mile stone to adopt BIM for the project and set up an assessment to check each stage […] These was in line with a previous author regarding using a development assessment criteria to improve the issues of cloud in BIM Alreshidi et al. (2017). A few other participants were of the view that: “During the pre-design phase, a laser scanner can be used to pick points inside the ceiling. This would be more efficient than when the whole ceiling is turned apart for manual measuring […] "The main thing is uncovering the unexpected. Physically, we try to mitigate that by ensuring that the point cloud is done. In this way, the main users can trash so much about those issues about coordination and ensuring that the proposed signs does align with the physical building that exist on the site and the way to mitigate that is modelling the existing building and the point cloud carries the information about the existing building […] Majority of the participants has concern about positive culture in our industries towards innovation such as BIM: "I think, you need good team people, a positive culture. You also need to have good document to reduce the risks […] "The first thing is – I guess is about the leadership of the project. So, the key players need to have good communication [...] "I think about creating a good culture of communication and perhaps addressing these things at the beginning of the project that these are the way we work, meeting times etc. I think it's all about planning, making sure things are going to happen the way it should […] one-third of the participant are of the view to focus on the building section that require refurbishment other than the whole entire building complex: "In the past, a whole building model is done for a whole existing building, these are not necessary, it increases the cost of BIM, and makes the model to lack focus at that moment [...] "BIM should be implemented for that particular level of the building, where the refurbishment is to be taken place. This helps the stakeholders to produce a better-quality model, and with less cost. The laser scanner can merge these parts refurbishments point clouds capture to become one full building model […] This contrasts (Alwan, 2016) BIM adoption framework, who suggested whole building modelling which can make the BIM implementation very expensive.

The time frame should be made more accommodating to work out a program for the refurbishment project BIM adoption effectiveness. Two of the participants stated that: "Instead of minor capital work done yearly, we can run it on two-year bases. So, when we are pricing the project, we do that for two years' time bases, hence, we can give room for a lot of BIM consideration. This will help to get the outcome before the project starts […] "We need to understand time frames […]

The time frame has also been part of the reason to neglect BIM. A participant stated that: "Therefore, I would not recommend BIM adoption for refurbishment project "case A". It is not necessary since there is a lead time before the actual construction time […]

A few participants consider making BIM an obligation to enhance adoption of BIM for refurbishment projects: "I also think for educational institution facility, it is really important to use this as a new technology, to share it, you know, a kind of obligation for the students […] "Council people can also incorporate BIM as a regulatory factor during the consent […] "To improve the level of adoption for BIM, there should be a legislature to mandate BIM into law […]

Therefore, the interviewees confirmed that alignment of refurbishment project to BIM adoption considering the nature of its attributes remains one of the resolving avenues to motivate adoption of BIM for refurbishment projects in New Zealand. Starting from the complex buildings in tertiary institutions as found in New Zealand, these existing buildings are refurbished annually to suit a particular purpose and demands a high-performance standard. Majority of these houses are traditionally managed. The client organisations who manage these buildings should make effort to consider engaging with their refurbishment stakeholders to consider adoption of BIM for the management of their existing buildings in tertiary institutions. Furthermore, New Zealand government should also consider making a stronger awareness on the use of BIM in managing existing buildings in tertiary institutions by authorising BIM use for every existing building in New Zealand tertiary institutions.

5.6 Conclusion

This paper examined how the characteristics and nature of refurbishment projects contributes to BIM adoption barriers. The results show that despite most of the complex buildings in tertiary institutions are refurbished annually with traditional methods, there are still many challenges faced by her project stakeholders in managing these existing projects. Although, BIM adoption can leverage the potential to improve the performance of these projects, the study however, pointed out several factors which impacts BIM adoption including, people’s attitude, lack of skills and expertise, lack of information management, lack of openness, and nature and scope of refurbishment projects. The study also offered solutions to BIM adoption such as (1) Develop a programme and assessment criteria, (2) Adopt tools for information sharing/collaboration, (3) Develop a positive culture, (4) Re-address project timeframe, (5) Focus the laser scanner survey on the required space for refurbishment, and (6) Make new policies for BIM adoption motivation. The study contributes to the current knowledge on BIM adoption for refurbishment projects by identifying perceptions of refurbishment stakeholders and the nature of refurbishment projects so that appropriate steps will be developed to mitigate BIM adoption risks specific to refurbishment project stakeholders towards BIM adoption. The knowledge of the underlying nature of refurbishment projects and her stakeholders technology maturity concept would contribute to offer solutions to how BIM is perceived by FM in tertiary institutions in New Zealand and other stakeholders that refurbish and maintain multipurpose existing buildings, and for the formulation of effective strategies to adopt BIM irrespective of the demand of real BIM benefits for refurbishment projects by the project stakeholder. Therefore, the next chapter will investigate the real benefits of BIM adoption for refurbishment project stakeholders to address the research question 3 in chapter 2.

Chapter 6 An Optimisation Process to Motivate Effective Adoption of BIM for Refurbishment of Complex Buildings

6.1 Prelude

This chapter empirically examines the potential real benefits between traditional network and BIM network for a real-time refurbishment case study project, through agent-based simulation modelling. In this chapter, the benefits of BIM for refurbishment project will be treated based on collaboration effectiveness. This is to address the importance of the research framework (validations) as shown in chapter 2. A social network analysis theory is adapted to model the project interaction networks and a BIM prototype network. An assessment of the main stakeholders for BIM perception is carried out. We offered three prototype interaction networks for comparison of real BIM benefit.

An agent-based Bayesian network model is used to simulate the propagation of design error within the project networks. The result of the analysis show that BIM project diffuses error efficiently, while stakeholders recovers faster and nearly at the same time than traditional network. The optimised network shows better performance to the traditional network, when there is early involvement of subcontractors. The main contribution of this study is providing a novel approach to compare real benefits for traditional method to BIM method for refurbishment project and to provide avenue for project stakeholders to optimised their interaction through adoption of BIM.

6.2 Introduction

The challenges towards adoption of Building Information modelling for refurbishment of complex building is starting to have considerable debate within the literature (Okakpu et al., 2018). However, one practical problem persistent to adoption of BIM is that most studies investigate within the limits of technical factors with a departure to social factors (Lee et al., 2013). Despite that adoption of innovation is fostered by cooperation among different participants (Barrett et al., 2007), this would make the analysis of project stakeholders more important to ascertain their perceptions about IT innovation. To encourage BIM adoption for refurbishment project, there is a need to examine refurbishment project stakeholders separate roles, responsibilities, relationships and interactions among themselves of which can be hampered by internal or external environmental factors (Liu et al., 2016).

Although, BIM adoption environment requires a more multidisciplinary collaboration effort of different disciplines against information sharing, building design, construction techniques (Sebastian, 2011), the push might still be contingent upon restructuring of business processes and relationships, and some requirements could be outside of the current capacity and capability of either the technology or human resources (Rogers et al., 2015). It is also dependent upon the presence of participant firms that share compatible technologies, business processes, and cultures, led by people who hold attitudes and display behaviours conducive to collaboration (Brewer & Gajendran, 2012). Some of this aspect is inherited termed as organisational culture such that its effects are identified as a business process, technologies implemented or adopted and peoples' work practices (Okakpu et al., 2018). In addition, the construction industry is highly fragmented among the construction stakeholders, resulting to a high level of complexity of workflows due to a high number of companies participating on the same project and this increases the inefficiency of construction projects (Arayici et al., 2012). With these in mind, organisations can differ based on forms, functionalities, and the way they respond to changes. These forms or functionalities can be conventional standalone disciplines such as project implementation and facilities management, design, procurement, integrated professional services (IPS), executive, non-executive functions and services and other management innovations within a project delivery system. Therefore, these variables can be influenced based on their perceptions of IT technology with the impact of internal and external factors.

Hence, optimising organisational process to suit BIM adoption for refurbishment projects requires a thorough investigation on the entire project stakeholders and their interactions within the project. Even though, previous studies have centred on technical aspect of BIM (Arayici et al., 2011b; Park & Kim, 2014; Sheth et al., 2010b), Tulenheimo (2015); (Zheng et al., 2016b) affirmed that technology adoption should involve technical and social activities.

Therefore, this study examines the level of interaction for refurbishment project stakeholders in a traditional method and compare its level of benefit to a BIM prototype of refurbishment project stakeholders interaction under the same environment. The study also carried out optimisation process on the traditional method. To optimise the traditional method, the adopted case study project is subjected to Social Network Analysis (SNA) to model interactions and perceptions based on the role of project stakeholders, and consequently provide a virtual process of the prototype BIM interaction, for comparison of real benefits. Therefore, the main objective of the study is to answer the following research questions (Okakpu et al., 2018);

I. What are the perceptions of refurbishment stakeholders on BIM adoption for refurbishment of multi-purpose building?
II. What are the clear benefits between traditional method of refurbishment and BIM method?
III. In what ways can the interaction of stakeholders be optimised to enhance a platform where BIM can be implemented?

A case study of a multipurpose building complex project in a tertiary institution in Auckland is adopted in this study to obtain the interaction of project networks during the refurbishment of the building project. This paper is structured as follows: the literature review about process optimisation, followed by the background for social network analysis and BIM. A description of case study and discussions on research findings of the empirical investigation follows. This will be followed by the result and discussion and then the conclusion follows.

6.3 Research Background

6.3.1 Optimisation Process

Construction project is seen to portray social interaction and project collaboration (Chinowsky et al., 2008). For the refurbishment project stakeholders, this social interaction can be isolated, and highly fragmented in nature in addition to procurement practices (Ali, 2014). It is also possible that the three common types of relationships in the construction firm (communication, information exchange, and knowledge exchange) are inefficient (Chinowsky et al., 2008; Pryke, 2004). One of the means to improve collaboration is through process optimisation. Although BIM can bring about collaboration, however, lack of collaboration can influence how innovation is accepted in an organisation. Optimisation involves a way of structuring an organisation to accepting technology development among the refurbishment stakeholders. It is also the process of finding the most effective or favourable value or condition within a set of prioritised criteria or constraints by maximizing factors such as strength, reliability, communication, efficiency, including productivity among project stakeholders (Merrill et al., 2007). The refurbishment stakeholders are those actors that have an interest in a particular refurbishment project (Beringer et al., 2013). Accordingly, one characteristic of AEC industry is the unconventional nature of networks of stakeholder interaction which constitute building, refurbishment and construction projects (Linderoth, 2010). This has contributed to the challenges within projects including knowledge transfer in organisations and the diffusion of innovation propensity (Linderoth & Jacobsson, 2008).

Therefore, the benefits of process optimisation can be achieved with stronger interaction of stakeholders in a project. However, with few studies around the adoption of BIM for refurbishment projects implies that there is little innovation diffusion and uncover of other factors such as optimisation to improve interaction of refurbishment stakeholders. A previous author suggested that there is a need to assess the actors of refurbishment, construction and building projects to enable adoption of BIM (Linderoth, 2010). Therefore, this research suggests improvement of social network of entire refurbishment projects using social network analysis. In addition, the study examined interactions within and between teams of project stakeholders for refurbishment project according to their is necessary which involves assessing their roles, positions with Linkert values (Kelley, 2010), and connection with each other to determine the dynamics of healthy collaboration which would un arguably impact BIM adoption.

6.3.2 Social Network Theory and Application

Social network analysis (SNA) is a method of investigating relationships among stakeholders especially when it concerns a particular interest. This process helps to explore the conditions of social structures (Hu & Racherla, 2008). Many field of study such as sociologist, and scientist have been studying and applying the theory of SNA in diverse fields, which includes communication studies, information science, biology etc. to describe, visualise and statistical modelling (van Duijn & Vermunt, 2006), it is also used to study the natural mechanics occurring within (Li et al., 2011). SNA is proved to be an essential tool for assessing collaboration pattern of an organisation (Park et al., 2010).

The visual graphs implemented by this tool to map the networks consists of the nodes having metrics which describes the closeness, betweenness and degree centrality of actors, while the network has metrics as the density, modularity, average path length, and clustering. These metrics are used to translate complex visual analysis into quantitative values and can be used for interpretation of existing values, attitudes, and node features. Table 1 contains the definition as adapted from (Tichy et al., 1979) for some important metrics as used in this research

Table 6.1: Social network quantitative metrics

Type	Metric	Definition
Node	Closeness	This defines the shortest average length between nodes (Leonardi et al., 2013)
	Betweenness	This describes how many number of pairs of individuals are connected to a node (Fang et al., 2015)
	Degree of centrality	This describes the number of other nodes a node is connected to (Fang et al., 2015).
Network	Clustering	This describes how clustered group of individuals are compared (Xue et al., 2018)
	Average path length	Defines as the average step a node required to connect to each other (Alarcón et al., 2013)
	Density	This is the extent of how densely and cohesively the nodes are connected within a network (Hickethier et al., 2013)
	Modularity	The strength of the connections within a group of node compared to other group of node (Xue et al., 2018)

As many refurbishment project studies started gaining momentum to BIM adoption investigation, the lack of interest has been centred on slow innovation diffusion. Although, many research work focused on organisational collaboration in complex engineering tasks, SNA can also be applied in this venture (Xue et al., 2018). SNA is also employed in organisational behaviour studies (Easley & Kleinberg, 2010) and in construction management studies to investigate information flow between participants or project team and better integration of multi-disciplinary team (Alarcón et al., 2013).

6.3.3 Background of BIM and Traditional way of Refurbishment of Complex Building Projects

It is very easy to think that BIM requires no definition however, it is surprising that BIM is very ambiguous based on different meanings as portrayed by different professionals. For example, based on empirical result of this study, for some people BIM is a software application, while some perceived it as a process for designing and documenting building information while as for other people, it is a new approach to practise to progressively implement new policies, contracts and relationships among project stakeholders. This can help stakeholders make effective decisions and carryout project with reduced costs, rework, schedules and better rework.

Traditional method is mainly concerned with 2D representation of information throughout all the entire project phase (Al Hattab & Hamzeh, 2013). The rate of collaboration in refurbishment project in a traditional settings is relatively little and is fraught with increase rework, cost and schedule overruns and errors are bound to be present at each project interphase (Al Hattab & Hamzeh, 2015). For some authors, the traditional way is perceived to be most suitable for project with small size by the SMEs and hence do not make extra effort to invest in new technology and to reform their organisations in order to meet up with requirements of industry (Lam et al., 2017). Although, small projects have been proved to be much easier to adopt BIM compare to larger projects (Bryde et al., 2013), it offers much benefits through collaboration, error minimization and even early decision making. However, the benefits of BIM to traditional methods has been a concern for project stakeholders. Although BIM increases project collaboration, it should not be considered as just a software towards adoption but rather an effort of project stakeholders and their interactions. Hence, this will ensure a dynamic diffusion of BIM innovation for refurbishment project stakeholders.

6.4 Background Instruction

In order to achieve the list of milestones, this study proposes an optimised client organisational process to enable investigation of real BIM benefits for refurbishment project stakeholders who are planning to adopt BIM. To understand the effectiveness of BIM adoption in this venture, we adopted a case study refurbishment project (Fig 6.2 & Fig 6.3). The refurbishment case study project is a multi-purpose building facility in a tertiary institution in Auckland. This project was selected based on the difficulties and challenges during its execution. Although, the project was fast tracked, there were many loses and uncertainties during the project execution. We adopted a snowball technique to identify the refurbishment stakeholders involved in the project case study. We administered a quantitative interview to assess the collaboration and consequently the BIM perception. A social network analysis software is used to model the interaction of the case study project stakeholder's 'A'. A virtual network of interaction of the stakeholders is modelled with BIM and named 'B'. The two networks are compared based on the real benefits. This is followed by optimising the traditional method to yield 'C'. The three models are also compared for real benefits using agent-based modelling simulation for error propagation. Thereafter, conclusion was drawn including the limitation of the study. The methodological flowchart for the study is shown in Fig 6.1. Figure 6.1 demonstrates the steps, methods and outcomes for each level of the research. It can be noted that "A" denotes the traditional method, "B" denotes the BIM method, while "C" denotes the networks that have improved collaboration or edges known as optimised network in this study.

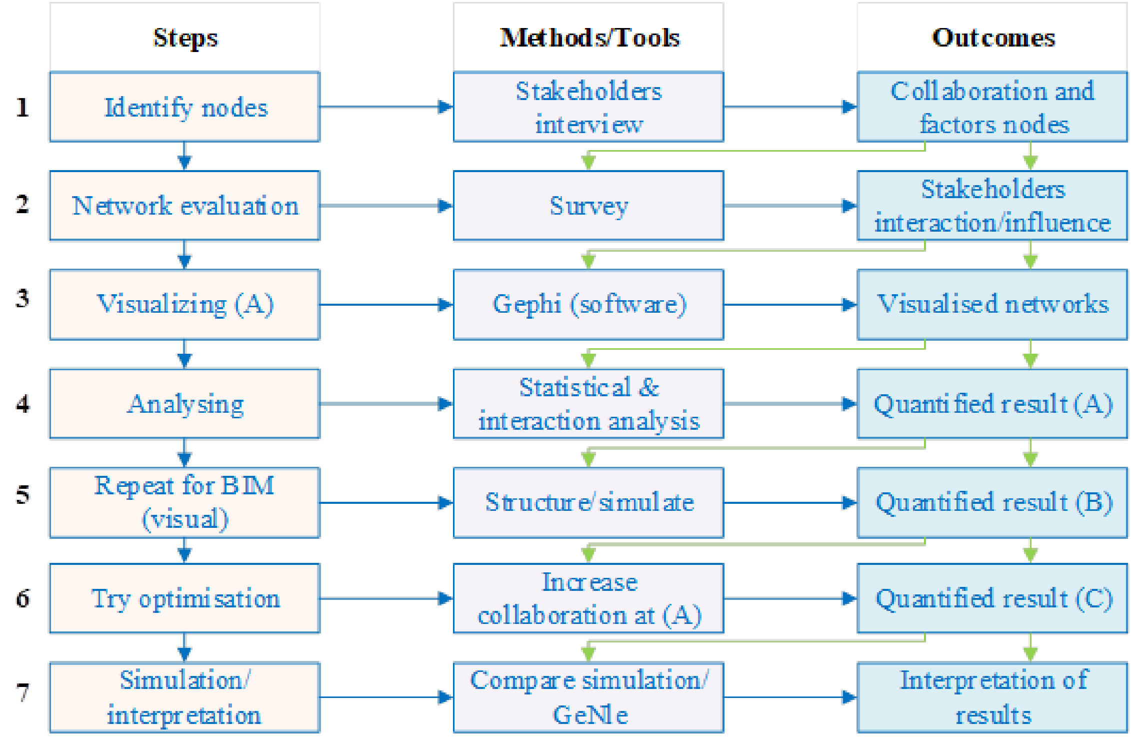

Figure 6.1: Methodology flow chart

6.4.1 Experimental Design

The aim of the experiment is to assess the interaction of project stakeholders using social network theory and to compare with the virtual BIM interaction of the project stakeholders. The idea is to test the environmental factors that impact on stakeholder's decisions and as well as the interaction (information flow) of project stakeholders in the given project. The project stakeholders were identified through a snowball technique. The table 2 shows the demography of the project stakeholders.

Table 6.2: The demography of the project stakeholders involved in the case study project

Main stakeholders	Organisations	Number in the group
Project manager	1	1
main contractor	1	1
Architect	1	3
Sub-contractor1 F.S	7	Minimum of 4
Prin consult Mech	1	3
space manager (client)	1	6
space coordinator	1	1
Value manager	1	1
Prin consult Elect	1	3
Cost estimator	1	1
Space planner	1	1

Supplier	1	4
IT man	1	4
Client representative	1	1

Although, SNA views the relationships between project stakeholders as a multi-layered independent network structure, in this study, it will be used to visualise the collaboration in the case study project coalition with Gephi software and also to provide a quantitative metrics. And as well to assess how environmental factors impacted on their role in the project. The result would be used to assess the nudge to adopt innovation.

6.4.2 Case Study

A case study design was chosen in line with the aim to investigate optimisation process through a network of relationships in a refurbishment project. In this context, a collaboration-based questionnaire is needed. The main environmental factors that impact refurbishment project stakeholders are adopted to assess the project stakeholder’s role. The study is focused on a completed refurbishment project of tertiary institution in Auckland. The project is initially executed without BIM. Because of the complexity of the refurbishment process, we examined the effect of introduction of BIM (virtual process) and compared with the conventional process for real time benefit. We will then propose an optimised process to increase benefits from the current process.

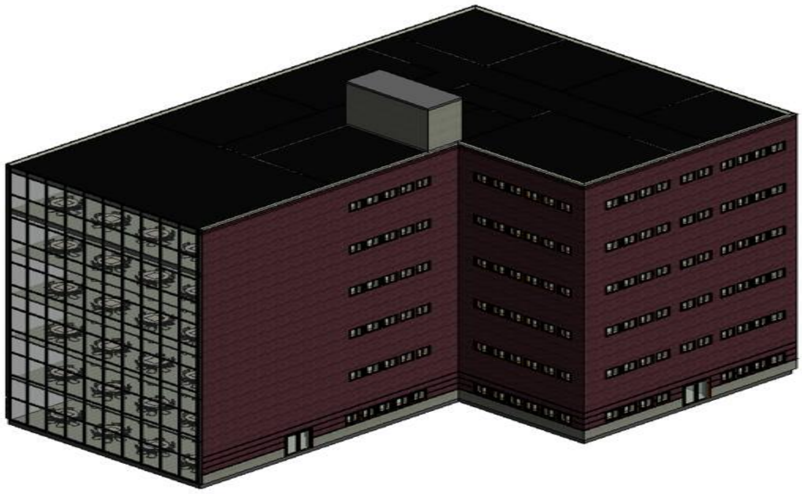

Figure 6.2: 3D view of the existing building (case study adopted: Auckland tertiary institution Auckland)

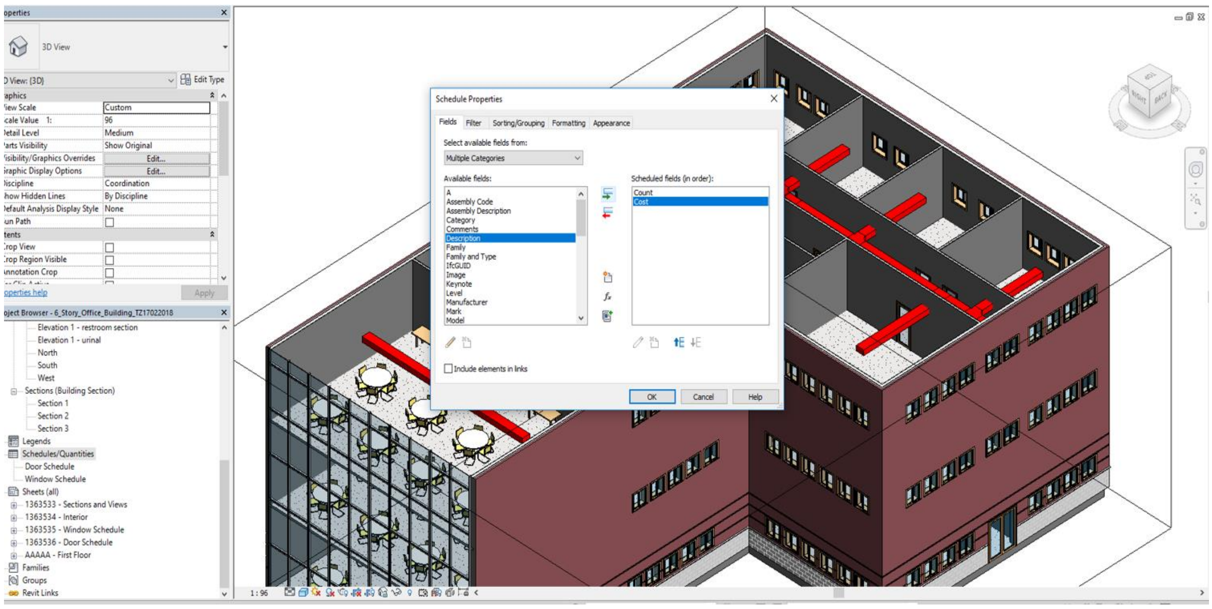

Figure 6.3: Case study (adapted: 3D view, multipurpose existing building model for Auckland tertiary institution)

6.4.3 Project Background

The selected case project (figure 6.2&6.3) is a multipurpose commercial complex building situated in Auckland. This building is used for lecturer offices, student classroom, and lecture classes. Multipurpose building has many characteristics such as large-scale, functional cooperation, multi-functions. It involved multiple participants. Therefore, the case study project has a wide range of stakeholders whom we abstracted as the network nodes in this study. We considered a collaborative relationship to analyse the density and centrality of the refurbishment process. This is because effective collaboration can be hampered between individuals with different roles or priorities in the project. Overall, the project was proposed to last for 3 months between November 2016 to January 2017. It however lasted for 5 months. The total cost of the project is approximately $5 M. However, because of the short time stipulated to the project, the budget as well as the project was fragmented into having different level of the storey refurbishment at different project time. This resulted to interdependence and newness of functions and the different stakeholders involved ranging from client organisation, designer/Architect, general contractor, subcontractors, consultants, suppliers, house managers, project manager, client representatives, IT, etc.

The project manager coordinates the contract awards to the externals. The main contractors coordinate the subcontractors, material supplies and equipment. Figure 3 shows the organisational chart.

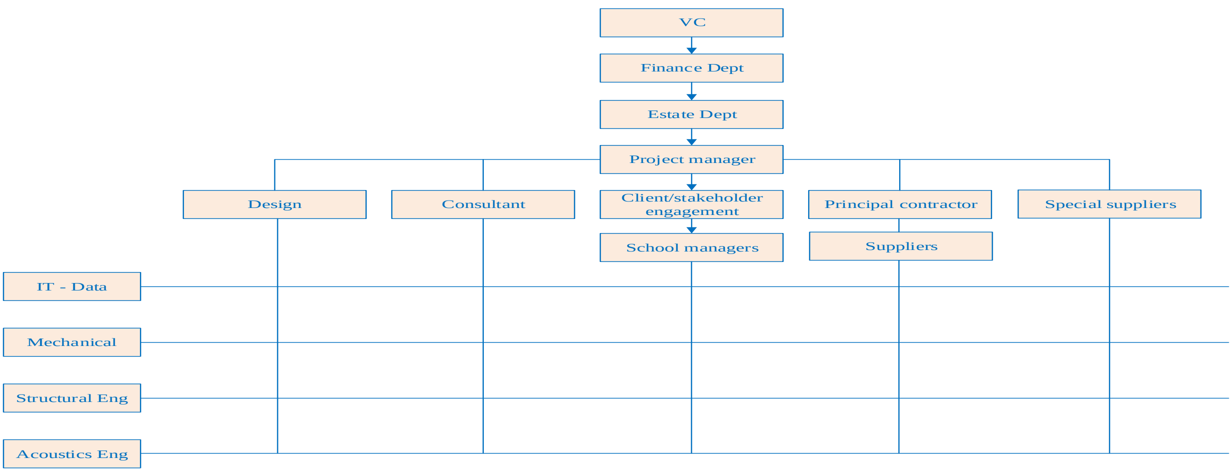

Figure 6.4: The formal Organisational structure of the Case Project

6.5 Data collection

The project stakeholders or actors are considered important in refurbishment project when dealing with relationship network. These actors are the nodes in the present network model (Fig 6.5). The actors have been coded due to ethics and privacy. In the analysis of the social network, the ties indicate the communication between the individuals within the process of the project execution. The data where administered using a paper-based questionnaire distributed to individuals involved in the completed refurbishment project. The innovative network of this project is analysed by the collaborative event that occurred between the project stakeholders. The most important role in the project is identified through the interaction process. Although, the project organisation can be seen as a combination of social groups with a defined pattern of interaction over time, this constitutes difficulties for SNA data collection (Zheng et al., 2016a). The nature of the interview was a collaboration questionnaire designed to extract the intensity of interaction among the project stakeholders. For example, the project stakeholders can be asked to list the number of stakeholders they interacted during the project and how often they interacted. The rate of interaction can be measured with "frequent" "less frequent" and "none"

Therefore, a structured questionnaire is more suitable to determine the relationship between variables and also the statistical processing of data. Hence, the map network assumed to be a quantitative data. While the main stakeholders were assessed for BIM perception for the refurbishment project using environmental impact factors, a collaboration questionnaire identifies the level of interaction and the most important actors involved in the project interaction for the entire project duration.

6.6 Results and Discussion

6.6.1 The Completed Relationship Network

We adopted the main environmental factors suggested identified in chapter 3 from an empirical and validated study which forms part of this study for assessment on the project stakeholders. We only assessed the main stakeholders to determine their BIM perceptions. Overall, the entire network interaction was analysed to show the connections and level of communication among the project stakeholders. From the network, the case study project is highly fragmented, as each different team in the project collaborate closely at the expense of other team. This is as a result of poor information exchange and transparency, leading to poor project value and lack of awareness. Figure 6.5 (a&b) shows the traditional network structure and its virtual BIM network structure.

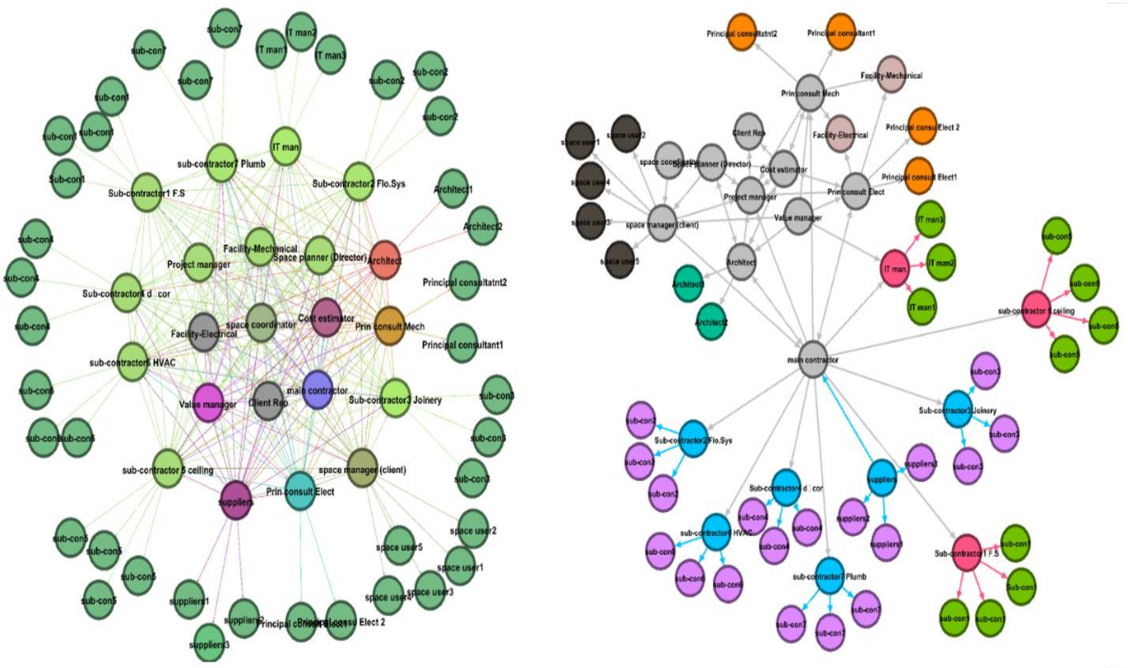

Fig: 6.5a Fig: 6.5b

Figure 6.5: Traditional network (b) and the BIM virtual network (a)

In this case study, it can be seen from the traditional network that there are 12 groups all having heads and links to represent existing interaction pattern and information exchange. Therefore, the groups work separately and closely. In the traditional network, the information revolves around the main clients and hardly go towards the sub-contractors. The main contractor bears the central role in the project. This can be seen where the main contractor has the highest connection. While on the BIM virtual network, all the participants are connected, and this allows the integration of any change at the early stage.

6.6.2 Case study: Assessment of Main Project Stakeholders BIM Perception using a Five Linkert Scale

We conducted a BIM adoption assessment on the main actors to understand how their BIM perceptions impact their decision to adopt BIM using the main environmental factors that influence BIM adoption for refurbishment project in New Zealand construction industry (Okakpu, 2019). The assessment of project stakeholders is necessary in order to determine where there is less BIM perceptions and collaborative environment (Abdirad & Pishdad-Bozorgi, 2014a). The assessment model uses a five Linkert-scale. For example, the stakeholders were asked to indicate from 1 to 5 how such factors impact their decisions to adopt BIM for the refurbishment case study project. The result of the assessment shows that standards and culture of organisation generally impacts refurbishment stakeholder's decision to adopt BIM (Figure 6). It further shows that with the current traditional networks, the sub-contractors are not involved in the decision making and therefore contributed no effort to adoption of BIM. Figure 6.6 is the adapted validated assessment model from previous empirical study which also forms part of the current study.

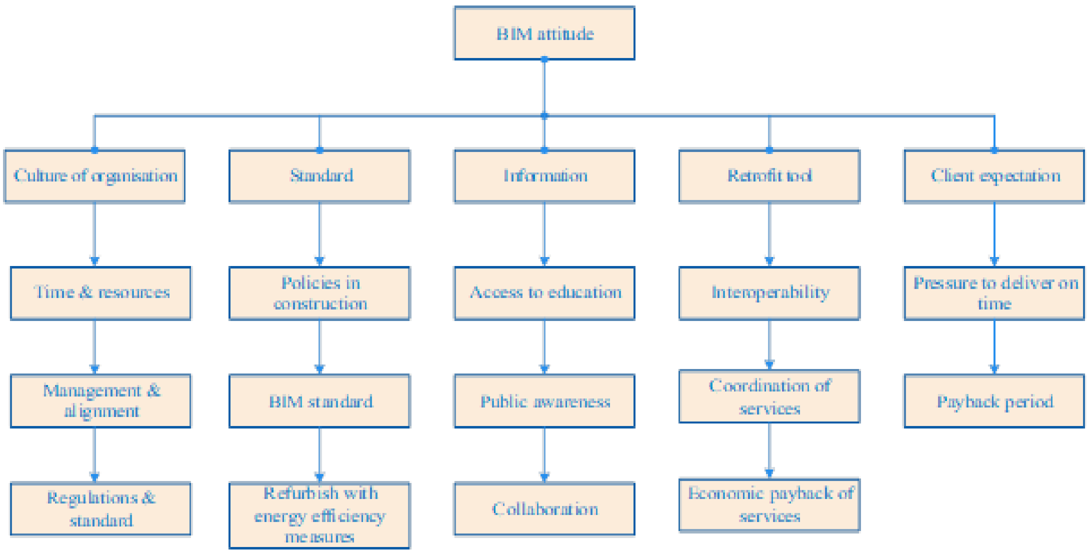

Figure 6.6:The environmental factors that impact BIM adoption decision for refurbishment project adopted from Chapter 3

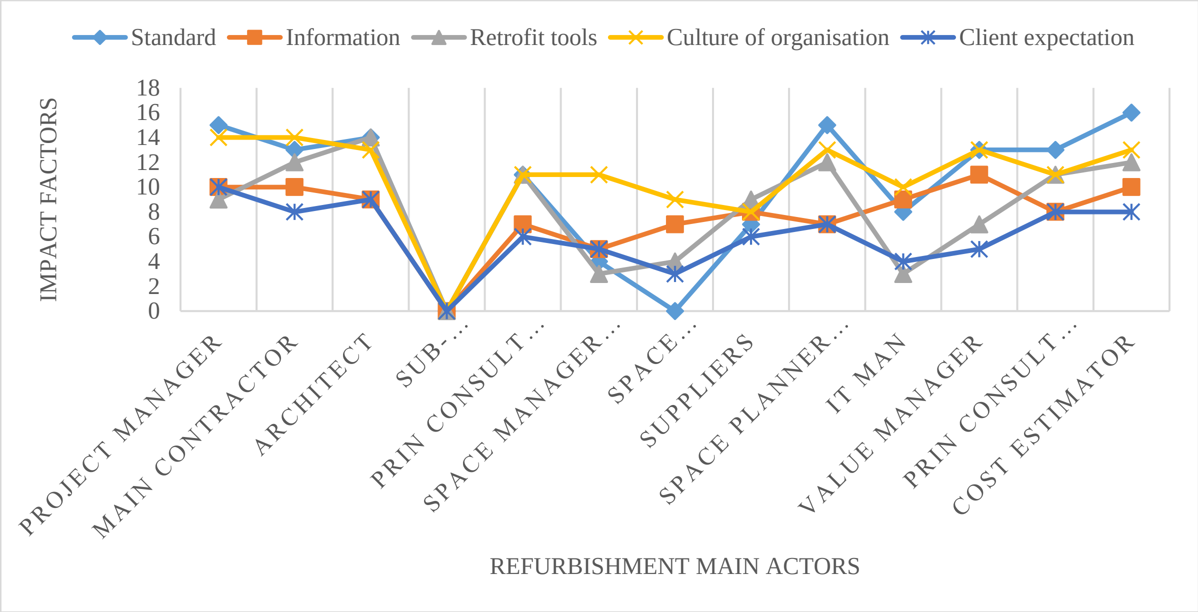

Figure 6.7: The result of the BIM adoption assessment on a case study in Auckland.

Figure 6.7 shows the perceptions of the refurbishment project stakeholders regarding the environmental factors and its impact towards the decision to adopt BIM. We can deduct from the figure above that culture of organisation highly impacted the stakeholders. For example, culture of organisation mostly impacted on the main contractor’s role in the project. While project manager including the cost estimator perceives standard as the main impact factors for their BIM decisions, space users are mainly impacted by culture of organisation and the information sharing. Therefore, the environmental assessment indicates how much need to address these environmental factors for a successful BIM adoption for those refurbishment project owned by client organisation. Hence, based on figure 6.7, we identified the main stakeholder with lowest BIM perceptions in the case study project namely; sub-contractors, space coordinator, and IT technician and thus, their positions can be optimised for real time benefits.

6.6.3 The Social Network Structures

The results of the network structures were calculated with Gephi software and hence summarised in table 3. Hence, the table 3 shows the metrics for the traditional network (A) versus the BIM virtual network (B).

Table 6.3: The comparison of traditional network (A) vs the BIM network (B)

Type	Metric	Network A	Network B
Structure	Number of nodes	62	62
	Graph type	undirected	undirected
	Number of edges	73	263
Node	Degree centrality	2.345	8.484
	Closeness	3.287	2.267
	Betweenness	38	35
Network	Density	0.039	0.139
	Number of groups	13	13
	Modularity	0.642	0.125
	Avg. clustering coefficient	0.159	0.827
	Average path length	3.408	2.267
	Diameter	5	4

For the structure metrics, the graph type is undirected for each of the networks as the information can happen both ways. Considering the traditional structure, there are less interaction between the nodes (actors). There seems to be a restriction of communication between the clients and the sub-contractors. These shows lack of involvement of some of the project actors at the conceptual stage of the refurbishment project. However, the number of edges is higher in BIM virtual interaction compared to the traditional (existing) network as there is more collaboration and teamwork exist between the project stakeholders as opposed by the traditional network. Therefore, on average, the degree of centrality and betweenness for the two networks (traditional and BIM) is A" and B" respectively. This indicates that refurbishment project with BIM has more connections with higher collaboration and the actors can easily reach out within their network. The closeness values are "A" and "B" for traditional and BIM network respectively. It can be noted that the higher the value of closeness, the higher the edges are required to connect with the nodes. The path length and modularity values for traditional and BIM were “A” and “B” respectively. From the result, it can be seen that traditional network has higher values compare to BIM network. This can be explained that the higher the path length and modularity the more edges are required to connect to each other, and this is significant in the traditional network as shown in figure 4. The BIM network structure has a higher value on density, average clustering coefficient, compared to the traditional structure. This can be explained by higher number of connections between the main project stakeholders from each group in the BIM network structure. The diameter of the two structures is found to be same.

6.6.4 Optimisation Process

The values obtained from the traditional network (A), and BIM virtual network (B), is considered to propose an optimised network termed (C). Although, the concept of partnering a variety of practices is assumed to facilitate greater collaboration among the project stakeholders (Barlow et al., 1997). Hence, we considered the traditional network as the minimum values (A) while BIM network (B) has the maximum value. We recalled that in construction industry, stakeholders’ interaction may be short term and project oriented or long-term and project oriented (Barlow & Jashapara, 1998). This means that short term interaction is likely to depend on project governance issues to secure immediate project benefits rather than developing advanced collaboration, while a long-term interaction involves optimising the stakeholders’ interaction through a closer collaboration in order to maximise benefits on a long-term (Beach et al., 2005). Addition, we examined the result between network A and Network B. We found that there is a significant difference at the edges where network A has 73 edges and network B has 263 edges. We determine a new network by increasing the collaboration (number of edges) by using optimisation (MaxValue) to extrapolate an acceptable value which offers increased collaboration. Although, the density of the network describes the interactions and connectivity of the actors (nodes) (Pryke, 2004), it has been regarded as the best indicator for network's connectivity as shown in equation (1) where L is the number of existent lines/edges/connection, n represents the number of nodes.

$$Density = l/(n * (n - 1))/2 \quad (1)$$

$$Maximum\ number\ of\ edges\ (PC) = n * (n - 1)/2 \quad (2)$$

Therefore, from the equation (1) and (2) we deduced that density of the network is related to the potential number of connections and the actual connections (equation 3)

$$Network\ density = \frac{actual\ connections}{potential\ connections} \quad (3)$$

Table 6.4: Actual number of connections for the optimised networks from Gephi

Network	Density	Potential connection	Actual connections
Network 1	0.06	1891	114
Network 2	0.043	1891	82
Network 3	0.044	1891	84

From the experiment based on the traditional network using Gephi, it can be deduced that there are increase in the values of average path length. In network 1 we increased collaboration between the project manager and the subcontractors. While in network 2 there is an increase in interaction around the **clients,** while in network 3 considered both increase interaction at the **sub-contractors** and the **user groups**. Therefore, the networks show higher performance compared to the traditional network but lower to the BIM method. Table 6.4 shows the values of the metrics for the generated networks. Figure 6.8 shows the comparison of the five different networks.

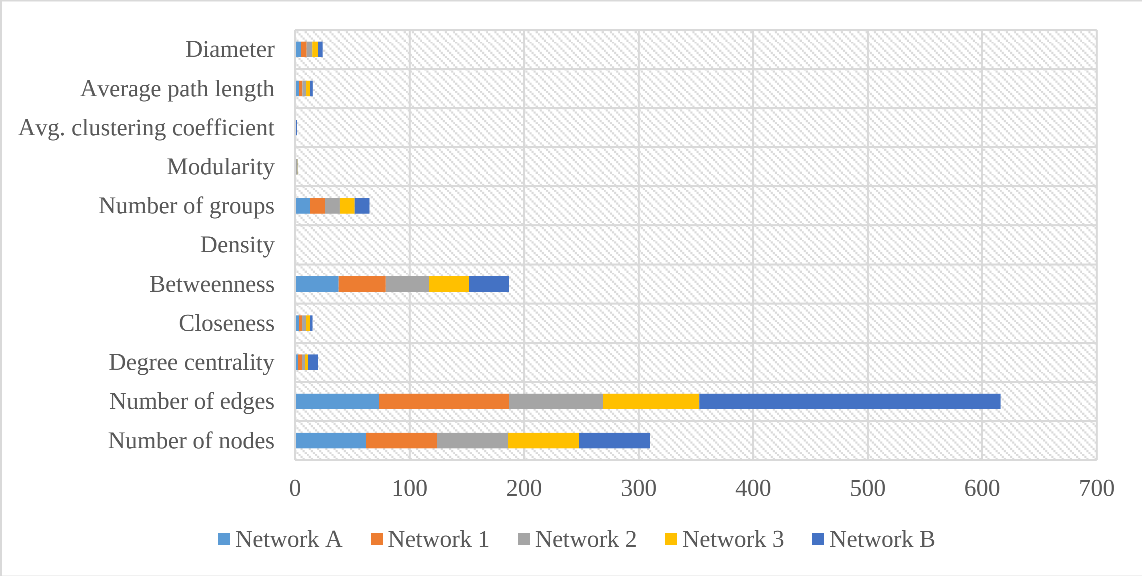

Figure 6.8: The five different refurbishment project network comparisons

From figure 6.8, it can be seen that even though the networks have the same number of nodes, the number of edges marks a distinction between the networks. The average part lengths for the traditional network is higher compared to BIM network. The networks generated as network C (table 5) shows relatively lower average part lengths. This shows that the smaller the average part length the closer the stakeholders to collaborate with each other in the project. Network 3 has the lowest average part length, and this network involves collaboration with the sub-contractors at the early design phase of the refurbishment project.

Table 6.5: Values of the metrics generated from SNA for network C

Type	Metric	Network 1	Network 2	Network 3
Structure	Number of nodes	62	62	62
	Graph type	undirected	undirected	undirected
	Number of edges	114	82	84
Node	Degree centrality	3.677	2.645	2.71
	Closeness	3.006	3.337	3.263
	Betweenness	41	38	35
Network	Density	0.06	0.043	0.044
	Number of groups	13	13	13
	Modularity	0.354	0.565	0.527
	Avg. clustering coefficient	0.365	0.135	0.189
	Average path length	3.006	3.337	3.263
	Diameter	5	5	5

6.6.5 Experiment 2: Design error Diffusion Simulation in the Case study Project Network

The main aim of this experiment is to overcome the limitations of Gephi which lacks the ability to determine which of the networks enhances error diffusion and ability to recover on timely. However, Bayesian network model using GeNIe software supports the dynamic simulation of the network. It also shows how individual stakeholders respond to uncertainties based on the project network. In this experiment, an agent-based model was prepared to examine how error could diffuse through the various network's structures modelled (traditional to BIM network). In this experiment, we adopted the Bayesian network model for diagnoses and management of liver disorder using an approach on Hepar II. The world 'agents' is the stakeholders with ties or linkage. These agents can be asked to have an opinion or act according to a behavioural circumstance. For example, the introduction of error into a model will allow the agents to respond based on the nature of ties they have with each other.

The application of Bayesian network using Hepar II model

The Bayesian network are acyclic directed graphs modelling probabilistic dependencies and independencies among variables. In this study, the dependencies and independencies occur between nodes or also called the project stakeholders or agents as per in Bayesian network. The graphical part of Bayesian network shows the structure of interaction among the project stakeholders and these are quantified by conditional probability distributions (Seixas et al., 2014). In order to adapt Hepar II, we considered the effects of the level of complexities of the networks from Gephi but less consideration to the level of initial error break-out. Hence, the disorders are considered as the error introduced into the network and are allowed to simulate through the network as designed error. The time to identify the error, error percentage, recovery chance is measured by each node in the network. The nodes are set as observers with a defined probability of occurrence of 0.3 %, 0.3 % and 0.4 % respectively. The error and where it will occur is set as the target while other nodes observed the effects. Five different networks were modelled as per previously in Gephi. The first network (A) is the traditional network. The last network is the BIM network while the three other networks are the optimised generated network as derived from Gephi. Figure 6.9 and 6.8 shows a sample model and the target menu box for the simulation. Note that the question mark in figure 6.9 indicates that simulation of error has not been initiated. Carrying out different iteration for the initial error out-break was insignificant for all the five networks as the results clearly shows the same values. The results obtained were mainly based on the complexities of the project network.

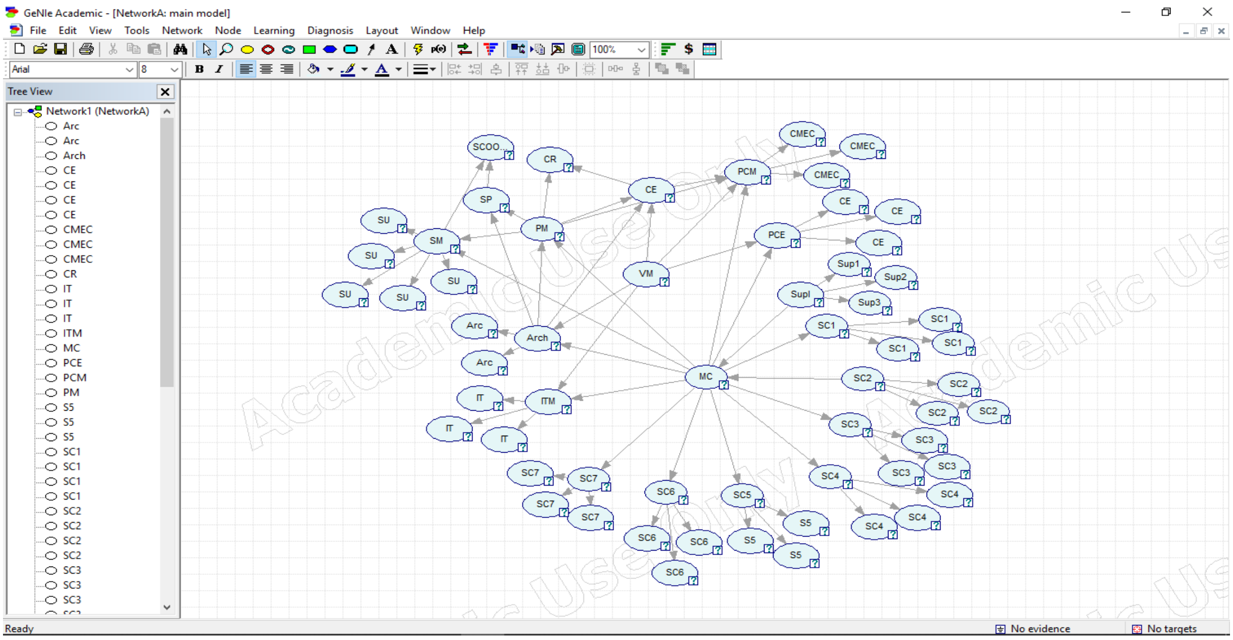

Figure 6.9: sample of a Bayesian network model for the traditional network structure interface

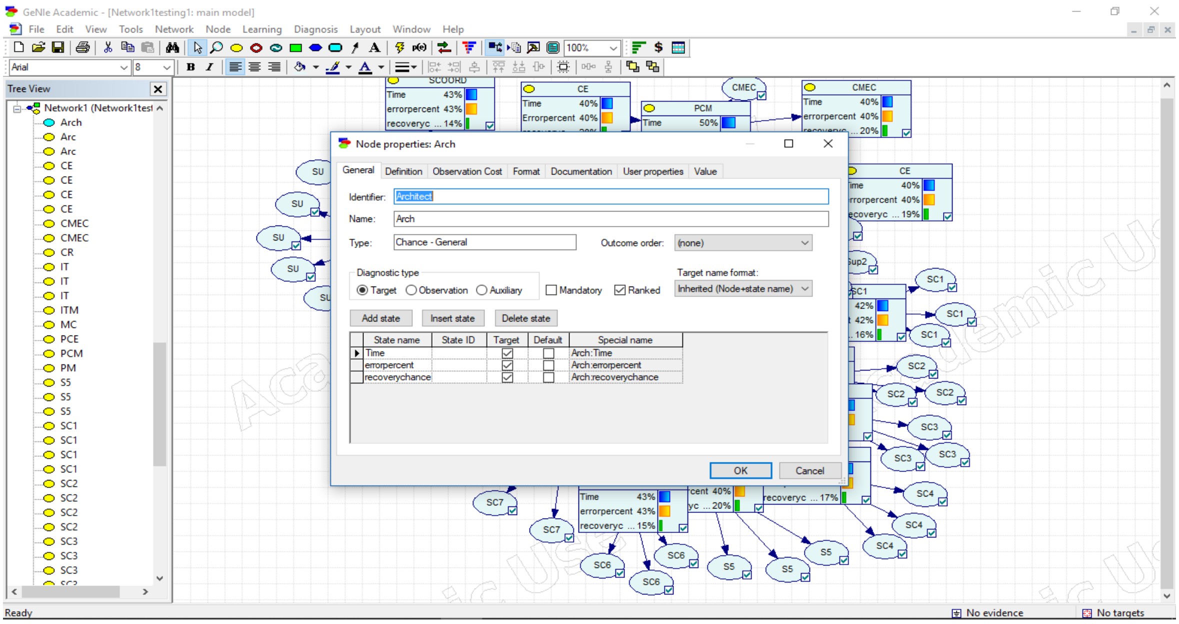

Figure 6.10: Parameter drop down menu for target, observation and auxiliary nodes.

The table 6.6 shows the parameters considered in the experiment. Three different combination where performed on each network structures giving a total of six iteration. For all the iterations, an initial error percent, initial time to identify error and recovery chance for the target node where established at the architect's node.

Table 6.6: The parametric used by Genie

Parameter	Definition	Applied values
Target node	Number of individuals generating design error	Percentage of individuals
Observation node	Frequency of design error checks to identify errors	Number of weeks
Time	Time to identify error	Final percentage
Error percent	The quantity of error perceived by each node	Number of percentage increase
Recovery chance	Probability of an individual not continue to do error	Number of percentage increase

The examination was viewed by checking through the time to identify error, error percentage and recovery-chance over the established phenomenon. The various iterations for the five networks are compared as shown in the graphs;

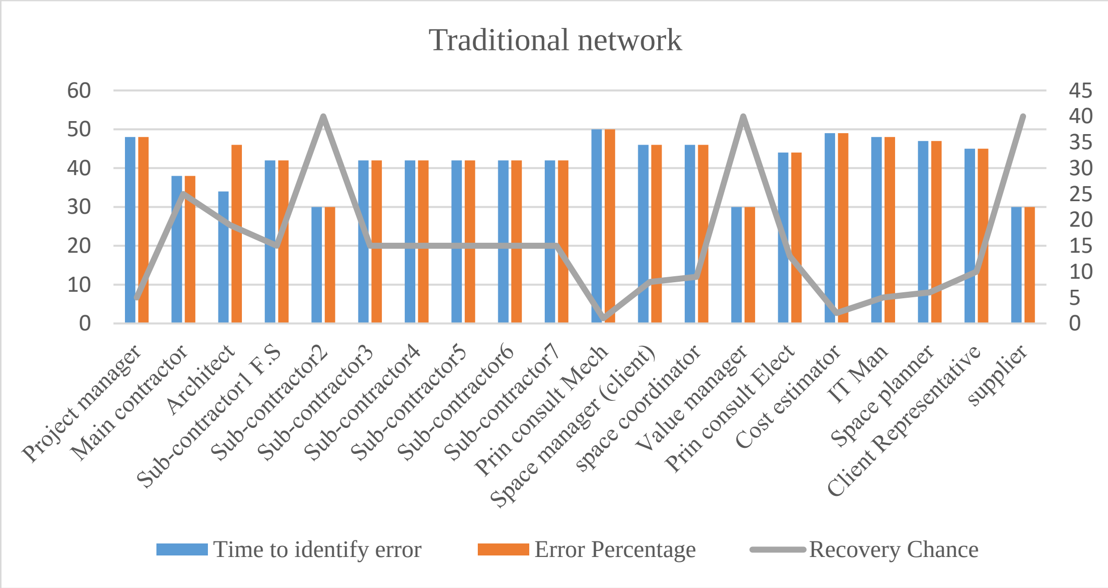

Figure 6.11: Simulation result for the main traditional network

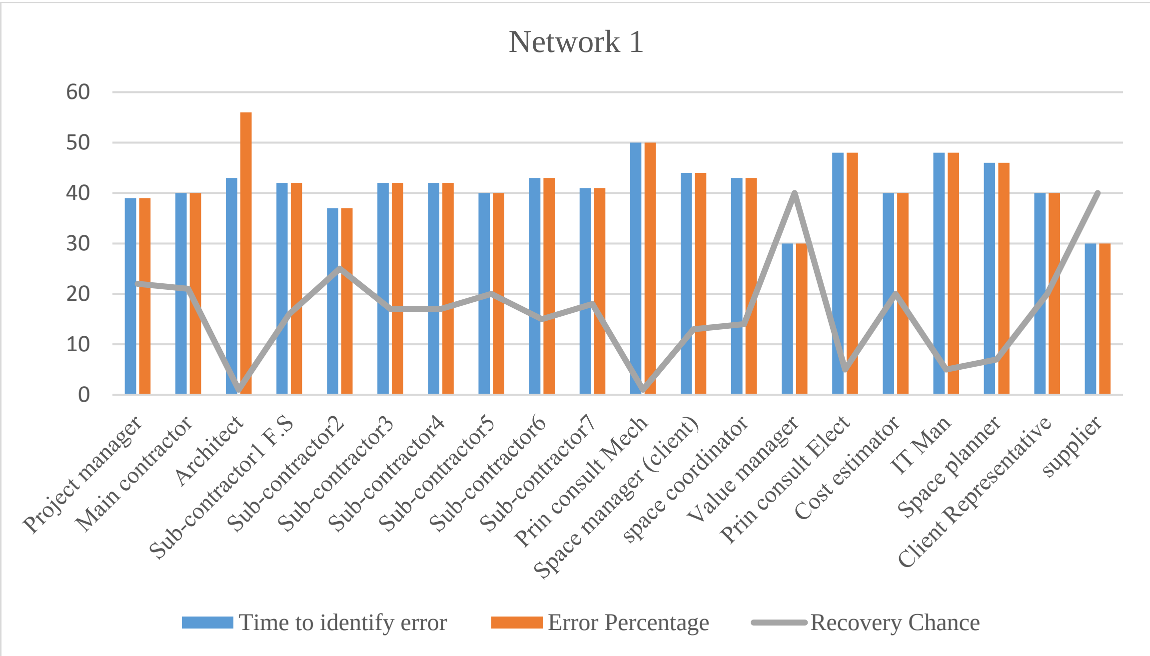

Figure 6.12: simulation result for error propagation on optimised network involving project manager and subcontractor

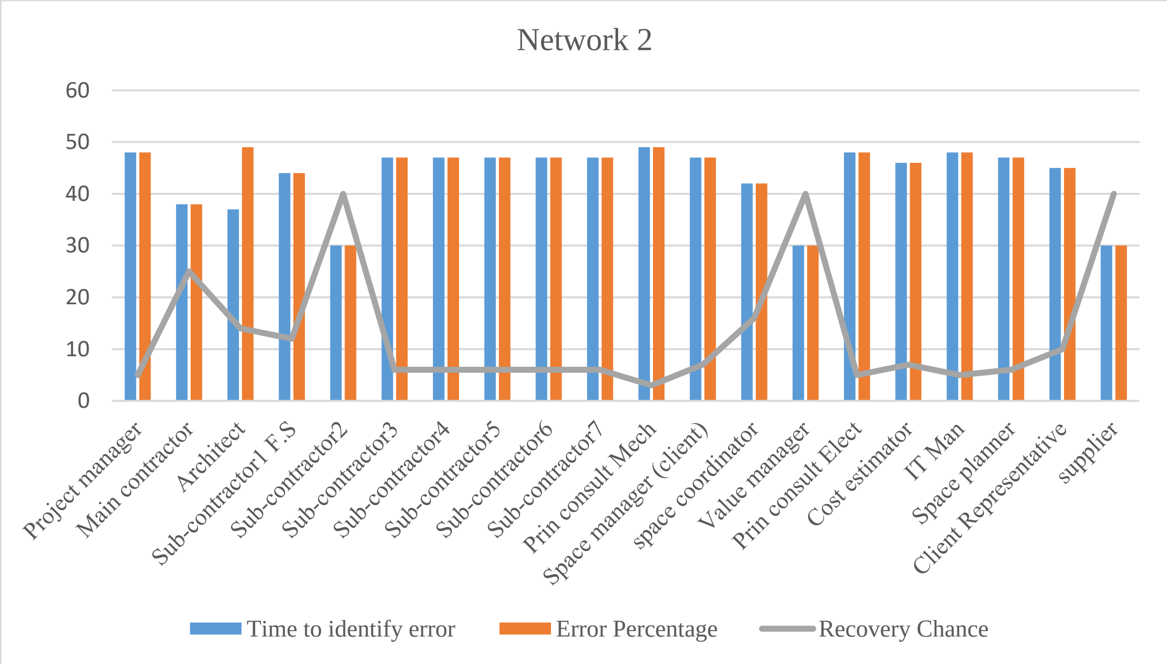

Figure 6.13: simulation result for error propagation on optimised network involving clients

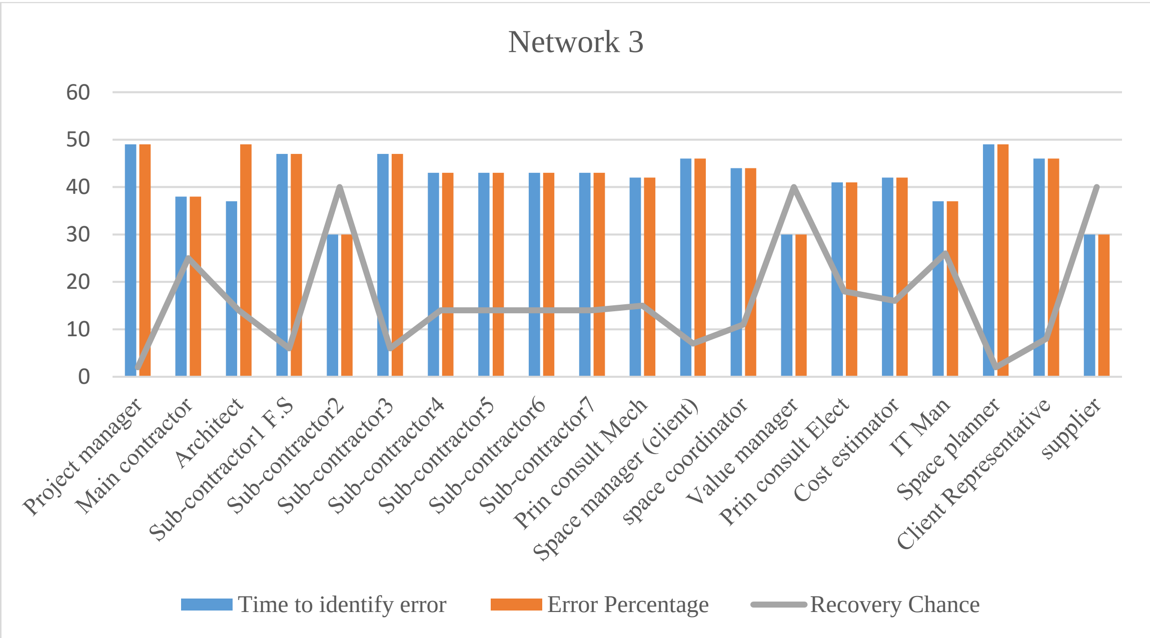

Figure 6.14: simulation result for error propagation on optimised network involving subcontractors and IT man

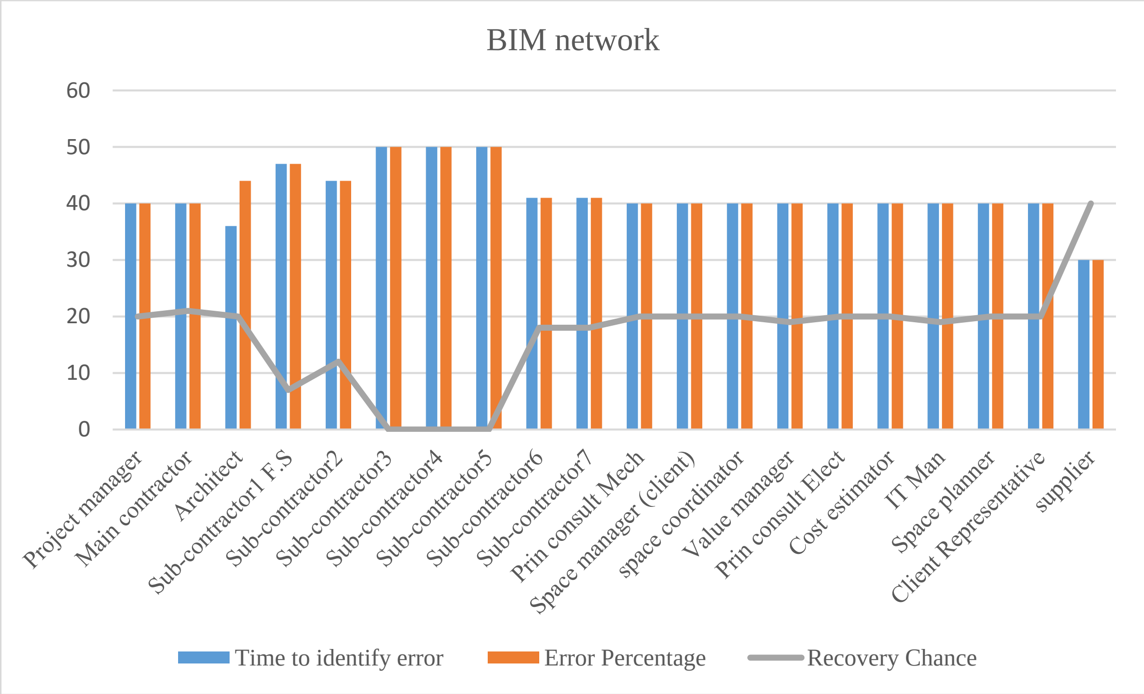

Figure 6.15: simulation result for error propagation on BIM network

For each of the scenario, we plotted graphs to represent the different interactions for the five networks. In addition, each of the iterations shows different sources of errors and different diffusion parts. The results show the amount of errors perceived by main stakeholders, lent of time to identify the design error and the ability to recover and resolve the problem identified to avoid further design error. These are compared over the entire networks. The result also demonstrates the time (in weeks) it takes the entire project stakeholders in the network to identify the error as well as to make design changes as required. The plots indicate the overall diffusion of errors and recovery within all the networks (figure 6.16).

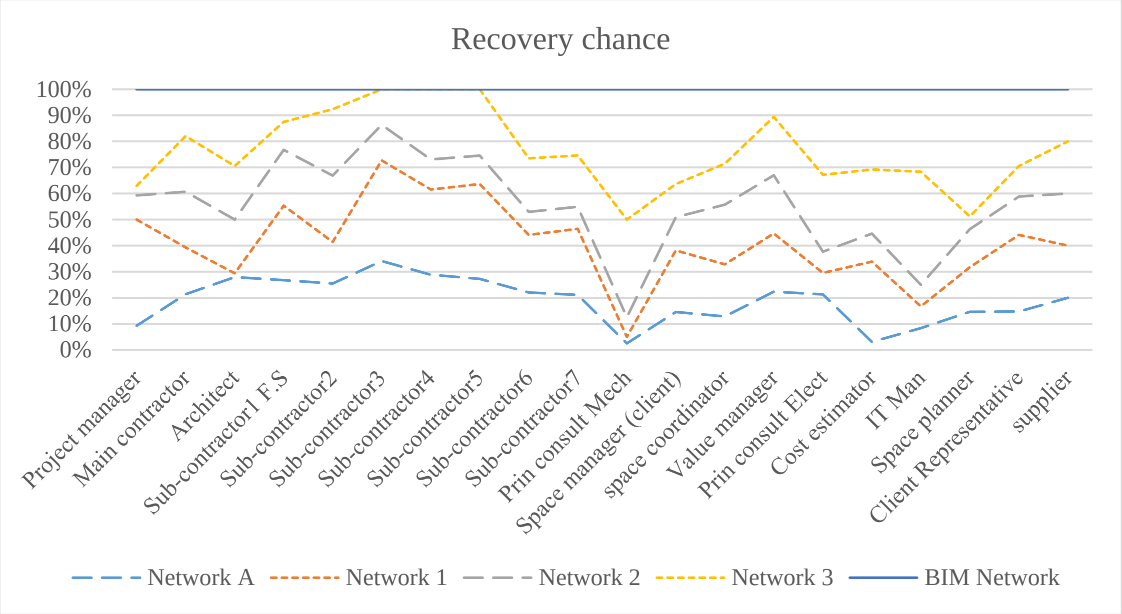

Figure 6.16: The overall recovery chance for each network

The result indicates that it takes more time for error diffusion on traditional network compared to the BIM network. Considering the three scenarios for the optimised network, the three network shows faster network diffusion compared to the original network (A). The three new network shows differences at the time for error diffusion and the time to recover or gaining resistance. The BIM network also shows higher recovery and resistance and shows that these errors spreads and dies out quickly while the stakeholders recover from such errors. It can be noted from the plots that all the network resist and regain from the design error, however, the differences are based on the time required to recover from the error demonstrated as percentage recovery. Although, the BIM network recovered 100 percent, because there might be deficiencies due to human errors, hence, should not expect the recovery to be 100 percent efficient in real world. The 100 percent occurred due to the higher level of interaction such as the improved collaboration among the project stakeholders to indicate the benefit of BIM for the refurbishment project. Other networks showed lesser performance due to less collaboration within the project network.

The implication of the optimised network is that the three-network presented offers any construction organisation to consider the best strategy to improve collaboration in their refurbishment projects. It also shows the importance of some roles regarding project coordination and the importance of adopting BIM which offers an improved collaboration. For instance, the improvement of collaboration among the main stakeholders such as the sub-contractors increased the performance of the project. This is in line with (Barlow et al., 1997) who suggested that improving the relationship for subcontractors and suppliers in projects can offer cost and quality savings. Even though most organisations are sceptical to adopt BIM for refurbishment projects, the benefits of BIM can be realised through closer relationship with different main stakeholders such as the subcontractors and the suppliers. Clearly, the advantage of optimised project network in this study offers a stronger collaborative partnership in which the organisations would work in a more cooperative manner. These networks are seen to perform better than the traditional method used by the project stakeholders for the case study and hence entails that client organisation should re-address the business processes to improve the exchange of information, including cooperative relationship while building collaboration mechanisms. Therefore, this paper covers the gap identified by (Okakpu et al., 2018) for optimisation process to adopt BIM for refurbishment project.

6.7 Conclusions

This paper presents the real benefits of adopting BIM for refurbishment projects to counteract the current reactive traditional measures that are ineffective in reducing the effects of uncertainties that occur in refurbishment projects. A case study refurbishment project is adopted from an Auckland tertiary institution. The case study provides the avenue to examine the refurbishment project stakeholders and their interaction within the project. A social network theory approach is adopted to analyse the traditional method of refurbishment and the virtual BIM method based on the project interaction. An environmental impact assessment is carried out on the main stakeholders BIM perception. Specifically, by comprehensively assessing and quantifying the contextual BIM impacts on the main project stakeholders, three main project stakeholders are proposed to improve their project interaction namely; the IT technician, the space coordinator and the sub-contractors as a result of their low BIM perception which invariably determines their low interaction in the case study project. Using Gephi to model the two networks (traditional and BIM network) and additional 3 project networks based on the proposed 3 main project stakeholders improvement interaction, and with consideration to the theoretical assumptions, the resulting metrics shows that using BIM improves the coordination and information exchange within the project compared to the traditional network. The improved links or edges within the optimised network created a stronger social network with increased collaboration between the project team members. Furthermore, agent-based modelling was employed to simulate the propagation of error in the five different networks using a Bayesian network model with consideration to Haper II for complex networks. The result portrays that BIM network model was almost hundred percent effective in reducing errors or project uncertainties. Therefore, the implementation of information exchange, clash detection and collaboration offered by BIM use could be the main reason for quick recovery from uncertainties within the project. The traditional method shows very low recovery mechanism from the project uncertainties and hence, would have many challenges and risks for a building refurbishment. Other three network showed a better recovery time than the traditional method network 1 (project manager and subcontractors), network 2 (client or space coordinator), and network 3(subcontractors and IT technicians). Among the three optimised networks, improving collaboration across the subcontractors with IT man significantly improved the performance of the project network. (network 3). It is worthy to note that although the links in this network is smaller than other optimised network such as network 3, the error was introduced at the architect domain and the architects has a direct effect to IT technician. This confirms why subcontractors should be adequately involved during the early phase of the project. It also significantly shows that project dependent on IT innovation can be cheap to meet the required project performance. This study considered a real case study in order to compare the real benefit of BIM adoption for refurbishment project and by the traditional technique. The study shows that refurbishment project with BIM implementation can minimise error with adequate error identification time.

In the next chapter, we intend to measure the BIM benefits by using sensitivity analysis and expert judgement to comment on the relevance of the five different Gephi network and Bayesian network to BIM collaboration, error management and recovery time for project stakeholders real time benefits.

Chapter 7 Identification of BIM Adoption Benefits for Refurbishment Project Stakeholders in New Zealand using Bayesian Network Model.

7.1 Prelude

This chapter is the penultimate chapter 6 and attempts to validate the benefits of BIM adoption through error management within the project network. It also validates the research framework in chapter 2 as a useful mechanism to identify BIM benefits through the sensitivity analysis and the workshop desktop audit. BIM is an IT enabled technology that supports information sharing, access, update of data and use, and allows storage of information and management. While the technology itself is not new, similar approaches have been in use for the construction of new builds, the refurbishment domain is yet to catch up with the ability to exploits BIM real benefits. In the present study, a case study refurbishment project is adopted to examine the interaction of project stakeholders' network through social network analysis (SNA) with Gephi software. However, with the structural interaction produced by SNA shows limitations such as testing how different interaction networks impacts the management of uncertainties within project stakeholders' network.

Therefore, to cover this gap, the current study adapts simulation of interaction of refurbishment project stakeholders to identify the real-time benefits of BIM adoption for complex refurbishment project by using agent-based modelling performed through a parameterized Bayesian network. The result shows that BIM project network efficiently diffuses errors while the project stakeholders involved in the project recovers from uncertainties on timely. A desktop audit is organised allowing the industry partners to give feedback based on the relevance of the different networks. The result of the study indicates that adoption of BIM will offer a profound benefit for refurbishment projects stakeholders by minimising errors and having quick decision-making process.

7.2 Introduction

The adoption of BIM for refurbishment project is just emerging despite that it has many benefits for complex refurbishment projects and its entire life cycle (Ghaffarianhoseini, Tookey, et al., 2016). BIM has the potential power to transform the industry during the whole lifecycle of the projects. Although, a strategic approach to BIM adoption requires the incorporation of people, process, and technologies on timely bases, it also leads to capacity buildings and good managerial improvements (Alwan, 2016). Although, the delivery and uptake has been slow for existing building projects (Chong et al., 2017), to encourage uptake on BIM adoption for refurbishment project, Okakpu et al. (2018) proposed a research framework for effective adoption of BIM for refurbishment project. While the research is based on the existing literature regarding the BIM-refurbishment project research framework, the study advocates that to maximise BIM adoption for complex refurbishment projects, there is a need to examine real BIM benefits and as well examine whether the stakeholders are doing the right thing to improve BIM acceptance through a healthy project interaction. This paper presents a quantitative approach based on agent-based simulation by producing a virtual interaction within a network of stakeholders in order to assess the real BIM benefit using error diffusion mechanism and sensitivity analysis. Thus, this paper addresses the research question (Okakpu et al., 2018);

I. Are there Benefits?

To achieve these objectives, this paper is divided into three parts. The first part uses simulation software to investigate the interaction dynamics of the refurbishment project stakeholders based on real-time benefit and compare between conventional methods and BIM methods using design error propagation interaction management. The second part uses the perspectives of industry expert to determine the relevance of the networks and its implications in real-time refurbishment project. The implication of the sensitivity analysis on the various modelled project network is reviewed through the desktop audit. Hence, the client organisations, and all stakeholders planning to adopt BIM will learn real benefits of BIM and as well the baseline risk mitigation towards adoption of BIM for their refurbishment projects.

7.3 Background of the study

The aim is to introduce the importance of sensitivity analysis and error management in construction projects. These factors have been used in this study to compare the added benefits of the project networks based on their level of project interactions.

7.3.1 Design Error Management

An error is a shift from the true value and lacks precision and could vary in measurement as a result of lack in human and mechanical perfection (Kaminetzky, 1991). While errors can manifest in design as a result of omissions in drawings, calculations, and specification, the impacts is received due to human input, and is attributed to human generated errors (Andi & Minato, 2004) . These errors results to project uncertainties such as schedule delays due to rework, and more importantly causes catastrophic construction and refurbishment failure (Rasmussen, 1990).

Although, errors can be attributed to influences from surrounding environment (Sowers, 1993), the current authors are of the view that error mechanisms need investigation through a social context to address the fundamental issues of design errors. Several authors are of the view that errors can be managed through organisations that operate on refurbishment projects (Busby, 2001; Love et al., 2014), these studies are lack on the dynamic characteristics of error generation and diffusion which can occur as a result of interaction of refurbishment project stakeholders. SNA can be used to investigate and model the interaction dynamics of project stakeholders within a social network (Hatala & George Lutta, 2009). Therefore, the current study uses SNA to investigate and compare error management within a set of stakeholders for a refurbishment project case study where a conventional approach was used, and modern (BIM virtual) method prototype is modelled for comparison purpose.

7.3.2 Sensitivity Analysis

Considering the refurbishment projects case study, sensitivity analysis can be used to determine the most critical variables (stakeholders) that have the greatest effect on the feasibility and effectiveness of the project. Despite the impact of SNA to study the interaction dynamics of project stakeholders' interaction, it lacks the ability to sufficiently consider individuals' behaviour or attributes in isolation within the project (Love et al., 2011). Hence, the authors implemented sensitivity analysis (SA) to cover this gap. The main purpose of sensitivity analysis is to implement and predict the effects of error occurrence or uncertainties in refurbishment projects (Pang et al., 2007). Three key performance indicators are established for prediction namely; time to identify error, error percentage and recovery time. Upper limits are set at the target nodes while the lower limits are set at the observer nodes. To carry out SA, we used GeNIe software to run a Bayesian network simulation.

7.4 Methods

A social network analysis and an agent-based Bayesian network has been built to model and simulate the interaction of project stakeholders for a recent completed refurbishment project is presented. A Delphi desktop technique is used to comment on the relevance of the simulated result. The project stakeholders are represented by the nodes of a network linked to each other based on their social interaction. A questionnaire designed to obtain the interaction network is administered on the project stakeholders who participated on a recent refurbishment project in a tertiary institution in Auckland. Owing to the shortage and lack of interest of refurbishment stakeholders on BIM interest, a snowball technique was used to identify and nominate the participants who were involved in the project to enable modelling of the interaction network. A purposive sampling technique was used to identify experts in the New Zealand construction industry who had experience in BIM and refurbishment projects and were called to express their opinion on the relevance of the networks, the simulation results and its implications on the sensitivity analysis of the project network stakeholders in New Zealand construction environment.

Before conducting the quantitative interview, approval was sought from the (Auckland University of Technology ethics, 2018). This was to protect the safety, privacy, health, welfare and social sensitivities of the various participants involved in the provision of research data. Figure 7.1 details the demographic representation of the research participants

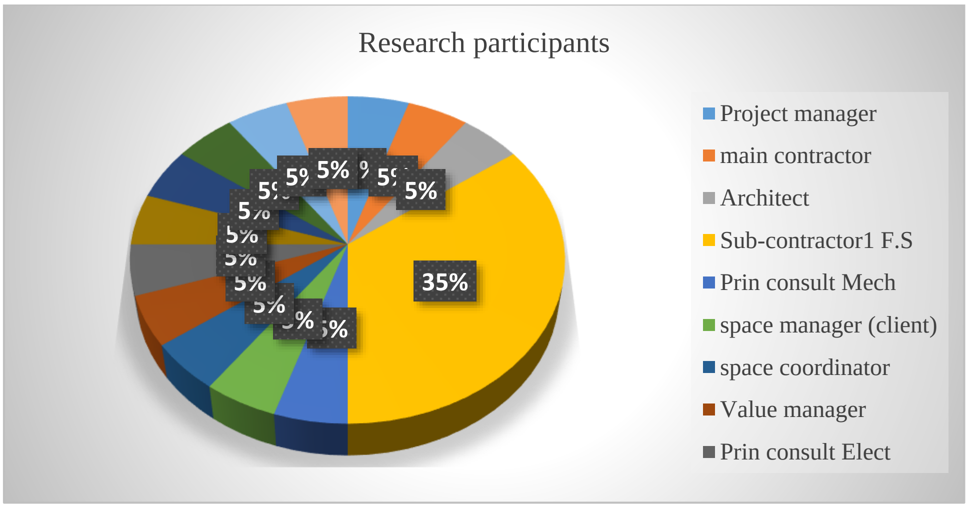

Figure 7.1 : demographic representation of participants

7.5 Results and Discussion

In this section, we will present the network models developed from SNA software such as Gephi and the simulation with GeNIe for Bayesian network.

7.5.1 Introduction to Social Network Analysis

Social network analysis (SNA) is a method of investigating relationships among stakeholders especially when it concerns a specific interest. This process helps to explore the conditions of social structures (Hu & Racherla, 2008). SNA is proved to be an essential tool for assessing collaboration pattern of an organisation (Park et al., 2010).

The visual graphs implemented by this tool to map the networks consists of the nodes having metrics which describes the closeness, betweenness and degree centrality of actors, while the network has metrics as the density, modularity, average path length, and clustering. Although many research work focused on organisational collaboration in complex engineering tasks, SNA can also be applied in this venture (Xue et al., 2018). SNA is also employed in organisational behaviour studies (Easley & Kleinberg, 2010) and in construction management studies to investigate information flow between participants or project team and better integration of multidisciplinary team (Alarcón et al., 2013). In this study, we present 5 networks; a traditional network, three optimised networks obtained from the traditional network, and BIM network from social network analysis model. Table 7.1 and 7.2 details the metrics for the traditional network (A) versus the BIM virtual network (B) and the three other networks derived from traditional network are presented.

Table 7.1: The comparison of traditional network (A) vs the BIM network (B)

Type	Metric	Network A	Network B
Structure	Number of nodes	62	62
	Graph type	undirected	undirected
	Number of edges	73	263
Node	Degree centrality	2.345	8.484
	Closeness	3.287	2.267
	Betweenness	38	35
Network	Density	0.039	0.139
	Number of groups	13	13
	Modularity	0.642	0.125
	Avg. clustering coefficient	0.159	0.827
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	Diameter	5	4

Table 7.2: Values of the metrics generated from SNA for network C

Type	Metric	Network 1	Network 2	Network 3
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	Graph type	undirected	undirected	undirected
	Number of edges	114	82	84
Node	Degree centrality	3.677	2.645	2.71
	Closeness	3.006	3.337	3.263
	Betweenness	41	38	35
Network	Density	0.06	0.043	0.044
	Number of groups	13	13	13
	Modularity	0.354	0.565	0.527
	Avg. clustering coefficient	0.365	0.135	0.189
	Average path length	3.006	3.337	3.263
	Diameter	5	5	5

Overall, the entire network interaction was analysed to show the connections and level of communication among the project stakeholders. From the network, the case study project (network A) is highly fragmented, as each different team in the project collaborate closely at the expense of other team. Figures 1 and 2 shows the traditional network structure and its virtual BIM network structure.

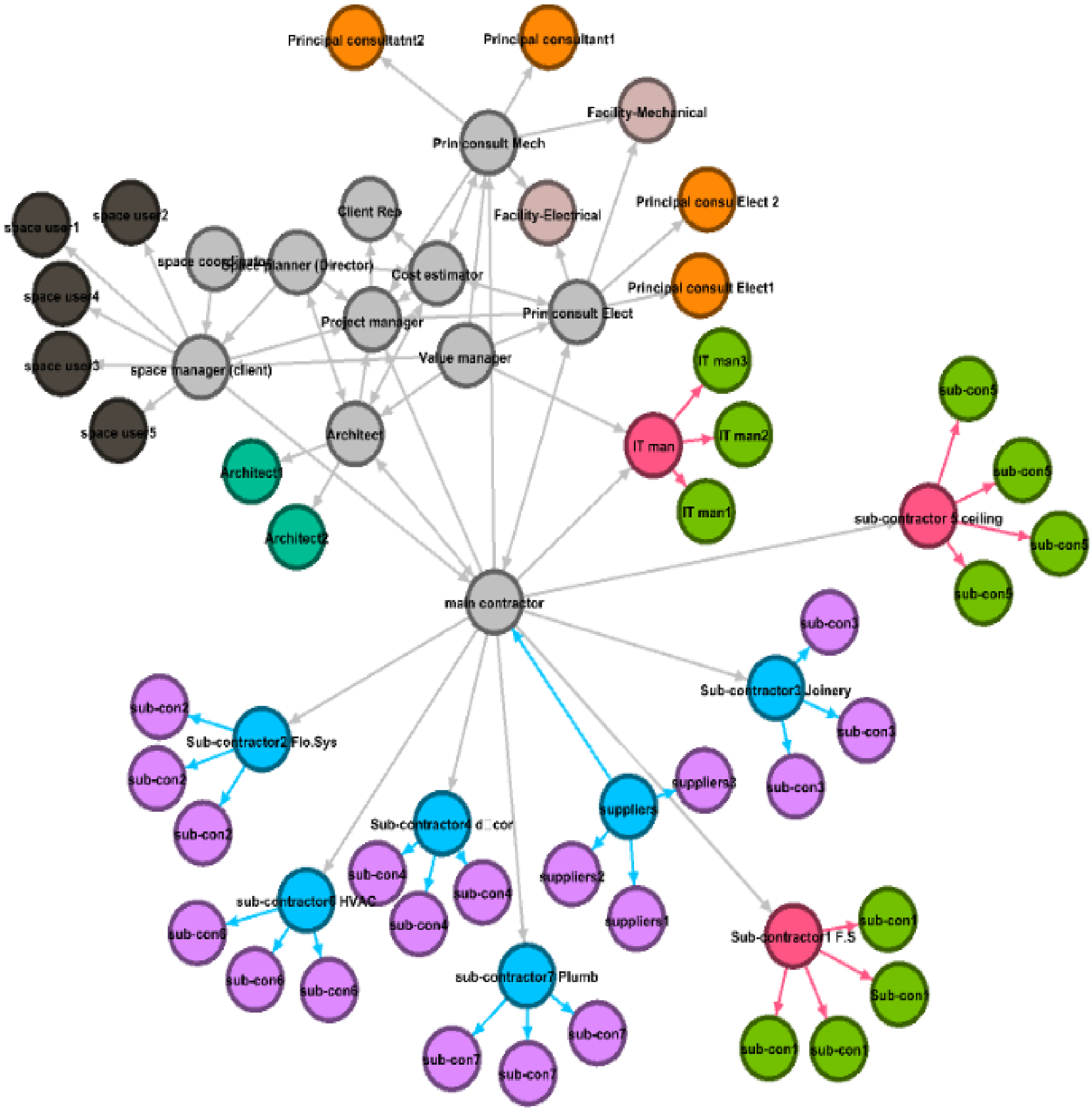

Figure 7.2: Traditional network from social network analysis model

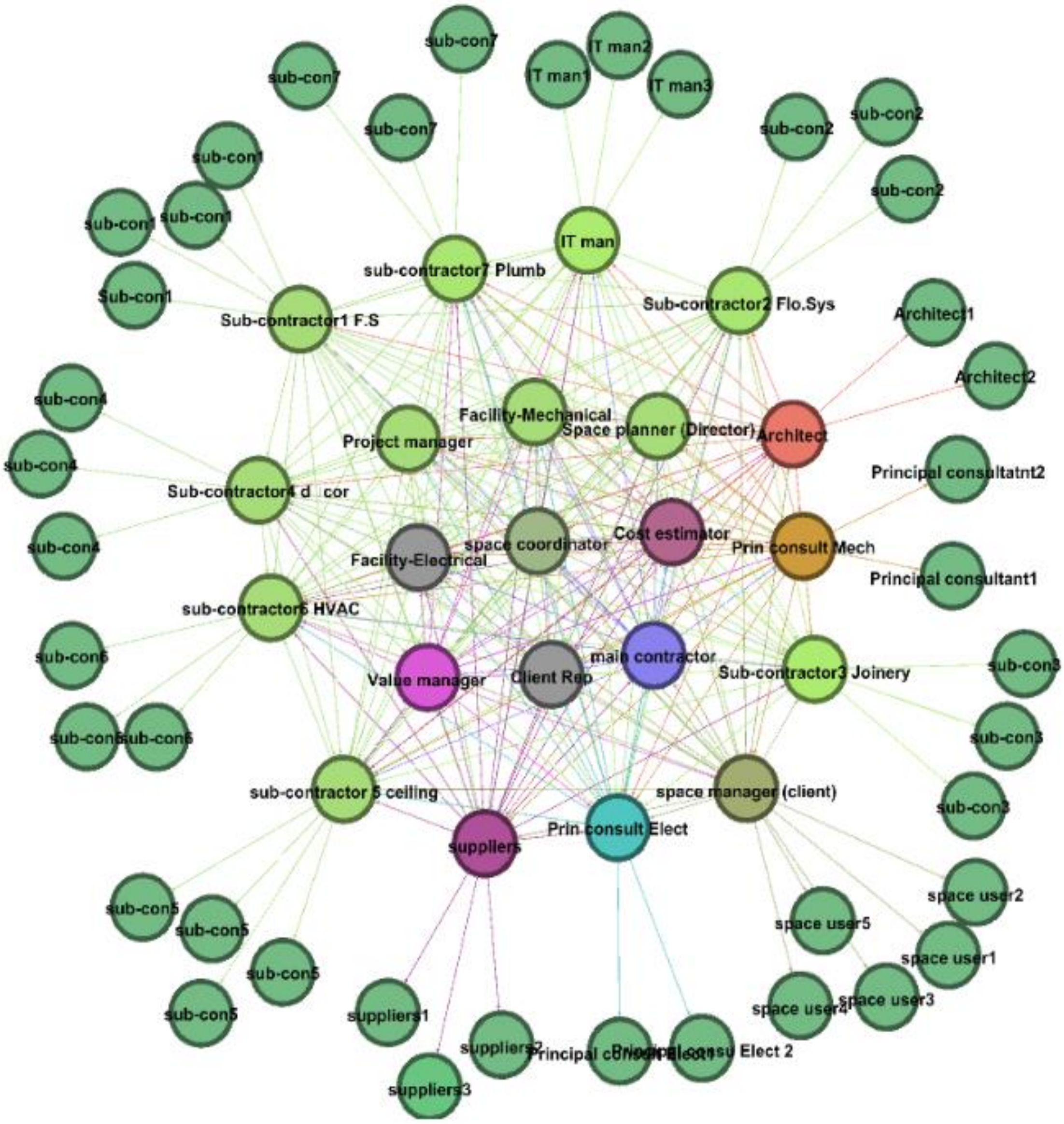

Figure 7.3: The BIM network model from social network analysis tool

From figure 7.2 and 7.3, it can be seen that even though the networks have the same number of nodes, the number of edges marks a distinction between the networks. The average part lengths for the traditional network is higher compared to BIM network (table 2). The networks generated as network C (table 3) shows relatively lower average part lengths. This shows that the smaller the average part length the closer the stakeholders to collaborate with each other in the project. Network 3 has the lowest average part length, and this network involves improvement of collaboration on the subcontractors at the early design phase of the refurbishment project.

7.5.2 Introduction to Bayesian Network using Hepar II Model

The Bayesian network are acyclic directed graphs modelling probabilistic dependencies and independencies among variables. In this study, the dependencies and independencies occur between nodes or also called the project stakeholders. Therefore, the graphical part of Bayesian network shows the structure of interaction among the project stakeholders and this are quantified by conditional probability distributions (Seixas et al., 2014). In order to adapt Hepar II, we considered the effects of the level of complexities of the networks from Gephi but less consideration to the level of initial error break-out. Therefore, the disorders are considered as the error introduced into the network and are allowed to simulate through the network as designed error. The time to identify the error, error percentage, recovery chance is measured by each node in the network. The nodes are set as observers with a defined probability of occurrence of 0.3 %, 0.3 % and 0.4 % respectively. For all the iterations, an initial error percent, initial time to identify error and recovery chance for the target node where established at the architect node (0.2, 0.7, 0.1). The table 7.3 shows the parameters considered in the experiment.

Table 7.3: the parametric used by GeNIe

Parameter	Definition	Applied values
Target node	Number of individuals generating design error	Percentage of individuals
Observation node	Frequency of design error checks to identify errors	Number of weeks
Time	Time to identify error	Final percentage
Error percent	The quantity of error perceived by each node	Number of percentage increase
Recovery chance	Probability of an individual not continue to do error	Number of percentage increase

7.5.3 Sensitivity Analysis

To introduce error in the five different network model propagation and to analyse the effect of the error, sensitivity technique was implemented. The sensitivity analysis is a technique which can be used to validate the probability parameters of a Bayesian network

(Castillo et al., 1997). This was done by investigating the effects of little changes on the numerical on the output parameters. A high sensitivity parameter affects the reasoning results. Using GeNIe software, we implemented an algorithm proposed by (Kjærulff & van der Gaag, 2000) that performs simple sensitivity analysis in Bayesian networks. Considering a given set of target nodes, the algorithm calculates efficiently a complete set of derivatives of the output distributions over the target nodes and, over each of the numerical parameters of the Bayesian network. In this study, the target node is the main Architect while numerical parameters are contained by other nodes set as observation nodes. The sensitivity analysis algorithm gives results that are context dependent. This indicates that the value of derivatives calculated depend on the current target set and the set of observations made in the network. Therefore, the sensitivity analysis is presented in the figures 7.4 to 7.8. The figures show the five different networks for examination of BIM benefits. The red colouring of some of the main stakeholders indicates the participants who are strongly affected and more sensitive to the introduced error based on the selected error target. Although, we considered only one error target in the network, it can be seen that the effects of the error improved with increased collaboration on the network from network A to network B.

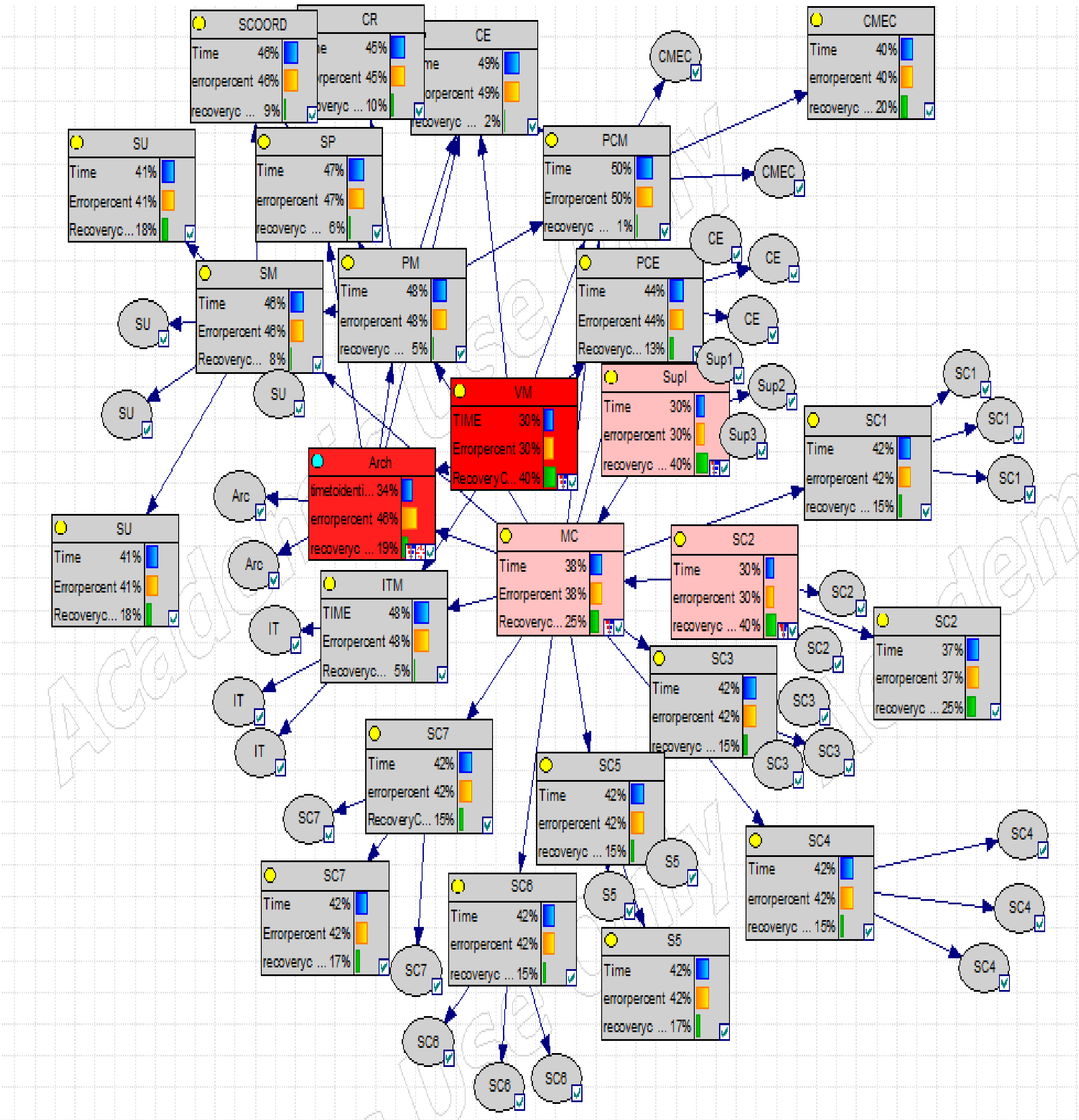

Figure 7.4: The traditional project network A

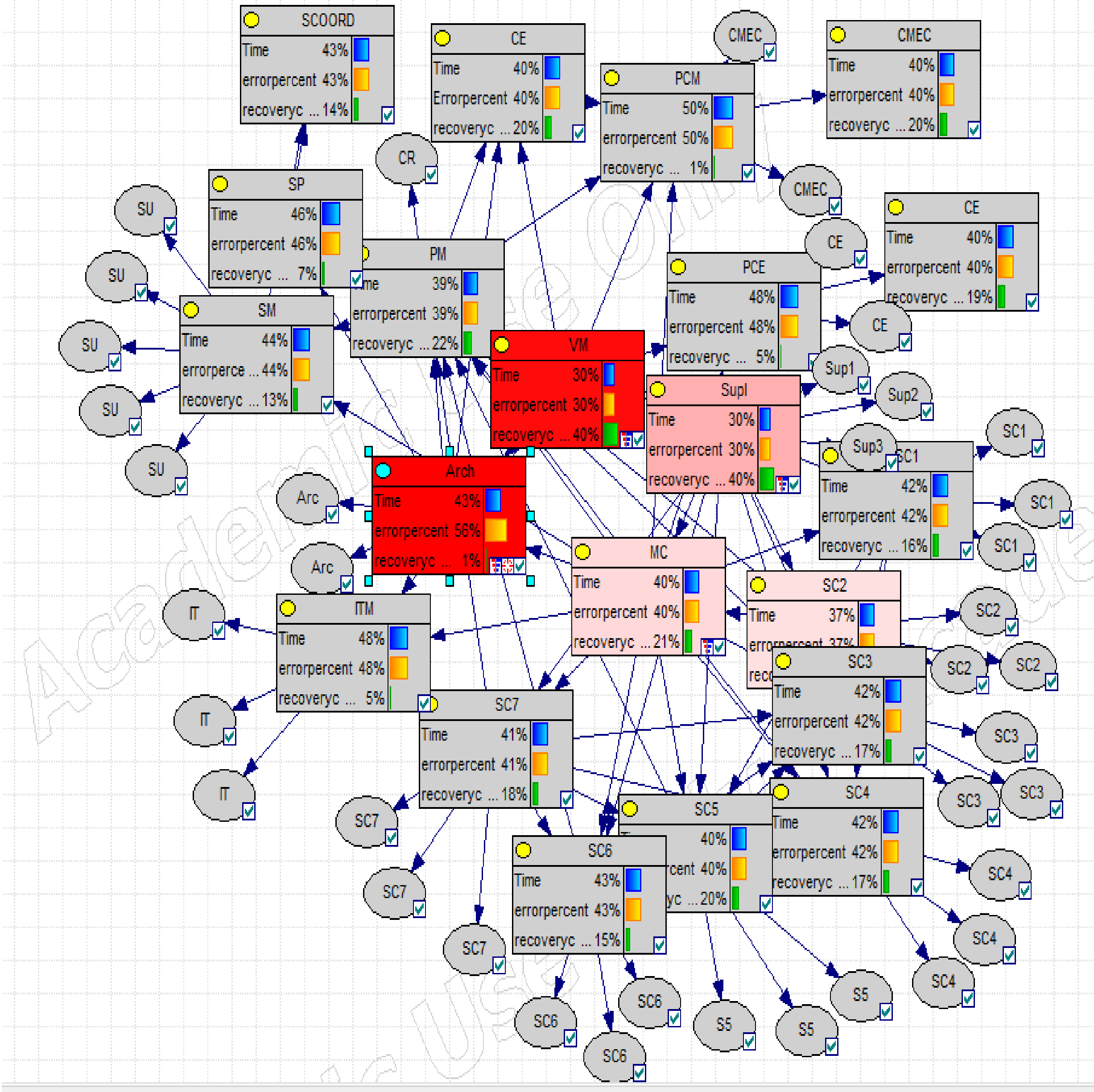

Figure 7.5: First optimisation on the traditional network (network 1)

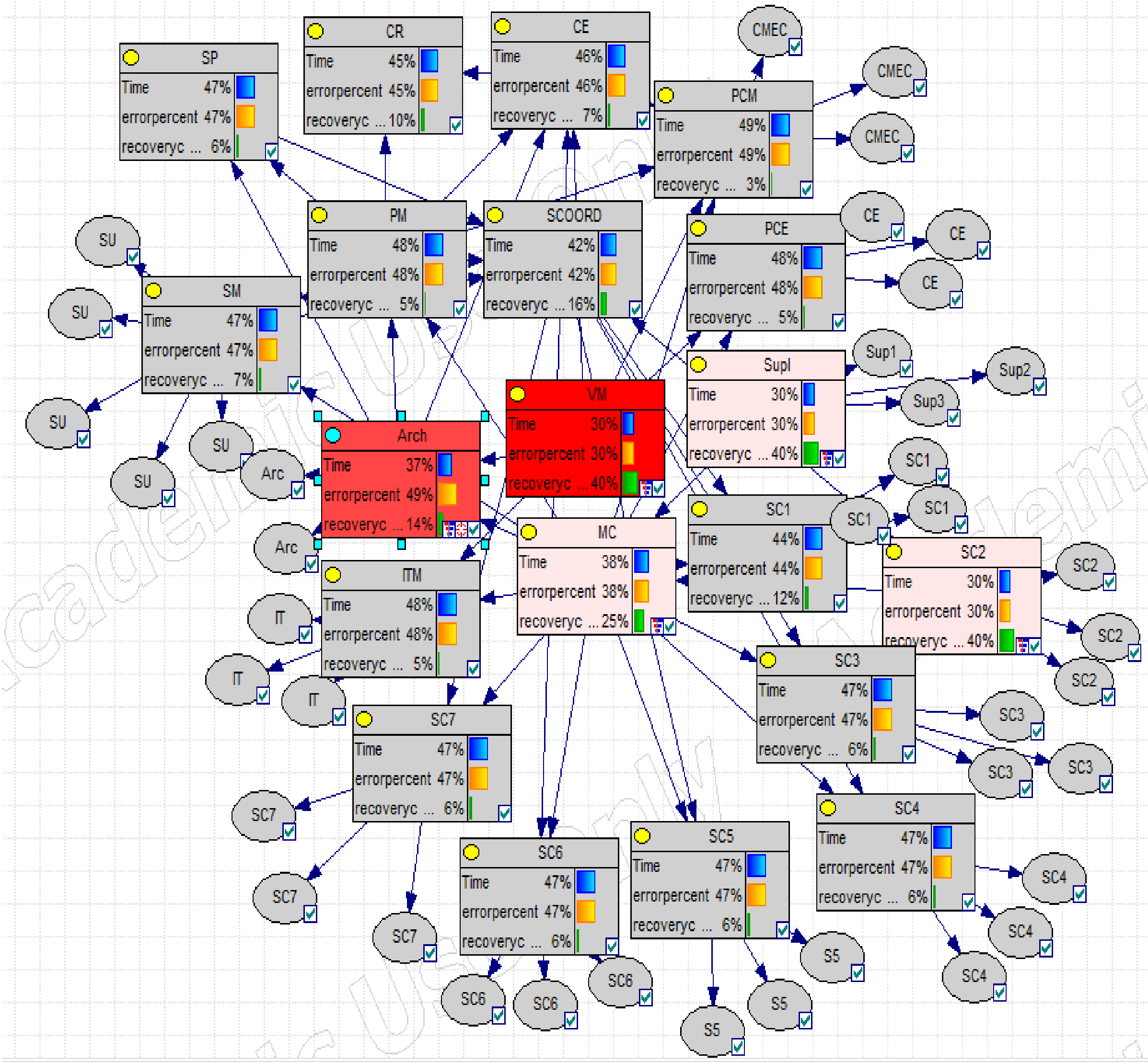

Figure 7.6: Second optimisation on the traditional project network (network 2)

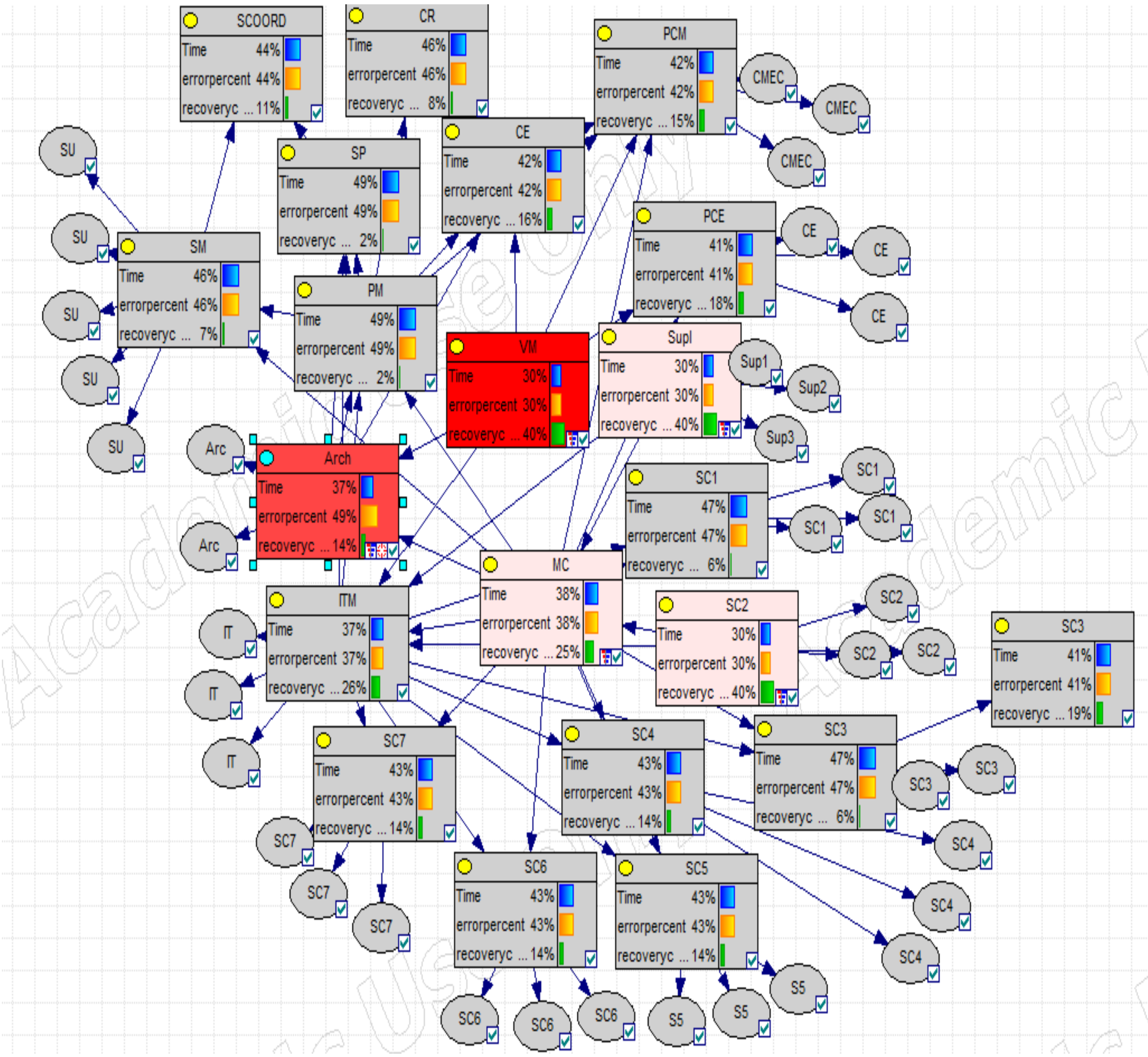

Figure 7.7: The third optimisation on the traditional network (network 3)

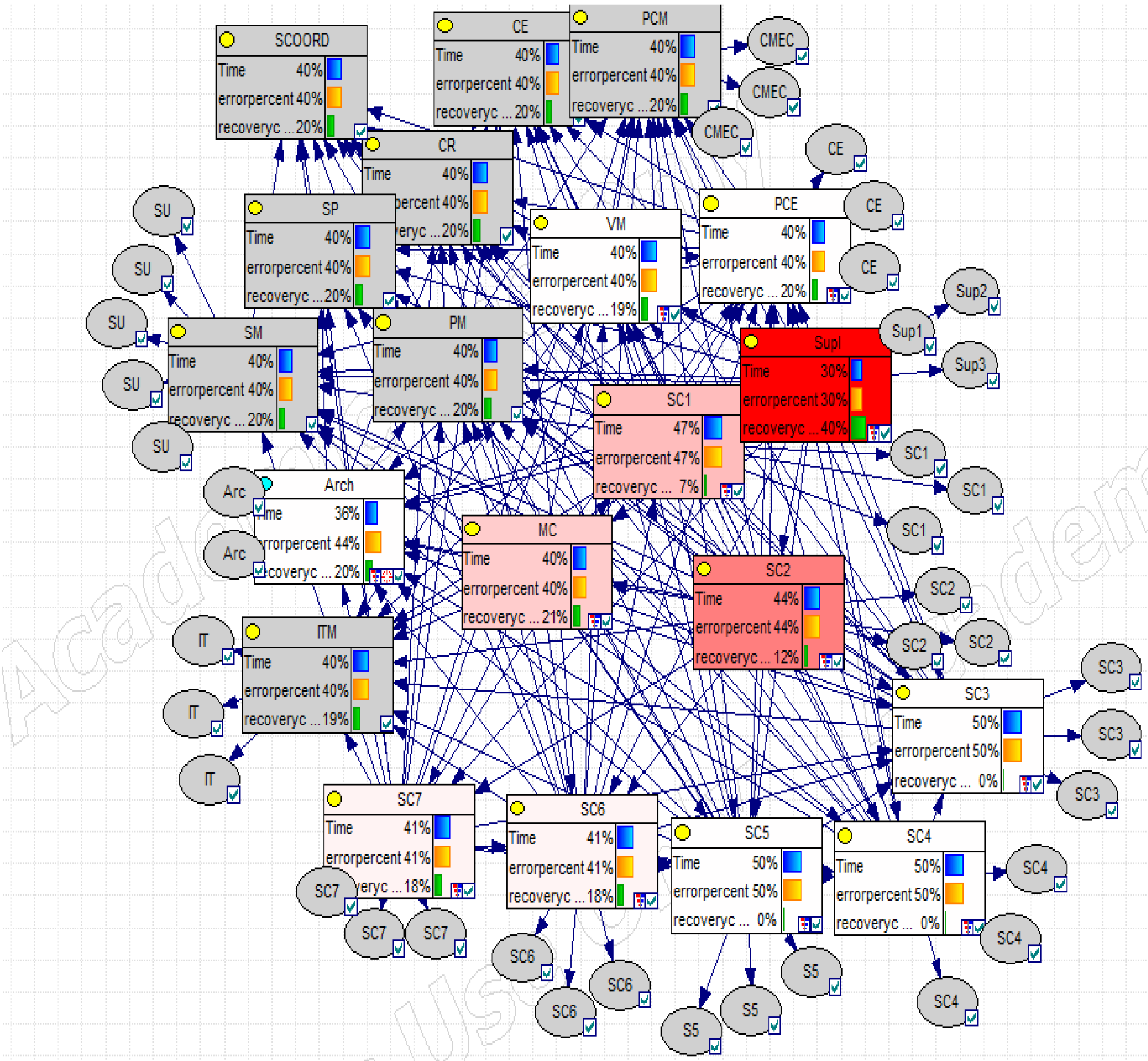

Figure 7.8: The virtual BIM project network B

From the sensitivity analysis conducted on the five project network models using Bayesian network model, the effects of the error progresses from the architect based on network A and becomes highly intensive on the suppliers (main stakeholders). This could mean that in the traditional settings, suppliers are favoured with respect to organisational culture, but with BIM adoption, suppliers are highly sensitive, and from figure 7.8, it takes longer time for suppliers to recover from error compared to other main stakeholders. While the architect recovers under time limit, the sub-contractors appears to recover at that instant. The sensitivity analysis is dependent on the set target. During the simulation test, the set target is the main architect. The result of sensitivity analysis can vary with different set targets. The figure 7.9 details the summary result of the sensitivity analysis to validate the error propagation in the project case study. The main stakeholders responded differently to the error propagation in the different interaction network for the refurbishment project. The sensitivity of different stakeholders reaction increases while few others shows decrease in their reaction to error diffusion (Fig 7.9).

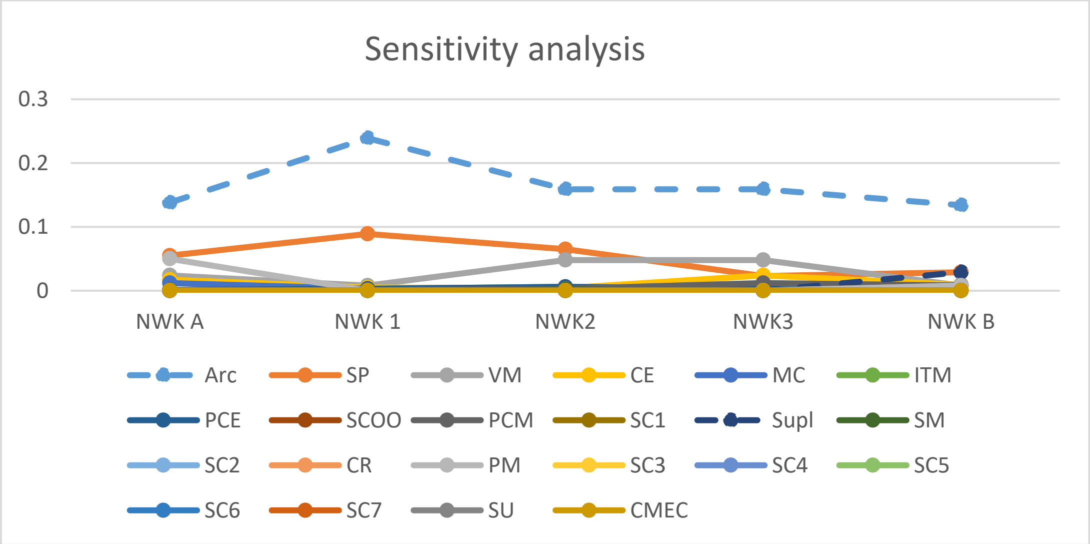

Figure 7.9: The sensitivity Analysis of the project main stakeholders

7.5.4 Simulations Results

Our empirical test focused on comparison of the diagnostic performance for all the five different network models simulated. We were interested mostly under the identification of error, quantity of error perceived and the time to respond to the error. The performance of the five models were similar since it was the same project, and the same number of stakeholders. However, with the increase in collaboration dynamics, BIM network shows better performance based on error recovery of the project stakeholders as shown in figures 7.10- 7.15. The agent-based model indicates in each network the project stakeholders who are likely to be highly affected by the introduction of error under sensitivity analysis. The plots represent the overall diffusion of errors, recovery time, and the percentage of error perceived. The result shows that it takes more time for traditional project network to recover from uncertainties such as design error compare to BIM network while, the sensitivity analysis show project stakeholders who are highly in risk or are affected by the uncertainties. The main architect who makes the error recovers instantly at the BIM network compare to the traditional network. There is a gradual improvement from the traditional network (A) across the optimised network (1,2,3) to BIM network.

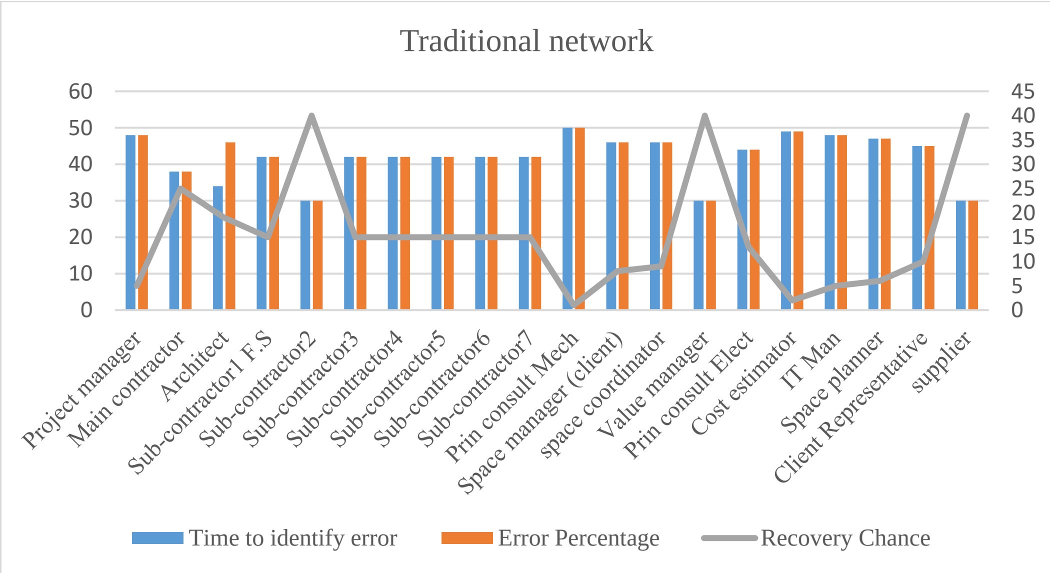

Figure 7.10: Simulation result for the main traditional network

Figure 7.11: simulation result for error propagation on optimised network involving project manager and subcontractor

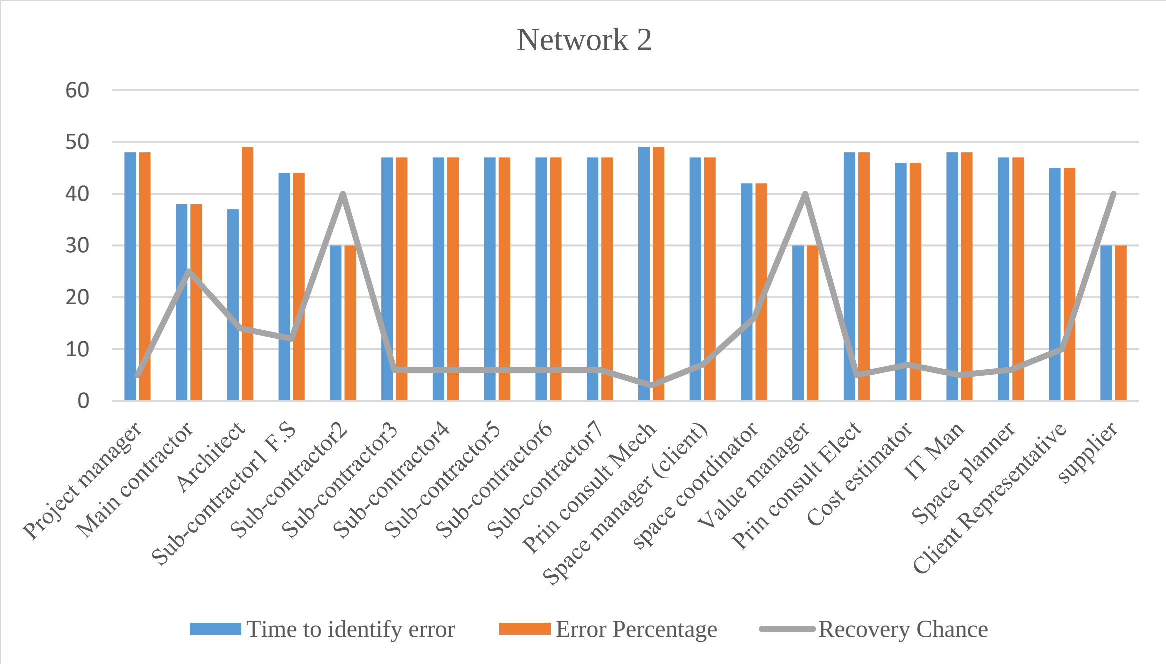

Figure 7.12: simulation result for error propagation on optimised network involving clients

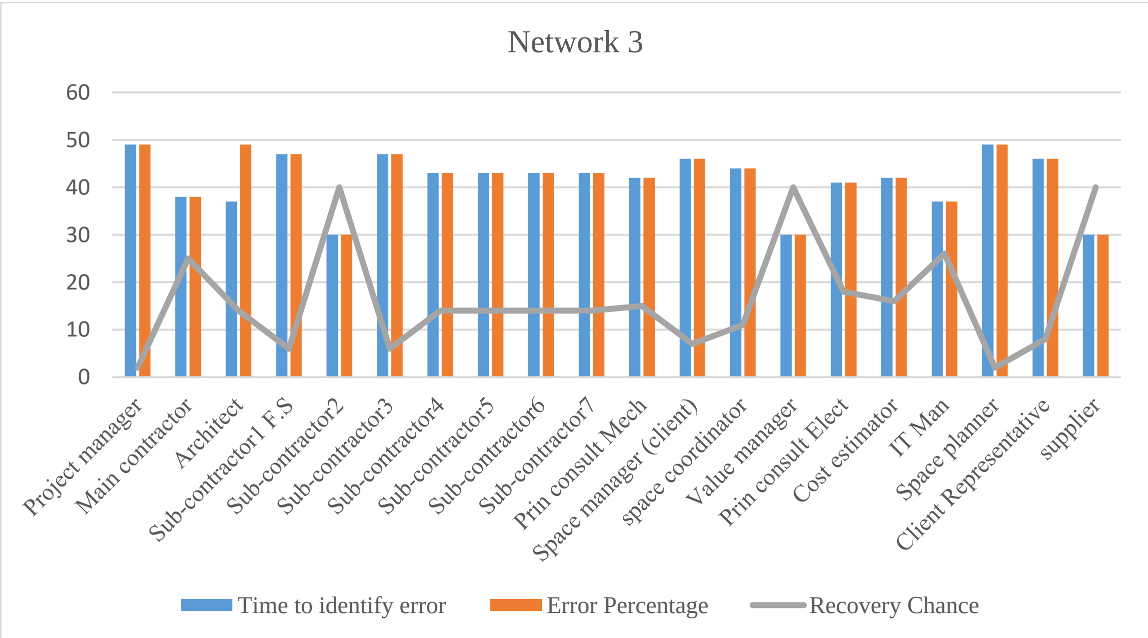

Figure 7.13: simulation result for error propagation on optimised network involving subcontractors and IT man

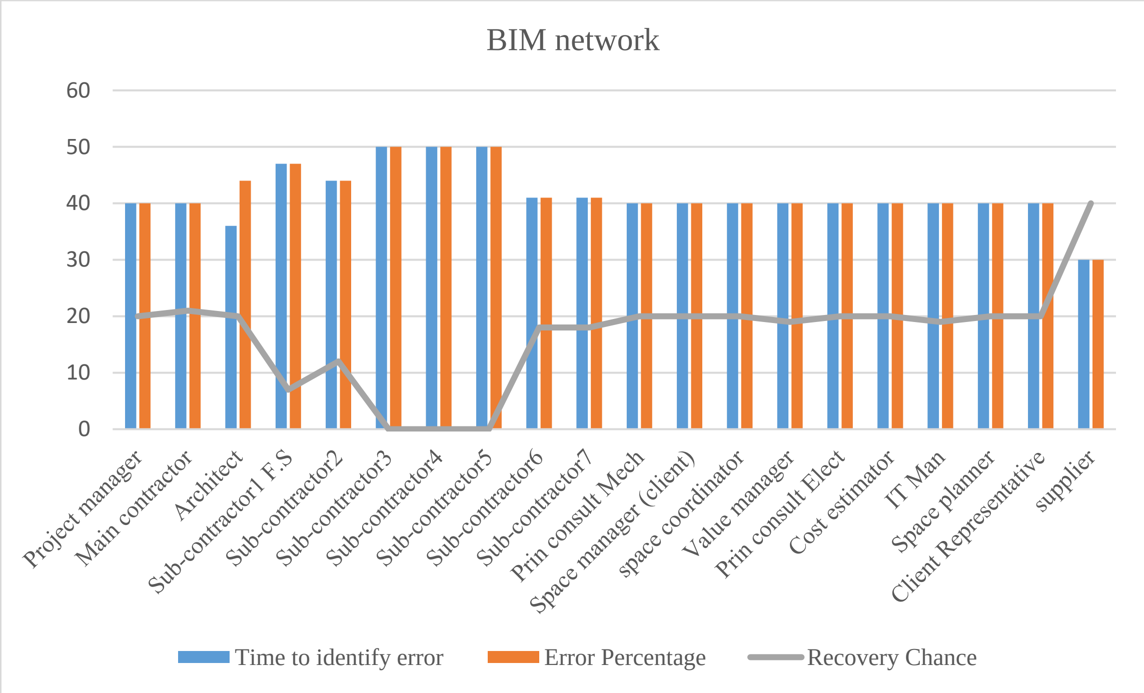

Figure 7.14: simulation result for error propagation on BIM network

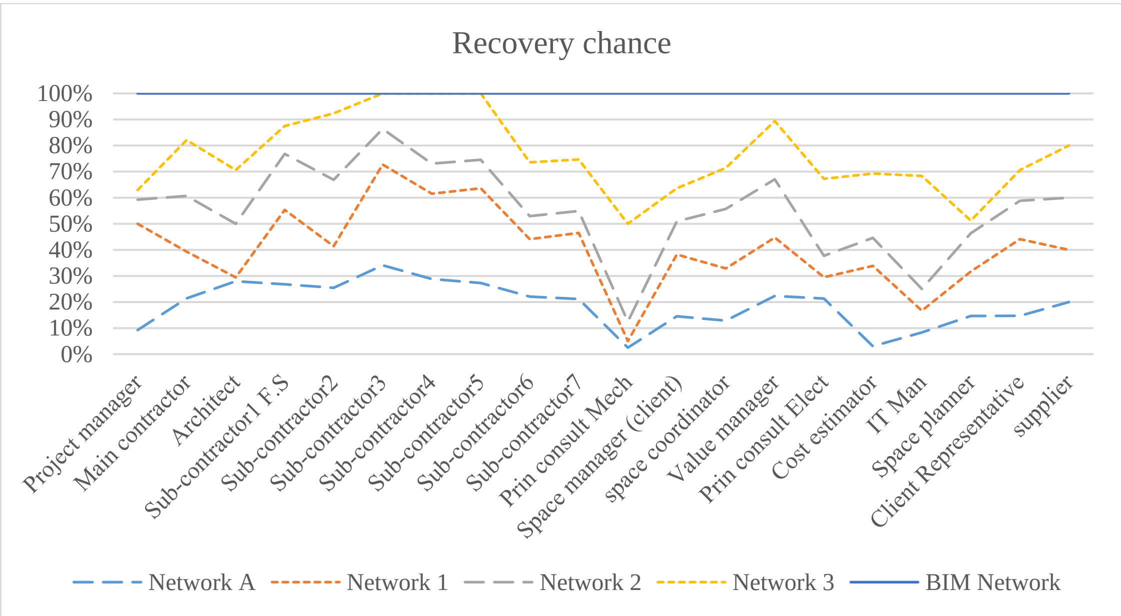

Figure 7.15: The overall recovery chance for each network

The simulation results (figure 7.10 -7.14) shows the propagation of error, the identification of error and response by the main stakeholders. Throughout the simulation results, the error identification time differs progressively from the traditional network and tends to be more stable at BIM network. The error recovery part as shown in figure 14 indicates that BIM network almost recovers at 100 percent compared to traditional methods and the other optimised network. Overall, the simulation results indicated that BIM network is more efficient to identify error in the project compared to the current traditional method used for the case study. The sensitivity analysis also indicates that stakeholders of traditional method are more ineffectual towards making a decision while the stakeholders at the BIM network construed to take decisions towards solving problems at that instant.

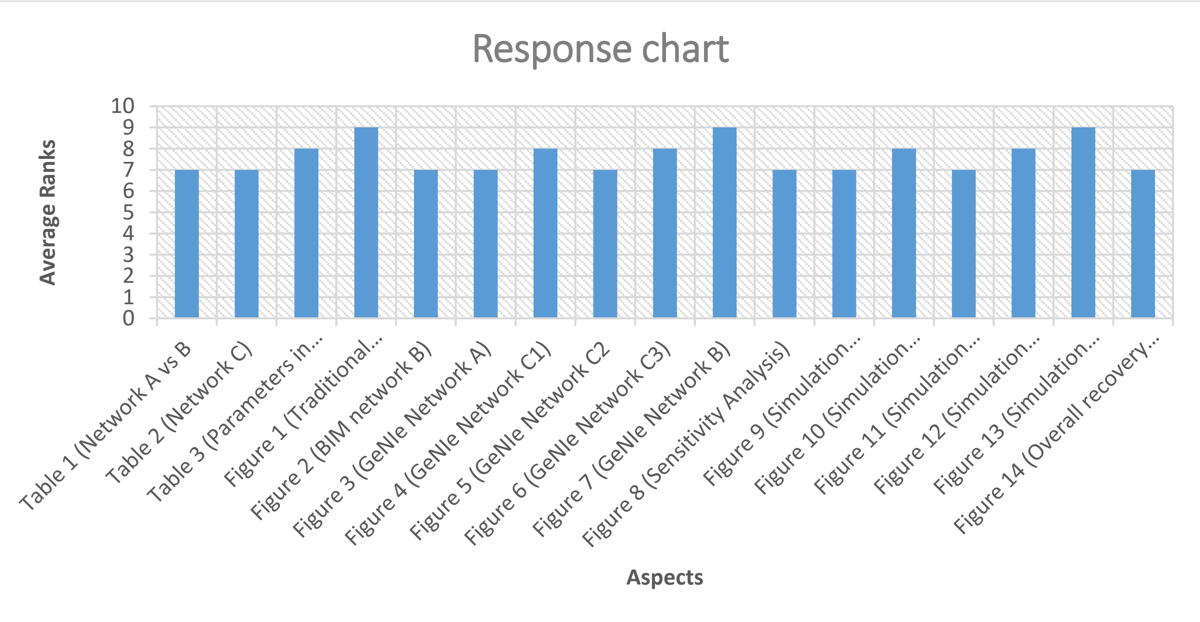

Figure 7.16: Responses of the experts

7.6 Conclusion

The primary objective of this paper is to examine the real-time benefits of adopting building information modelling for refurbishment project by using agent-based simulation mechanism. A Bayesian network was very effective in identifying the impact of error on the different stakeholders in the project network. The error introduced at the architect domain shows different impacts on the project networks. Although the different networks show almost the same pattern of error propagation, there are differences based on the impact of errors on the project stakeholders. The sensitivity analysis indicates in each network (Figures 7.4-7.8) the project stakeholders who are likely to be highly influenced by the introduction of error by the differences on their colour as shown on the nodes. The nodes were set to be observers. The red coloured box/es indicates that the stakeholders are negatively impacted, and their decisions are not construed, while the white colouration shows positive impact and their decisions are construed. This is also evident based on the simulation result of the error propagation observation of each node as shown in Figures 7.10-7.14. The plots represent the overall diffusion of errors, recovery time, and the percentage of error perceived.

In summary, the result shows that it takes more time for traditional project network to recover from uncertainties such as design error compare to BIM network. It also indicates that stakeholders in a BIM network almost identify errors and recovers at the same momentum compared to the traditional network. The main architect who makes the error recovers instantly at the BIM network compared to the traditional network. This is because of the improved linkages (or edges) offered by the BIM network creating a stronger social network with increased collaboration between the project team members. Hence, these shows that there are real benefits for adopting BIM for refurbishment projects as shown with the sensitivity analysis and error diffusion mechanism carried out on the different network model. This is significant through the improved collaboration mechanism of the project stakeholders within the project.

In conclusion, this chapter provides justification for BIM adoption as a dynamic process and very essential having increased performance benefits for an improved work quality through a healthy collaboration of stakeholders on the refurbishment project case study. The desktop audit (Figure 7.16) indicated that the networks are a representation of the case study project network and highly relevance to the projects. The next chapter will use focus group research method to examine real factors that impact project stakeholders' decisions to BIM adoption.

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Chapter 8 The Implication of BIM Adoption for Refurbishment of Complex Buildings in New Zealand

8.1 Prelude

This chapter concludes the validation of the findings in chapter 4, 5, and summarises the solution to implement BIM for project stakeholders who are interested in refurbishment of existing buildings giving optimisations as offered in chapter 3, and 6. Although, The need for the adoption of Building Information Modelling (BIM) for refurbishment of complex building projects in New Zealand construction industry has been widely acknowledge by the scientific community, however, the level of its implementation is less encouraging. Most of the literatures examined only the benefits (drivers) of BIM adoption and barriers in general perspectives, little or no research has been made specific to refurbishment project stakeholders and what influences their decisions to adopt BIM. This qualitative research study critically analyses the main factors that influences BIM adoption, and offered solutions to BIM adoption in refurbishment projects in New Zealand through an in-depth focus group data collection method with key industry practitioners and stakeholders. The research findings reveal a contrast in perceptions regarding factors that impact BIM adoption among those who have already adopted BIM and others who are still in pre-maturity BIM adoption stage in refurbishment projects. These findings are useful for validation of results obtained in the current literatures on the factors that impact refurbishment project stakeholders to adopt BIM. The results of this study conclude that the perception of the BIM Implementation cost is the main factor contrary to the cost of establishing a BIM model by different literatures.

8.2 Introduction

Building information modelling (BIM) is the new technology breakthrough that is necessary to modernise architecture, engineering and construction (AEC) industry, ensuring increase in productivity and value across many stakeholder groups. Although the challenges towards adoption of BIM for refurbishment of complex building is starting to have considerable debate within the literature (Okakpu et al., 2018), considering the triumvirate on BIM which includes people, process and technology, people have been the slowest entity to evolve (Gu & London, 2010). Numerous authors investigated the BIM adoption implementation challenges and issues within the perspectives of engineers including consulting services (Arayici et al., 2011a; Gardezi et al., 2014; Mohd-Nor & Grant, 2014; Won et al., 2013), however less focus has been towards main refurbishment stakeholders such as the facility managers and space coordinators including space users within tertiary institutions. A comprehensive and integrative view of key refurbishment stakeholders is necessary as these key stakeholders can help in contributing towards BIM transition within their operations as a client-organisation. In addition, most employers or government parastatals play an important role in adoption of BIM in the developed countries such as US, Australia (Porwal & Hewage, 2013; Sebastian, 2011), New Zealand is still at the midst of BIM adoption (Salleh & Phui Fung, 2014) despite being among the developed countries in the world. Therefore, using New Zealand as a case study for refurbishment projects can contribute to an added advantage to all developed and developing countries planning to adopt BIM for refurbishment project in order to understand the most influential factors and face solution dynamics.

The present study aims to investigate the overview and adoption of BIM from the perspectives of New Zealand client-organisation who are facility managers for refurbishment of multipurpose buildings (e.g., tertiary institutions). Subsequently, the current study objectives are to determine the key impact factors and solutions to BIM adoption for refurbishment of complex buildings from refurbishment stakeholders and BIM experts in New Zealand. The practical manifestation of the results of this research study would open up new avenues for facility managers and all other client organisation at prematurity level that manage existing buildings to understand what BIM is about, BIM's diffusion, and hence, increases the adoption rate. Considering the rapid evolvement of BIM in other developed countries, the timing of, and path of entry into BIM are of great importance for refurbishment projects. Gu and London (2010) affirmed that most industries are slow to adopt BIM in practice regardless of BIM rapid growth in capabilities and the availability of BIM supporting functions.

The identification of factors that causes the highest barriers to BIM adoption for refurbishment project could accelerate BIM adoption and encourages appropriate strategies to motivate solutions to BIM adoption. Although, a good number of empirical studies investigated barriers and strategies of BIM adoption, these studies are limited to quantitative survey questionnaires. Hence, this study adopts a focus group (qualitative) study in order to present a richer, more comprehensive picture of the influence factors and solutions to BIM adoption for refurbishment projects.

8.3 Research Background

The potentials of BIM adoption is to improve the refurbishment work flows so as to mitigate cost overrun, critical decision and save time by project stakeholders (Chong et al., 2017). There are authors that have contributed to BIM adoption study for refurbishment project. For example, Volk et al. (2014a) focused on the technical problems related to BIM implementation. This includes updating and handling of uncertainty of data information of BIM in existing buildings. Earlier studies proposed a framework to understand tools and drivers that motivate BIM adoption for refurbishment projects (Gholami et al., 2013; Sheth et al., 2010b). Another study also focused on the clients as homeowners preferences and how it influences BIM adoption for refurbishment projects (Park & Kim, 2014). Essentially, homeowners' choice is mainly "cost" against the method of refurbishment as "thermal performance" preferred by contractors.

Furthermore, there is an investigation for the essential barriers to hinder BIM adoption for housing refurbishment (Kim & Park, 2013a). The barriers are twofold: the first is from the clients indicating lack of knowledge about refurbishment technologies, while the second is the construction professionals indicating lack of skills, and fragmented practices. These portray the lack of unawareness and subsequently lead to underestimation of real BIM benefits for refurbishment projects. Although one benefit of BIM for refurbishment project is that it enables life cycle data management which facility managers (FM) can use to maintain an existing facility (Ilter & Ergen, 2015), Volk et al. (2014a) suggested that there are hindrances to adoption of BIM for existing buildings considering the lack of research to investigate the risks and barriers for post construction stakeholders and FM in adopting BIM for existing building facilities. However, an author indicated that it is as a result of low participations of FM and refurbishment stakeholders towards the development of strategies to adopt BIM for refurbishment projects (Becerik-Gerber & Rice, 2010b). Following the existing literature (Okakpu et al., 2018); Okakpu et al. (2019) identified influencing factors for BIM adoption specific to refurbishment project stakeholders in New Zealand using survey method. These factors include; policies and standards, client expectation, information sharing, organisation culture, and retrofit tool.

Chapter 4 and 5 identified the risks factors and refurbishment project attributes that impact BIM adoption for refurbishment projects. These included technical, financial, social-cultural, and skill factors, as well as contractual project attributes including people's attitude, openness towards the project stakeholders, skills and expertise, scope of the project, data and information management. The table 1 shows the gap on the methodology approach for recent BIM adoption and refurbishment projects. It also summarises the different methodologies applied. It further shows that current literatures are mainly based on literature reviews methodology and survey-based questionnaires.

There are however limited number of qualitative research method using focus group method to understand critically the underlying factors that impact refurbishment project stakeholders to adopt BIM for refurbishment project (figure 1). This is because, focus group can be used to examine the differences and flaws from different group members in order to shed more light on the issues (Hydén & Bülow, 2003). Considering general BIM adoption studies, (Arayici et al., 2009b) identified two main barriers to BIM adoption which is the insufficient familiarity of companies on BIM use and the reluctance to adopt new workflow and train staff.

Table 8.1:previous literatures on BIM adoption for refurbishment projects

No	Authors	Research work	Research method
1	(Lewis, 2014),	Communication platform between stakeholders	Survey
2	(Bu et al., 2015),	Framework theory to education	Literature review
3	(Arayici, 2008a),	Production of 3D CAD models/BIM models;	Case study approach
4	(Gholami et al., 2013)	Improvement of social challenges of occupants;	Literature review
5	Alwan et al., 2015)	3D simulation transfer processes;	Case study approach/ simulation
6	(Geoffrey Shen et al., 2015),	Influence factors examined separately in the design process	Literature review
7	(Chaves et al., 2015),	Alternative solutions considering cost and energy performance	Simulations/ face-to-face interviews
8	(Carvalho et al., 2016)	Energy analysis;	Case study approach
9	(Khaddaj & Srour, 2016	Review for BIM and refurbishment projects	Literature review
10	(Zanni et al., 2013),	Capability of BIM in rating systems	Case study approach/modelling
11	(Chong et al., 2017),	Streamline BIM uses in every refurbishment aspect	Literature review

12	(Im & Bhandari, 2012)	BIM and energy analysis software;	Case study approach/modelling
13	(Khaddaj & Srour, 2016)	Uncovers where BIM is lacking in refurbishment projects	Literature review
14	(Di Giuda et al., 2015)	Management and maintenance	Case study approach/modelling
15	(Ilter & Ergen, 2015),	Feasibility of BIM: current status and future direction	Survey and face-to-face interview
16	(Kim & Park, 2013a),	Barriers to BIM application, solutions; increase BIM awareness and financial support	Survey and face-to-face interview
17	(Park & Kim, 2014),	Homeowners preferences	Survey
18	(Volk et al., 2014a	Handling uncertainty data information, a review.	Literature review
19	(Alwan, 2016),	BIM framework to manage aging housing	Analysis software
20	(Sheth et al., 2010b)	Adoption of BIM to increase sustainability	Survey, site visit, interview
21	(Kim, 2015)	Development of a BIM framework to formulate a financially and environmentally affordable whole-house refurbishment solution based	Survey
22	(Barbosa et al., 2016)	Discussion on improvement of collaboration towards the production and usage of BIM standards in various countries.	Literature review
23	(Okakpu et al., 2018)	Formulation of research framework for investigation of BIM adoption dynamics for refurbishment projects	Literature review
24	(Kelly et al., 2013)	Investigated the value-adding potential of BIM and the challenges hindering its exploitation in FM	Literature review
25	(Okakpu, 2019)	Risk factors that impact adoption of BIM for refurbishment projects	Face-to-face interview
26	(Okakpu, 2019)	How project attributes of refurbishment project a driver or barrier?	Face-to-face interview

Ku and Taiebat (2011) identified cost and lack of skilled personnel as major barriers to BIM adoption. Ghaffarianhoseini, Doan, et al. (2016) in their earlier studies in UK, identified lack of awareness and understanding about BIM to impact BIM acceptance within small and medium scale construction companies in UK. While McCartney (2010) identified change in the design and construction process to impact BIM adoption in New Zealand. Overall, many authors are of the view that cost of implementation and lack of training were the main BIM adoption barriers. Nevertheless, McCartney (2010) argued against this notion about cost of implementation after conducting an interview in Auckland through a survey. For this reason, they recommended change in procurement method of traditional practices to integrated and collaborative as such under design and build. However, most of the literature is based on quantitative surveys and have limited response rates. Secondly, the researcher may not be certain if the respondent is indeed the target person under the questionnaire. Hence, the respondent might therefore not be the appropriate person for the research. Consequently, it portrays a risk that the respondent might not have knowledge of BIM.

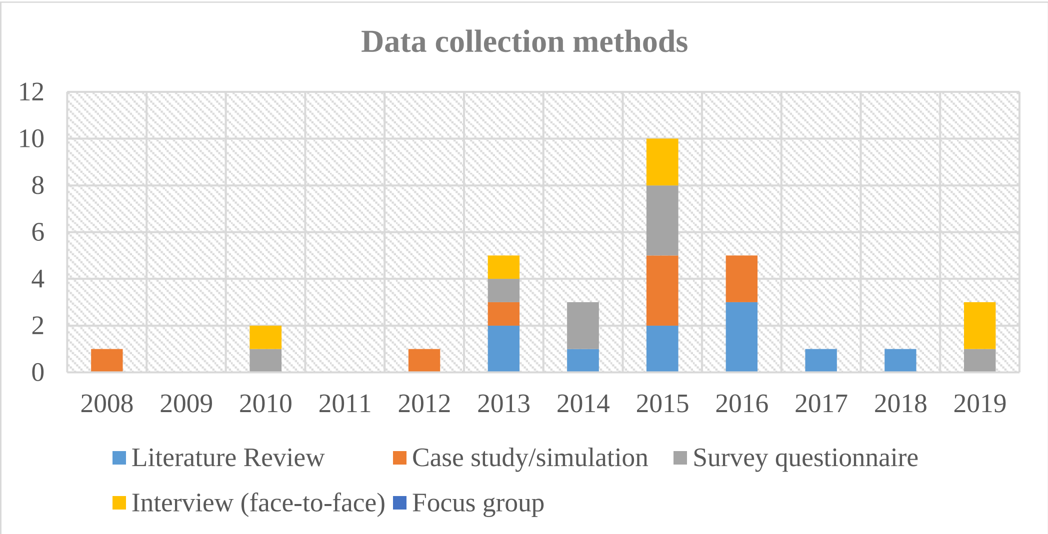

Figure 8.1: Previous data collection methods in the literature

Therefore, the purpose of this study is to further investigate and validate the recent findings from the current literatures by using focus group discussions in the scope of a

BIM workshop since focus group method is a useful approach to explore differences in the previous findings (Liamputtong, 2011) in order to obtain a validation on the major drivers and barriers to BIM adoption for refurbishment project. In addition, focus group discussions can be viewed as the appropriate method to achieve the purpose of this study. The focus group method will be expanded in the following section.

8.4 Methodology

This study is based on issues identified in the existing literature and uses focus group discussions in a BIM workshop. The literature focuses on previous investigations and the methodologies adopted by the authors who investigated BIM adoption for refurbishment projects. It further extended this review to acknowledge other factors found by previous authors in a general perspective, and then concluded by updating with the current literature on influencing factors specific to refurbishment projects based in New Zealand construction environment. Several factors are obtained through a survey method and later analysed using structural equation model. Since most of the earlier studies employed survey methods, hence qualitative data obtained from these is limited in nature. Therefore, the second phase of this study uses focus group meeting to discuss specific topic on the study. Thus, the aim is to extract an understanding through interpretation made by the selected people from the study background (Liamputtong, 2011).

The participants were selected based on their BIM experiences as suggested by (Burrows & Kendall, 1997). For example, four of the participants have BIM experience but have not started using BIM for their refurbishment projects, while the other half equally have BIM experience and are using BIM regardless the size of the project. As the aim of the study is to identify drivers, barriers and the solution to adoption of BIM for refurbishment project, the selections based on the participants constitutes a richer and a more detailed approach for exploring diverse viewpoints on the participants having some BIM knowledge, and thus would allow to reach a fuller understanding of the topic. As such, focus group meeting extracts a multiplicity of views and perspectives within a group and larger amount of information can be obtained within a short period of time.

The focus group consist of 7 participants from different backgrounds in order to facilitate better interaction and richer discussion from different professions. A typical number of focus group participant ranges from 6 – 12 within 60 to 120 minutes is sufficient enough to produce a rich data (Morgan, 1997). This is to ensure that there is a broad range of perspectives that constitutes a representative of the opinions of various professional background. Through these means, the main drivers, barriers of BIM adoption for refurbishment projects are elicited and appropriate solutions are proposed by the participants. All the previous findings where designed as a guide for the focus group meeting. Although, to avoid repetition of same questions, the questions were remodelled to cover the entire data collected from the previous data collection on the current literature. A moderator was appointed to facilitate interaction between the participants. The meeting lasted approximately 60 minutes. Extensive notes were taken by the moderator during the focus group meeting. At the end of the section, data was collected and analysed based on (Krueger & Casey, 2000; Rabiee, 2004) procedures. Based on these procedures, analytically we used five key stages were followed: familiarization; thematic framework identification; indexing; charting; mapping and interpretation, all as recommended by (Krueger & Casey, 2000) to analyse and manage the qualitative data.

After the collection of data, the notes taken during the meeting was read several times during the discussion in order to make sense of the idea and to formulate major themes. Short notes were taken for formulation of the thematic framework through the ideas arising from the notes taken to develop categories (Rabiee, 2004). To reduce and filter the data, indexing and charting was conducted by pasting similar quotes together. In order to map and interpret the data for validation, establishment of relationships and links between the data and the current literature is conducted. Therefore, at the end of the data analysis, the results were discussed with the research team to confirm their validity and that nothing was left out. The findings are reported in the next section.

8.5 Results and Discussions

8.5.1 Overview

Through the focus group meeting, the research team were able to gather important players that covers important stakeholders that are majorly involved at the operational level of building, refurbishment and maintenance of the AEC industry. They were specifically BIM managers, Architect, Value Manager, Project Manager, Space Coordinator, Engineer, and Contractor. With the active participation of such participants, the main goal of the focus group was to validate the findings in chapter 3, 4 and 5 of this thesis by uncovering and analysing the industry perceptions on the drivers and barriers of BIM for refurbishment stakeholders and thus, the solution to remedy the barriers to BIM adoption is discussed. Ethics was sorted to ensure the anonymity of the participant (Auckland University of Technology ethics, 2018). The focus group meeting showed that the level of BIM awareness, knowledge and interest across the disciplines varies. Although, the main issues to adoption of BIM are often shared among each of the participants, the responses gained during the section are reliable and provides information of high value for this study.

8.5.2 Drivers to BIM Adoption

The drivers to BIM adoption for refurbishment project were discussed by the industry professionals during the focus group meeting. Participants considered that the drivers of BIM are dependent on what clients know about BIM or its benefits. For example, when you consider refurbishment projects stakeholders in New Zealand, a lot of clients really don't know what BIM is all about. Hence, they would expect that the consultant would sit with them and explain to them and give them the information: what it is and what to expect. The participants wondered why many clients would still say that *"I have heard BIM, but I don't know what it is."* The participants agreed that many industry people say this, looking for an explanation to them how BIM adoption would affect their projects. In this regard, the participants considered that drivers of BIM for refurbishment project have two sides: (1) the consultant perspectives and (2) the client perspectives. Most of the consultants who adopted BIM was due to that BIM drives efficiency, including understanding of better information as contained in the BIM model and the design so, would adopt BIM whether they are required to adopt BIM or not. Even though the client may not request for BIM model, the consultant already understand the benefit of BIM, and hence, uses BIM to deliver the project since for them, it has benefits towards a better product and performance of a delivered project. There are also internal decisions that favour the implementation of BIM regardless of the scope of the project. So, from the consultant perspectives, scope is not considered as a barrier.

In the second part which is the client perspectives, there is a long time benefit significant to BIM adoption. Hence, when organisations have a BIM model built with enough information recorded for it, then the stakeholders will be able to use the asset management system during the life cycle of the building. In the meantime, the refurbishment project attributes play an important role since in a traditional delivery of project, design and construction cost is too less as compared to the cost associated with the maintenance of the project throughout its life cycle. The participants who implemented BIM in the past confirmed that one driver of BIM adoption is that the model can be easily assessed by none BIM experts without paying any money since BIM is not a proprietary software. They don't have to pay for it, they are only required to use it. They can select any element and directly see the attribute and information in the model during a site inspection for existing building. In this regard, taking a holistic picture that contains deteriorated building member damages and attributes put into BIM are sent into 3D web virtual model, and advocate this model, select an item and see the properties of that element and link it to the report. So, the driver here is that someone without BIM skills or proprietary software to drive BIM can read the model and navigate the 3D model compared to reading the 2D plan where everyone knows how to read unlike the 3D model.

Participants stated that the next driver is that the BIM model can be an easy asset for client – historically the client has a digital twine of their facility. They can know the manufacturers; the specifications and what elements is used. During the life cycle of the building, the most expensive part is the facility management of the building. Hence, there is a need to improve how these facilities can be efficiently managed. More importantly, the participants confirm that one of the drivers is about improving the coordination within the project stakeholders. Therefore, putting all the information together from all the groups such as the different contractors, subcontractors, engineers and different organisations involved in the execution of the project can be enhanced more efficiently and provide better records and control. By considering these drivers in this study, relevant parties will learn the main factors that drive BIM for refurbishment project and within New Zealand construction industries. In summary, the participants pointed that information sharing, coordination of services, knowledge of refurbishment project attributes, long time benefits, higher efficiency of projects are the main drivers of BIM adoption for refurbishment project.

8.5.3 Factors that impact BIM Adoption for Refurbishment Projects

There is lack of skilled personal to adopt BIM. According to the participants, there is currently a pressing need to upskill the expertise refurbishment stakeholders to manage the BIM model. This include setting up of the system in place, the people that can pull the information out of it, the setting up of BIM and the time factor. By doing this, the benefits and capabilities of BIM can be explained to motivate stakeholders to learn the new way of delivering refurbishment project. The lack of trained personnel to handle BIM is likely to result in low adoption and poorer perceptions of BIM. Hence, stakeholders must be informed about the skills needed, and the changes that will take place to enable a platform that encourages BIM adoption.

There is limited budget that impacts BIM adoption for refurbishment project stakeholders. Adoption of BIM also incurs a lot of financial cost. Such limited budgets do not allow the contractors to add BIM to tendering. Hence, the contractors would not want to include BIM so that they will not lose the contracts. Therefore, from the perspectives of participants who have BIM knowledge but have not implemented or adopted BIM believe that cost is the huge barrier for BIM adoption.

The lack of trust among project stakeholders is a barrier. Hence, there is difficulty to appoint who will look after the BIM model and hence portrays as very expensive in doing so. Consequently, participants agreed that culture of organisation is a barrier. Considering this factor, the participants sited examples of when the stakeholders do their specific work contribution in a project such as designs and finishes, and when they give out the as-built for operations to the FM for maintenance. The result is that these people are happy with what level of information the design engineers provide to them now. This revealed that the clients or other stakeholders are not so much aware of the BIM benefits and still rely on the traditional method of carrying out a refurbishment project. As a result, the industry fails to embrace the true potential of BIM. Majority of the participants who have BIM knowledge but have not adopted BIM agreed that the major barrier is about cost, scope and time. It was also mentioned that the three factors must go together, however, cost is the main factor. The participants raised a concern regarding the cost of BIM in training professionals “what about in 10 years’ time and another system comes out like this one when you have spent so much upfront and done all the training and coming back to see a better system than this, so we got to do it again, therefore, someone in the line will better make a decision on how far he can go” In this regard, the participants agreed that most of the industry professional are reluctant to adopt BIM simply because they think that another program like BIM will surface one day and the time and money spent to learn BIM becomes a loss, and consequently, are already familiar and comfortable with existing working practises.

The cost of BIM adoption has been the universal issue. It was raised by a participant with BIM knowledge who has adopted BIM, that cost appears to be a universal issue. For example, the participants agreed that there is a high cost involved with BIM adoption and usually the extra cost is about 10 to 15% during the design phase. To clarify further, these costs are supposed to be on a long time a cheaper option, but however, the background about the cost of BIM adoption is still unclear to the clients. Hence, the clients only understand that there is a higher initial cost with the BIM option than the project without BIM. In this regard, the client would ask to give them a proposal of work with BIM and without BIM. Although, there are higher cost from the conceptual design but if BIM is implemented at the beginning, it saves time at the downstream processes, especially when it gets to the construction, virtual design, construction methodology and the assets component management. There was an indication that overall, a BIM approach does not cost more but can actually reduce costs. Hence, the perceptions are that BIM are expensive, and people think that 3D is very expensive compared to 2D. Hence, the project stakeholders can therefore make assumptions that BIM is expensive.

There is a lack of BIM awareness. It was also found that the issue is not only with clients but including the project directors or project managers as they might have the same kind of assumptions and thinking that BIM will make them spend all their budget and hence are really reluctant to do so unless there is quite a demand for it by the client. Hence, cost of BIM application is not the issue with BIM adoption in New Zealand but rather the perception of cost of BIM implementation. Therefore, the industry players are aware of BIM but lack the necessary understanding. Hence, the critical barriers pointed out in this study are in line with the findings in the current literatures on the risks, and project attributes of BIM for refurbishment project. At the end, the participants agreed that the main influence factor is the perception of the cost of BIM adoption as shown in Figure 8.2.

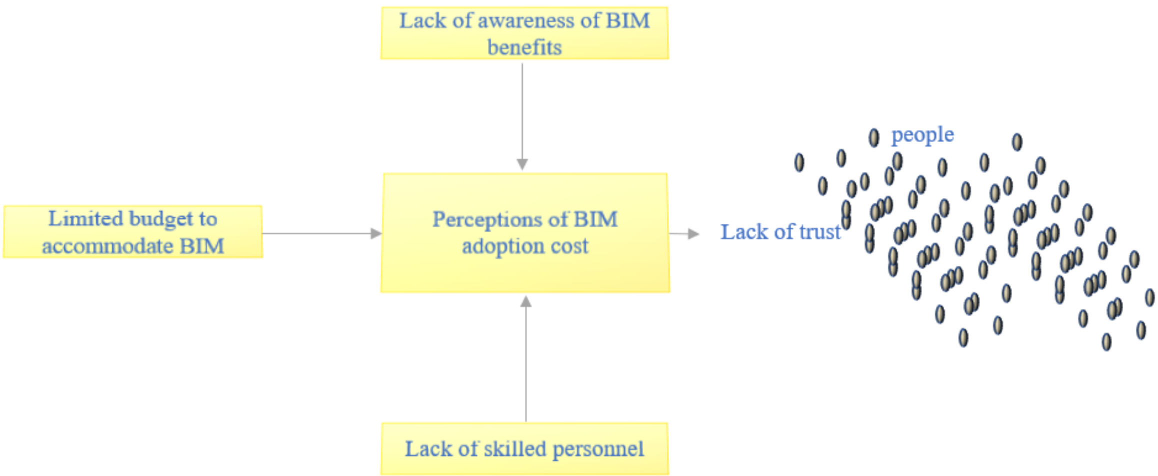

Figure 8.2: The main factors for BIM adoption specific to refurbishment project

8.5.4 Implication of BIM Adoption for Refurbishment of Complex Building

As highlighted by the focus group participants, there is a need to increase the knowledge about BIM. This could be done by creating awareness of how adoption of BIM will be better for facility managers, client's organisations, operations, maintenance and refurbishment stakeholders, and as a client organisation to show clients the benefit of what BIM will offer the entire stakeholders. The concepts of capabilities of BIM, the potential benefits and the clear understanding of BIM concept need to be explained to refurbishment project stakeholders in the industry. It is very crucial to indicate to the AEC industry how BIM adoption requires an up-front investment. An effective BIM implementation can offer organisations a long-term goal including maximizing return on investment (ROI) when compared to traditional method of refurbishment.

Moreover, there is need to educate the clients, and have them guided through the process. This process however can involve using the New Zealand handbook document throughout. There is equally the project BIM brief document which is a good guideline to use to sitting down with the client next to a BIM expert and to explain certain concepts, highlighting benefits, and what they can gain out of it. This includes how the downstream process is affected for effective BIM adoption. But it usually goes a long way if the educators will have the opportunity to sit with the client and have that kind of discussion and in terms of refurbishment project, if you are able to explain to the client will go a long way to improve BIM adoption. It is also difficult to retain staff with BIM knowledge as a result of lack of BIM experts. Hence, the participants suggested that tertiary institutions in New Zealand should start teaching BIM courses in their syllabus or provide outline courses for new buildings to existing buildings. In this regard, a proper linkage of BIM benefits to refurbishment project management would be realised. In this way, proper education about BIM to refurbishment stakeholders in New Zealand construction industry is necessary to cope with the slow adoption of BIM. Although the adoption of BIM requires a change in the working process and practices, this requires individual skill improvement to a greater collaboration.

The other challenge is people who have skills should move the BIM adoption. The first thing to do is to start with training plan and essential kind of skill, and then workout the skill development plan. Once the organisation decides to get the training in place, the stakeholders can start to equip themselves with BIM skills so that once the skills are okay, the BIM adoption process will start. Proper training is essential to ensure that the refurbishment stakeholders can use the BIM software, including understanding the new workflow requirements. The BIM adoption progress can be measured on 30% to 60% to 90% of the project as highlighted by one of the participants during the discussion. Hence, this can be achieved by fixing the deficiencies and coordination, and at the end of the project will be able to show what success has been achieved and that is where the success lies. In a real sense, the construction stakeholders who has no familiarity with BIM knowledge tends to remain in the traditional method. Hence, when there is no proper approach to dealing with these changes, the implementation or the acceptance of BIM is bound to become ineffective.

The policies surrounding adopting BIM for refurbishment of complex building projects with a minimum budget of five million dollars need to be addressed. The policies around refurbishment project was highlighted by the participants as one of the challenges that determine whether the refurbishment stakeholders would give a second thought to BIM adoption or not. The budget should not be specifically set at this value for a condition to adopt BIM because there are many organisations that use BIM irrespective of the scope of the project. What the organisations is after is a better performance of their products. In this regard, the industry stakeholders should change their perceptions of the notion to adopt BIM for a project scope of five million dollars and above. A lesser value might be more complex than the high scope projects as indicated in chapter 2. In addition, the majority of the participants maintain that in terms of BIM adoption for client organisations, since the clients work with consultants including contractors, the clients should establish a mandate for these professionals to work for them, are required to be BIM competent and hence it is required of them to use BIM to manage the design towards the refurbishment project. Then it will be established that the contractors who wants to work for the clients are those with BIM attributes and are BIM capable. Hence, these would enforce these professionals to improve on their skills in order to win contracts for better leaving.

Another requirement is to explain the benefits of BIM to project participants. For example, where a project manager would demonstrate to his organisation that it can take too long – and be too expensive – to achieve a set of goal in the project traditionally, and thereby believing in the benefit that BIM will change his way of delivering the project would absolutely work. The same is for all the facility managers that require the examples of BIM benefit to motivate their organisations to have a rethink towards BIM adoption. Even though the adoption of BIM has different approaches for different industries such as Engineers whose perceptions are that BIM takes longer time to adopt is contrary to the perceptions of the architects who lead BIM, and hence an easy avenue to improve adoption of BIM would be through education as highlighted by participants during the focus group meeting. Although the adoption of BIM is not an easy process and could take time for refurbishment stakeholders to be comfortable with the technology itself, in this regard, the focus group meeting had identified factors which is shown in four steps towards a fundamental approach to BIM adoption for stakeholders who are at the pre-BIM maturity state as shown in Figure 8.3.

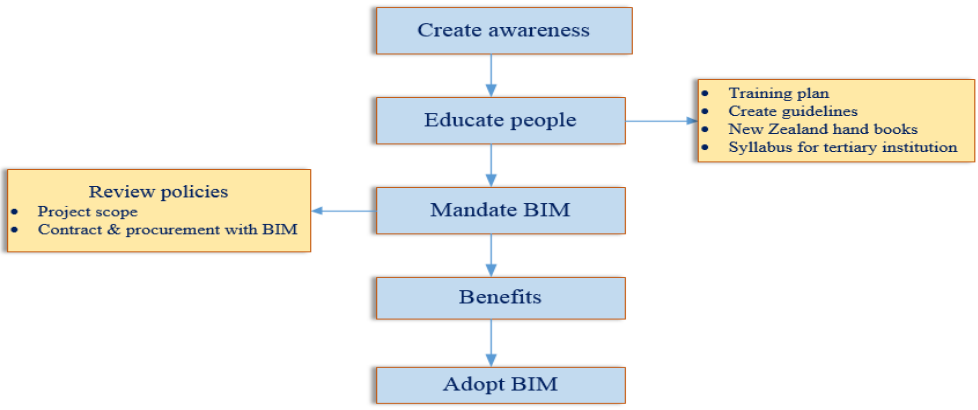

Figure 8.3: Steps to enhancing BIM adoption

The steps suggested by the focus group must be considered for BIM adoption to start gaining momentum for refurbishment of complex buildings in New Zealand construction industry. Firstly, proper awareness should be carried out to gain better understanding and confidence about BIM among the refurbishment stakeholders. This initial step requires a high degree of commitment from all the refurbishment stakeholders, institutions and competent individuals to preach awareness of BIM adoption and its benefits for refurbishment projects. Secondly, there should be a Syllabus and an outline to educate students about BIM and its benefits in tertiary institutions and as well as coordinating certificate classes on BIM knowledge for construction industry stakeholders. Thirdly, different organisations, clients and government parastatals should mandate that only BIM competent construction professionals can handle their project or obtain contracts from them. There is also a need to show the industry stakeholders the real benefits of BIM for their refurbishment projects. This is also very paramount as the industry stakeholders keep on demanding for real benefits of BIM to enable a greater uptake for project performance improvement. In this regard, understanding the potential benefits of BIM has the potential to increase the rapid growth on BIM adoption for refurbishment stakeholders in New Zealand construction industry. Therefore, it is believed that the steps suggested by the focus group participant offers an efficient avenue to channel stakeholders to become BIM capable.

8.6 Conclusion

This paper discusses the implication of BIM adoption for complex refurbishment project in New Zealand through understanding the impact factors towards adoption of BIM through a focus group meeting. From this, development of a strategy to minimise influence factors by offering solutions to BIM adoption for refurbishment project stakeholders at the prematurity BIM level was offered. With factors as pinpointed by the focus group participants such as the information sharing, coordination of services, knowledge of refurbishment project attributes, long time benefits, higher efficiency of projects, the broader adoption of BIM in the AEC industry is very promising. Although the level of BIM adoption is still low for the entire AEC, different researchers have carried out studies using different techniques such as quantitative methodology involving questionnaire-based survey and other qualitative face-to-face interviews. Based on the current literature, findings from the survey shows that the contextual factors that impact project stakeholders to adopt BIM is policies and standards, client expectation, information sharing, organisation culture, and retrofit tool and has been validated (Okakpu et al., 2019). Considering the face-to-face qualitative interview findings from the present study which highlighted the risk factors and the project attributes, indicates many factors that impact on stakeholders' decisions to adopt BIM. Although BIM adoption is considered an unknown novelty among different professionals in the construction industry, the application of focus group methodology introduces healthy interactions and reach discussions among the participants with a broad range of BIM knowledge (from little to full knowledge) regarding BIM for refurbishment project. Hence, the authors of the current study identified main factors of BIM adoption for refurbishment project and at the end, offered solution to BIM adoption to validate and ensure consistency of the discussions.

Based on the risk factors identified in the current literature, financial risk as cost is the main impact factor while in the focus group meeting, although cost of BIM adoption was mentioned as one of the main factor, further discussions based on the main factor was found that the main factor was the perception of the cost rather than the cost itself. In this regard, the perceptions of the stakeholders can be linked to their attitude and perceptions towards technology innovation. Hence, this indicates a similar finding in the refurbishment project attributes where one of the major factors are from the attitudes of the refurbishment stakeholders which requires greater work to increase BIM knowledge (Okakpu, 2019). The findings as found in the focus group meeting shows that some factors inhibit BIM adoption for refurbishment project including lack of training, resistant to change, culture of organisation, cost of BIM which goes with scope and time, and lack of BIM awareness. The lack of training is very important as the participants mentioned that with good skill about BIM will give a positive perception about the cost of BIM adoption. Therefore, the result of the finding shows that there is greater need to train refurbishment project stakeholders to become BIM capable and to create awareness as this will change the perceptions of the cost of BIM. The findings revealed that the main influence factor is not the cost which is in consistent with (McCartney, 2010) studies on quantitative survey of general barriers on BIM adoption in New Zealand construction industry. However, the current findings indicate that it is about cost perception regarding BIM. However, the focus group findings also indicated that the main factors that drivers BIM adoption for refurbishment project includes information sharing, coordination of services, knowledge of refurbishment project attributes, long time benefits, higher efficiency of projects. These factors are in consistent with previous literatures (Okakpu et al., 2019; Park & Kim, 2014) and also in consistent with validation for the environmental factors that impact project stakeholders to adopt BIM where culture of organisation, policies and standards, information sharing, clients expectation, and retrofit tools influence BIM adoption for refurbishment project. Therefore, the present findings portray useful reflection of the relevant BIM adoption influence factors for refurbishment project stakeholders in New Zealand.

Subsequently, the focus group participants suggested several ways to minimise barriers towards adoption of BIM for refurbishment of complex building projects. It is easy to say that technology adoption comes with many unfavourable conditions. This unfavourable condition to adopt BIM can be minimised by conducting awareness programmes either through seminars or workshops. This is the first key identified by the focus group discussion as it is a very import component towards an effective adoption of BIM. In addition, the use of education to train stakeholders and as well as introduction of BIM syllabus to tertiary institutions on how to manage an existing building with BIM guidelines will be very useful to improving the current state of BIM level. The next step is to mandate BIM through governments and private sectors. Hence, the client organisations such as tertiary institutions who has many existing buildings and can refurbish existing complex building yearly should make it compulsory for stakeholders who would like to tender for contracts to be BIM capable and as well produce BIM models used for refurbishment projects. Finally, the identification of BIM benefits is very crucial as a motivation factor for stakeholders since they refurbishment stakeholders continuously demand for real benefits of BIM. It has the capacity to enable BIM uptake. These steps have been proposed by the focused group participants to enhance BIM adoption.

Chapter 9 General Discussion of the findings & Recommendation

9.1 Introduction

This chapter presents a summary and synthesis of the important points of the entire research findings. This chapter portrays the concluding aspect of the findings across all aspects of the thesis. The chapter contains information about the challenges of BIM adoption for refurbishment projects and through the formulation of research framework for the research have been made in the preliminary parts of the thesis. The framework pinpoints the strategy to follow for a BIM adoption research for refurbishment project study. The results of the findings as presented by chapters 3 to 7 seeks to answer the questions posed in the literature settings and to address the issues identified. The questions have been addressed by the different manuscript chapters in the thesis. A synergy of all the information collated from the literature review through to the research investigations is therefore presented under the following sub-headings. Essentially, this chapter completes the triangulation of the research study.

9.2 Synthesis of Findings

The research has confirmed the multidimensional factors associated with the adoption of BIM for refurbishment project in New Zealand. This refurbishment project is generalised on the multipurpose building type and client organisations such as the tertiary institutions in New Zealand as building owner. It is now apparent from the investigations that, the four dimensions identified in chapter 2 provide direction for deeper research investigation. In the general perspectives of refurbishment project and BIM adoption in New Zealand, the adoption of a case study of a multipurpose building allows to identify the risks and project attributes as it impacts BIM adoption in New Zealand construction environment. Although, the evidence of the findings on contextual factors would offer optimisation for BIM adoption through the assessment of the project stakeholders, overall, solutions have been also proposed to optimise BIM adoption as it arises during the research study.

In the current study, the research reaches a conclusion that BIM adoption can be improved by providing awareness and education is among the topmost avenue to improve BIM adoption in New Zealand construction industry. The study, through the interaction study (chapter 6 & 7) indicated the area that require increase in collaboration among refurbishment stakeholders based on the case study adopted. By so doing, the realisation of potential BIM benefits will be achieved through investigations of error management and the sensitivity analysis carried out as presented in chapter 6 of the thesis.

Generally, the information obtained from the research encompasses the realisation of three research benefit mechanisms which includes (1) the early decision making, (2) improved collaboration and (3) error minimisation. An outline of the key research investigations is made on the following subheadings as addressed by the thesis chapters. Each chapter in the manuscripts addresses at least a research question as posed in the research framework in chapter 2. The research results are also discussed within the context of the research investigations and the opinions expressed by the subject matter experts to the study. The objective of each of the chapters in the thesis is to answer research questions. Although, the final chapter contributes to the overall validation of the findings obtained from the survey and as well as the qualitative face-to-face interviews, the discussion part comments on the final validation of the findings in the research. Therefore, the objective of this discussion is to bring all the findings in the manuscripts into a coherent form that will put any suggested effectiveness of BIM adoption for complex refurbishment projects.

9.2.1 The Research Framework Development

The literature review for this study is used to propose a framework for the research investigation. In chapter two, a review of relevant documents and journal papers to identify the gap in the literature which resulted to investigation of BIM adoption effectiveness for complex refurbishment projects has been completed. The literature review presented the research direction and the problems faced by refurbishment project stakeholders to adopt BIM. Several studies have investigated how to improve adoption of BIM for refurbishment projects (Ilter & Ergen, 2015; Park & Kim, 2014). The distinction in this thesis is that the previous studies are limited to research framework development which contains components that has been implemented through later studies as proposed in the literature review. A description of the components as contained in this framework is presented below.

9.2.2 Environmental Influence Factors

The literature review shows that there are factors that influence how organisations respond to the adoption of IT innovation for the refurbishment of building projects (Maahsen-Milan & Fabbri, 2013; Manfredini & Leardini, 2014). While these factors can be useful in analysing the needs of stakeholders, managerial risks, and project plan (Gido & Clements, 2014; Liang et al., 2015), the need to identify these environmental factors became apparent (see chapter 1). However, there is no consensus among scholars regarding the standard classification of these environmental factors (Liang et al., 2015). As identified in the literatures (chapter 1), one obvious thing is that the evolution of technology has affected the way businesses operate, thereby requiring construction firms to cope with the changes in their business environment (Ongori & Migiro, 2010). Considering that BIM tool is generic (Abdirad, 2016; Bew & Richards, 2008), the need to identify the main environmental impact factors, considering the culture and collaborative environment of complex refurbishment project will contribute to enhancing adoption of BIM (Abdirad, 2016).

9.2.3 Stakeholder Interaction

The refurbishment stakeholders are those actors that have an interest in a particular refurbishment project (Beringer et al., 2013). One characteristic of Architecture, Engineering and Construction (AEC) industry is the unconventional nature of networks of stakeholder interaction which constitute building and construction projects (Linderoth, 2010). This has contributed to the challenges within projects including knowledge transfer in organisations and the diffusion of innovation propensity (Linderoth & Jacobsson, 2008). Hence, the study proposes investigation within the interaction dynamics of refurbishment project stakeholders to understand the benefits in which BIM adoption can offer project stakeholders. At the end, the research study offered avenue to investigate how the interaction in the traditional method of executing refurbishment projects as per complex buildings impact on the adoption of BIM despite the uncertainties that occur in refurbishment projects. This intention was made to solve real-world problem order than relying on theories as suggested by (Freeman & McVea, 2001).

9.2.4 Refurbishment Attributes

The refurbishment attributes carry information about the characteristics of a given project (Ali, 2014). Because refurbishment projects are risky, complex and full of uncertainties within the construction industry (Ali et al., 2008), Miller and Buys (2011) added that refurbishment projects are more complex to a new build. This is due to lack of existing building information (Ali et al., 2008), complicated cost-sharing (Miller & Buys, 2011) and lots of stakeholder interactions (Klotz & Horman, 2009). This makes the design process very complex. In this regards, although BIM faces challenges of adoption due to a fragmented construction sector and complicated stakeholder requirements within refurbishment stakeholders (Park & Kim, 2014), the current research indicated that identification of attributes for complex refurbishment projects will go a long way to showcase the main drivers and barriers specific with BIM implementation.

9.2.5 Process Optimization

The study has shown that the investigation on the effectiveness of BIM adoption and its benefits for refurbishment projects requires a thorough investigation of the entire project stakeholders and the interactions within the project. Although earlier studies have been centred on a technical aspect of BIM (Arayici et al., 2011b; Park & Kim, 2014; Sheth et al., 2010b). Even though technology adoption should involve technical and social activities (Tulenheimo, 2015; Zheng et al., 2016b), hence, the current study investigated technical issues with BIM adoption as perceptions and social activities as the interaction of project stakeholders through structural or process optimization. To do this, the study used a case study and adopting Social Network Analysis (SNA) to simulate interactions and perceptions based on the role of stakeholders in a given refurbishment case study project versus a virtual BIM implementation for the same project. The potential findings are useful for real BIM benefits for refurbishment project stakeholders at pre-maturity level. By process optimisation, the main stakeholders with little collaboration was resolved through the social network analysis which shows the importance of increased collaboration among project stakeholders.

Given limitations in the literature, the overall question of this thesis was "What "environmental factors" influence stakeholders towards the adoption of BIM for refurbishment projects? and How does the structure of "interaction" of the stakeholders in the current refurbishment practice impact on BIM implementation?"

Specific questions were:

I. What are the environmental factors that influence stakeholders' decisions to adopt BIM for refurbishment of complex building projects?

II. What are the specific risk factors that influence stakeholders' role in refurbishment of complex buildings?

III. What are the clear benefits between the traditional method and the BIM method?

IV. What are the perceptions of BIM adoption by the refurbishment stakeholders?

V. In what ways can the interaction of stakeholders be optimised to enhance a platform where BIM can be implemented?

Therefore, the series of studies conducted addresses these questions and is used efficiently to investigate the effectiveness and usefulness of adopting BIM to increase value and as well as acquiring a competitive advantage for refurbishment projects.

9.3 Contributions

Key contributions of the thesis are provision of evidence for: (i) the main environmental factors that impact refurbishment project stakeholders to adopt BIM in New Zealand and validation using structural equation modelling; (ii) The risk factors that impact project stakeholders role towards BIM adoption for refurbishment project; (iii) Validation of benefit of BIM adoption for refurbishment project through error management; (iv) Validation of improved collaboration benefits of BIM using Gephi network; (v) validation of early decision making through sensitivity analysis using GelNIe software; (vi) identification of refurbishment project attributes; (vii) Overall validation of factors and provision of solution (optimisation) for adoption of BIM for refurbishment project.

The following discussion summarises the results and inferences of these studies for the main paradigms of interest: exploring the environmental influences, the risk factors that influence adoption of BIM. Including rethinking complex refurbishment project attributes, an optimisation process to motivate BIM adoption, simulating the interaction dynamics of refurbishment project stakeholders, and the implication of adoption of BIM for refurbishment projects.

9.3.1 Exploring the environmental influence on BIM adoption for refurbishment project using structural equation modelling

The chapter 3 discusses the identification and validation of environmental (contextual) factors that impact refurbishment stakeholders towards the decision to adopt BIM. This chapter describes an empirical testing of a structural model of environmental factors that influence decisions to adopt BIM for refurbishment of complex building. The study was based on response of 105 New Zealand construction professional who have participated in refurbishment project and have BIM experience. The result obtained from this study was to answer the following questions as contained in manuscript draft (chapter 2);

(1) What are the potential environmental factors that influences refurbishment project stakeholders' decisions to BIM adoption?

(2) In what ways can the interaction of refurbishment stakeholders be optimised to enhance a platform where BIM can be implemented?

Regarding the factors that impact BIM adoption for refurbishment project across New Zealand, several factors have been found to impact stakeholders' attitude towards BIM adoption. The result shows that most factors are significant predictors of BIM adoption. Org culture has the greatest impact on goal (BIM adoption) with a path coefficient of .673 (p= .000), followed by information (path coefficient of .531, p= .000) and standards (path coefficient of .445, p= .000). Only client expectations (path coefficient of -.378, p= .193) and retrofit tools (path coefficient of .096, p= .301) are non-significant. Overall, the model accounted for a large amount of variance towards goal (attitude to BIM adoption) at 58 percent. In the validation of the model, there is broad support for the constructs being tested, with four of the constructs significantly correlated to goal (BIM adoption): standards ($r= .266$, $p< .01$), client expectations ($r= .221$, $p< .01$), information ($r= .513$, $p< .01$), and organisational culture ($r= .535$, $p< .01$). Only retrofit tools was not significant correlated ($r= .159$, $p= .106$). The findings of this research are in consistent with recent BIM adoption studies (Bin Zakaria et al., 2013; Hong et al., 2006; Marcoulides & Heck, 1993; Succar & Kassem, 2015), where policies, culture of organisation, client expectation were found to impact attitude to adopt BIM a unique New Zealand findings.

A closer look at BIM adoption characteristics is important considering previous technology adoption model (TAM) studies which had examined the relationship between new technology and stakeholders' skills or time to familiarize their usage (driving factors), and thus was considered an important predictor of BIM adoption decision. Although the five latent variables have various degree of impact on the dependent variable of attitude towards BIM adoption, in Table 3.5, standard is seen to be very influential to impact BIM adoption for refurbishment projects. Overall, these direct effects corroborate well with (Blayse & Manley, 2004), who predicted that policies in form of regulations and standards impact IT innovation in construction industries. Interestingly, information sharing in this study strongly relates to culture of organisation but does not have a strong relationship to retrofit tools. At the same time, culture of organisation impacts retrofit tools. One explanation to this could be that the type of tools implemented for refurbishment project is not dependent on the level of information sharing or coordination of services, but rather based on the culture of the organisation handling refurbishment project. Here, the culture of organisation is highly portrayed as a factor or mediator between information sharing and retrofit tools. Hence, the factors are presented as a BIM adoption assessment model for refurbishment project stakeholders based on the validation from the empirical study.

9.3.2 Risk Factors that Influence Adoption of Building Information Modelling (BIM) for Refurbishment of Complex Building Projects: Stakeholders Perceptions

In Chapter 4, the factors that impact refurbishment project stakeholders are investigated in a more specific area of refurbishment project. This was to address the question posed by an existing literature – in chapter 2 (Okakpu et al. (2018);

(1) What are the specific risk factors that influence stakeholders' role in refurbishment of complex buildings?

And hence, discusses how refurbishment risks factors could influence adoption of BIM. Hence, the research examines the main risks factors in building refurbishment projects which has significant impact on BIM adoption. To achieve this aim, a case study of tertiary education multipurpose facility project is adopted. Semi-structured interviews were conducted with informed project stakeholders and BIM experts, and thereafter suggested solutions to BIM adoption for refurbishment projects in this manner. Refurbishment projects accounts for over 50 percent of cost of the project throughout the life cycle of an existing facility. This shows that a more sustainable platform is required to improve existing buildings that require refurbishment.

The research study revealed several risks factors that can impact stakeholders' decisions to adopt BIM. Thus, two distinct type of risks have been found: (1) the project type which is the BIM enablers and (2) the organisation risk that hinders BIM. The manifestation of these risks to BIM adoption is highly driven by financial and socio-cultural risks. After conducting face-to-face interviews with stakeholders through the adopted refurbishment case study, the findings reveal key BIM adoption risks that impact on stakeholders' decisions to adopt BIM. These include: (1) Technical risks, (2) Financial risks, (3) Socio-cultural risks, (4) Skill risks, and (5) Contractual risks as the organisational risks and Project uncertainties, (6) Lack of collaboration and communication, and (7) Coordination of services as project related risks. In the mean-time, the findings in this manuscript are in line with (Hong et al., 2016) and several others under socio-cultural (time) and expanded the previous knowledge in literature (Ali, 2014; Volk et al., 2014b), about factors that influence BIM adoption and this regard making it specific to existing buildings in tertiary institutions in New Zealand.

9.3.3 Rethinking the Complex Refurbishment Project Attributes for Building Information Modelling (BIM) Adoption

To my knowledge, this thesis presents the first investigation about the perceptions of project stakeholders towards the adoption of BIM to refurbishment project by distinguishing the project factors as refurbishment attributes and how it necessitates BIM adoption as shown in chapter 5 where the chapter attempt to address research question posed in chapter 2;

(*1) What are the perceptions of BIM adoption by the refurbishment stakeholders?*

With the adoption of case study of existing building in a tertiary institution, results show that despite most of the complex buildings in tertiary institutions being refurbished annually with traditional methods, there are still many challenges faced by her project stakeholders in managing these existing projects perceptions. BIM adoption can leverage the potential to improve the performance of these projects. In addition, the study pointed out several factors which impact BIM adoption including, people's attitude, lack of skills and expertise, lack of information management, lack of openness, and nature and scope of refurbishment projects. The study advocates that these influences need to change in order to have a positive impact towards adoption of BIM for refurbishment of existing buildings in tertiary institutions in New Zealand. The study also offered solutions to BIM adoption such as (1) Developing a programme and assessment criteria, (2) Adopting tools for information sharing/collaboration, (3) Developing a positive culture, (4) Re-addressing project timeframe, (5) Focusing the laser scanner survey on the required space for refurbishment, and (6) Making new policies for BIM adoption motivation. This research thesis contributes to the current knowledge on BIM adoption for refurbishment projects by identifying the perceptions of refurbishment projects stakeholders towards adoption of BIM for refurbishment project. Hence, providing solutions to client organisations, and FM in tertiary institutions in New Zealand and other stakeholders that refurbish and maintain multipurpose existing buildings for the formulation of effective strategies to adopt BIM.

9.3.4 An Optimisation Process to Motivate Effective Adoption of BIM for Refurbishment of Complex Buildings in New Zealand

Through this chapter, the study presents the first validations on the real benefits of BIM through optimisation of business process of refurbishment project in a client organisation. This was to address the research questions posed in chapter 2;

(*1) What are the clear benefits between the traditional method and the BIM method?*

An agent-based Bayesian network model is used to simulate the propagation of design error within the project networks. The result of the analysis show that BIM project diffuses error efficiently, while stakeholders recovers faster and nearly at the same time when compared to a traditional network. The optimised network shows better performance to the traditional network when there is early involvement of subcontractors. The main contribution of this study is providing a novel approach to compare real benefits for traditional method to BIM method for refurbishment project and to provide avenue for project stakeholders to optimise their interaction through adoption of BIM. The improved links or edges within the optimised network created a stronger social network with increased collaboration between the project team members.

Furthermore, agent-based modelling was employed to simulate the propagation of error in the five different networks using a Bayesian network model with consideration to Haper II for complex networks. The result portrays that BIM network model was almost hundred percent effective in reducing errors or project uncertainties. Therefore, the implementation of information exchange, clash detection and collaboration offered by BIM use could be the main reason for quick recovery from uncertainties within the project. The traditional method shows very low recovery mechanism from the project uncertainties and hence, would have many challenges and risks for a building refurbishment.

9.3.5 Identification of BIM adoption Benefits for refurbishment project stakeholders in New Zealand using Bayesian Network Model

To my knowledge, this study presents the first real BIM benefits validation for refurbishment stakeholders through error management and decision-making using sensitivity analysis. This study was to address the research question posed in chapter 2;

(*1) What are the clear benefits between the traditional method and the BIM method?*

The study carried out a simulation of interaction of refurbishment project stakeholders to identify the real-time benefits of BIM adoption for complex refurbishment project by using agent-based modelling performed through a parameterized Bayesian network. The result shows that BIM project network efficiently diffuses errors while the project stakeholders involved in the project recovers from uncertainties on timely. A desktop audit is organised allowing the industry partners to give feedback based on the relevance of the different networks. It was found that adoption of BIM offered profound benefits for refurbishment projects stakeholders by minimising errors and having quick decision-making processes. Although the different networks show almost the same pattern of error propagation, there are differences based on the impact of errors on the project stakeholders. The sensitivity analysis indicates in each network (see chapter 7) the project stakeholders who are likely to have higher influence by the introduction of error by the differences on their colour as shown on the nodes. The sensitivity analysis also indicated that decisions are quicker to be reached comparing from the BIM network down to the main traditional project network.

9.3.6 The Implication of BIM Adoption for Refurbishment of Complex Buildings in New Zealand

The present study is also the first to use focus group methodology applied to gain the perceptions of refurbishment project stakeholders on BIM adoption for refurbishment of complex buildings and as well offer validation on the findings of previous chapters (4 & 5). The study revealed factors that inhibit BIM adoption for refurbishment project namely: lack of training, resistant to change, culture of organisation, cost of BIM which goes with scope and time, and lack of BIM awareness. The lack of training was seen as very important since according to the participants “good skill about BIM will give a positive perception about the cost of BIM adoption”. Hence, the result of the finding shows that there is greater need to train refurbishment project stakeholders to become BIM capable and to create awareness as this will change the perceptions of the cost of BIM. The study, though is in consistent with (McCartney, 2010) studies on quantitative survey of general barriers where that the main factor is not the cost. In a bigger picture, it opposes the later study since the current study indicated that it is about “cost” that is to say, “the perception of cost of BIM”.

More importantly, the impact factors found in this study are in consistent with previous literatures (Okakpu et al., 2019; Park & Kim, 2014). In a bigger picture for New Zealand refurbishment industries, the study validates the environmental (contextual) factors that impact refurbishment project stakeholders to adopt BIM which includes culture of organisation, policies and standards, information sharing, client’s expectation, and retrofit tools influence BIM adoption for refurbishment project.

The study identified few steps that must be followed to improve BIM adoption for refurbishment project stakeholders. First is conducting awareness program about BIM, the use of education to train refurbishment project stakeholders including BIM syllabus in tertiary institution that incorporates management of existing buildings with BIM will be beneficial. Then the government and private sectors should mandate BIM, bearing in mind that there is enough room to demonstrate real BIM benefits for refurbishment project. It is worth noting that the present study has demonstrated real BIM benefits in (chapters 6 & 7), the testing of the benefits where possible using a case study refurbishment project in Auckland.

9.4 Thesis limitations

Methodological limitations must be considered in relation to this thesis research and these had been discussed in the previous chapters. In summary, these limitations mainly relevant with the research target, the population of the small sample of refurbishment stakeholders who show willingness towards adoption of BIM and including the testing of errors and sensitivity analysis.

- The group of refurbishment project stakeholders involved in the contribution to the research findings were from one big organisation (small population). It is assumed that since there are similar organisations in New Zealand who handles refurbishment projects would give the same result.
- The methodology used to collect data for contextual factors that impact refurbishment project stakeholders in New Zealand has some limitations that even though we selected the respondent, because it was anonymous, I cannot be 100% sure that I have reached the right people although I clearly stated the focus on BIM and expected those with no knowledge to not participate.
- During the validation of real BIM benefits using error management, only errors introduced at the architect domain was considered.

- The domain of the study was carried out in Auckland.
- The type of refurbishment project is multipurpose building found in tertiary institutions in New Zealand.
- Another limitation to this study is that the proposed model has been validated by the collection of data from New Zealand construction industry who handles refurbishment projects. In this regard, due to that environmental factors can differ within regions, there is a possibility of bias playing a role in the finale outcome of the study when compared to other region or country for example. Furthermore, while the data is from a single source, the use of SEM analysis does allay concerns around common method variance and provides robust statistical analysis to test relationships. Overall, the present study offers greater support for the proposed conceptual model including and empirical avenue for comparison in future research.
- While the performance of the networks in chapter 7 may not seem spectacular, there are some limitations. For example, the collection of project interaction data was extracted from stakeholders for refurbishment project in an Auckland Tertiary institution. Further investigations may compare different project stakeholders from different tertiary institutions or any other client organisation in that manner.

While this thesis reports substantial new findings that further broaden the body of knowledge surrounding the effectiveness of adopting BIM for refurbishment of complex building projects, the contextual impact factors, the risk factors, and related project attributes and the solutions to BIM adoption, validity of the influencing factors, and the validation of real benefits on collaboration, optimisation, sensitivity analysis and error management, the results need to be interpreted with caution given the aforementioned thesis limitations.

9.5 Recommendations for future research

The findings of this thesis have led to the following recommendations for future research as follows:

- Further studies should compare the perceptions of different organisations on the effectiveness of BIM adoption for refurbishment projects. The study will contribute to the body of knowledge for a comparative research finding.
- There is need to investigate other refurbishment projects to ascertain if the result found in this study would match with their findings.
- During the simulation of stakeholder's interaction, the identification of the errors propagated within the network of project stakeholders should further investigate the values of the error diffusion when there are observations of errors from different main stakeholders as targets other than the architecture.
- Further studies should investigate the effects of sensitivity analysis when different main project stakeholders are set as targets at different error propagation within an interaction network of refurbishment project stakeholders.

9.6 Conclusion

This research has addressed effectiveness of adoption of BIM for refurbishment project considering literatures and specially by adopting a case study in New Zealand to systematically address the issues that surround the decision to adopt BIM for refurbishment of complex projects in New Zealand. The case study refurbishment project is adopted from an Auckland tertiary institution. The case study provides the avenue to examine the refurbishment project stakeholders and their interaction within the project. A social network theory approach was adopted to analyse the traditional method of refurbishment and the virtual BIM method based on the project interaction. In addition, an agent-based simulation of Bayesian network is used to investigate the benefits of BIM adoption among the refurbishment stakeholders through a simulation of error diffusion among the project stakeholders. The simulation studies confirm the real benefits of BIM adoption by three examinations: (1) benefits through improved collaboration, (2) benefits through error management and (3) decision-making using sensitivity analysis of Bayesian model. The results conclude that error and quick decision making can be managed efficiently in a project network with improved collaboration. In addition, the client organisation who manages the refurbishment projects needs to include sub-contractors at the early phase of the projects to minimise error as can be seen from the case study where the collaboration on the subcontractors are increased among other project stakeholders.

There are also opportunities to optimise the processes around refurbishment projects to accept BIM as detailed in the quantitative research including standards, information sharing, retrofit tools, culture of organisation, client expectation. Therefore, to increase BIM adoption for refurbishment project, the implication can be divided into two. Thus, from the social point of view, BIM should be developed to target changes in the current standards and policies around refurbishment projects in New Zealand. In addition, the level of information sharing, the culture of organisation to enable BIM implementation, and the type of retrofit tools to use perhaps must be compatible to BIM. In doing so, the stakeholders' perception of BIM will be maximised to realise BIM. From the technical point of view, the result suggests that culture of organisation is a major factor that informs how organisations or project stakeholders' perceptions about retrofit tools as well as BIM. This invariably would impact how clients would visualise the BIM benefit. Therefore, when the culture of an organisation favours BIM adoption, it also improves the expectation of clients-organisations. This is also related to Retrofit tools having influence on Client expectations. A thorough consideration of these factors would offer optimisation opportunities towards BIM adoption capability and motivation for refurbishment projects in New Zealand.

Also, in the qualitative findings involving face to face interview, the findings reveal key BIM adoption risks that impact on stakeholders' decisions to adopt BIM. These include (1) Technical risks, (2) Financial risks, (3) Socio-cultural risks, (4) Skill risks, and (5) Contractual risks. The findings concluded that the main risks to BIM adoption opportunities for refurbishment project is the financial and socio-cultural risks. In addition, the perceptions of refurbishment project stakeholders towards BIM adoption is affected by people’s attitude, lack of skills and expertise, lack of information management, lack of openness, and nature and scope of refurbishment projects. In summary, the thesis identifies a number of important factors towards understanding how BIM can be more successfully adopted.

To address the gap identified by a previous study (Alwan, 2016), the current study offered solutions towards the cost of BIM adoption for refurbishment projects and hence, fills the limitation of against whole housing refurbishment. In addition, expanding on the refurbishment project attributes to BIM adoption, the semi-structured interview findings revealed BIM adoption solutions. These include (1) Develop a programme and assessment criteria, (2) Adopt tools for information sharing/collaboration, (3) Develop a positive culture, (4) Re-address project timeframe, (5) Focus the laser scanner survey on the required space for refurbishment, and (6) Make new policies for BIM adoption motivation. Thus, the research framework developed at the earlier study provided a solid platform to investigate the effectiveness of adopting BIM for refurbishment of complex projects.

By validating the result of the study, a focus group approach was adopted. The findings revealed that the main factor is not the cost which is in consistent with (McCartney, 2010) studies on quantitative survey of general barriers on BIM adoption in New Zealand construction industry. However, the current findings indicated the wrong perception of cost of BIM implementation as the major factor to adoption of BIM for refurbishment projects in New Zealand. However, the focus group findings also indicated that the factors which drives BIM adoption for refurbishment project includes information sharing, coordination of services, knowledge of refurbishment project attributes, long time benefits, higher efficiency of projects. These drivers are consistent with previous literatures (Okakpu et al., 2019; Park & Kim, 2014) and also consistent with validation for the environmental factors that impact project stakeholders to adopt BIM where culture of organisation, policies and standards, information sharing, clients expectation, and retrofit tools influence BIM adoption for refurbishment project. Therefore, the present findings portray useful reflection of the relevant BIM adoption influence factors for refurbishment project stakeholders in New Zealand.

It is hoped that the current study has provided insights into the effectiveness of BIM adoption and the real-BIM benefits for refurbishment of complex projects. It is believed that the set of solutions offered by the study such as optimisations factors and other mitigation plan will be useful initiatives that could be taken to forestall the implementation of BIM by refurbishment project stakeholders in New Zealand, as well as tertiary institutions. In addition, the project attributes for refurbishment project identified in this research need to be given a considerable debate by tertiary organisations and government parastatals in order to make a positive change to adoption of BIM. For example, is the refurbishment time frame, the budget allocated to refurbishment projects and as well as taken less priority for refurbishment project need to be changed in order for BIM adoption decision is to be achieved. By doing this, there will be a full potential consideration to BIM adoption for complex refurbishment project in New Zealand.

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Glossary

BIM	Building Information Modelling
SEM	Structural Equation Modelling
CBD	Central Business District
SNA	Social Network Analysis
AGM	Agent-based Modelling
SA	Sensitivity Analysis
FG	Focus Group
IT	Information Technology
LCA	Life Cycle Analysis
AEC	Architecture, Engineering and Construction
CFA	Confirmatory Factor Analysis
TAM	Technology Adoption Model
EFA	Exploratory Factor Analysis
GOF	Goodness of fit
FM	Facility Managers
BEP	Building Execution Plan
RFIs	Request for Information
BRANZ	Building Research Association New Zealand
IPS	Integrated Professional Services

Appendix A: Participants Information Sheets

Participant Information Sheet for Preliminary Interview

For preliminary Interview

Date Information Sheet Produced:

13th July, 2017

Project Title

Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand

Who are the project stakeholders? What are the main environmental factors that influence their role and interaction?

An Invitation

Dear [insert name]

You received this document [email] as I would like to invite you to participate in a preliminary interview.

I currently work as a PhD researcher at the AUT within the School of Engineering. My supervisors are Dr. Ali GhaffarianHoseini, Professor John Tookey, and Professor Jarrod Haar.

At the AUT, my study is investigating the effectiveness of adopting BIM for complex refurbishment projects in New Zealand. In New Zealand, the majority of execution of refurbishment projects is by traditional method. In the literatures, the main barriers are being pointed to fragmentation, lack of collaboration and integration in the industries.

I would highly value your contribution but please do not obliged to participate. Your participation will be anonymised in my research results, and will be organised as efficient as possible.

I look forward to your response.

Best regards,

(Mr) Anthony Okakpu
PhD research candidate

What is the purpose of this research?

In this research, I want to discuss the environmental factors and their influence on the interaction of stakeholders in a case study refurbishment project and to learn their BIM perceptions with the identified project stakeholders through interviews and focus group meeting. The identification of stakeholders will enable the researcher to model a visual interaction system which will be used to test the effectiveness of BIM, despite the influence of the environmental factors.

If you want to, you will receive summaries of my intermediate research findings. In a later phase, I first want to present (anonymised) results at the conference or in a journal and then want to publish my thesis. You can receive PDF copies of my publications, or follow my website.

How was I identified and why am I being invited to participate in this research?

I have selected you as I understand you previously in one way or the other participated in a refurbishment project at Auckland university of technology in the city centre, hence, I assume you have knowledge with refurbishment projects here in New Zealand.

I am particularly interested in discussing the topic when you have (more than 2 years of) experience in relevant procurement activities or refurbishment activities or innovation activities. Hence, I expect that we can have a good discussion on the stakeholders' role and interaction with their environment, and how it enhances or inhibit the adoption of BIM in New Zealand.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

During the interview, we will discuss a set of questions. Firstly, we will identify the internal and external stakeholders. Secondly, we will identify their roles and their likely interactions. Thirdly, we can learn the most environmental factors that influence the interaction of stakeholders.

What are the discomforts and risks?

There are no discomforts or risks. (Please see Consent Form). You will not disclose any information that may harm your company, your position or others. The names of stakeholders, their companies will remain confidential in my research findings.

What are the benefits?

FOR YOU: You may get deeper insights in your company's refurbishment project execution process, the performance of stakeholders' roles and interactions that may help your organisations to be more successful, and be able to develop a BIM platform for your organisation BIM execution

FOR OTHERS: Improved know-how on the relationships of stakeholders in a project execution, beneficial for construction companies, increases the knowledge on factors that influence adoption of BIM for complex refurbishment in New Zealand, clients, and students and for the wider community.

FOR ME: Your participation helps me to develop knowledge and insights for my PhD thesis.

How will my privacy be protected?

The Consent Form (Please find attached) describes how your confidentiality will be protected. All information (relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential and will only be used for academic purposes. The AUT and I will keep all information and identities of participants confidential. You may withdraw yourself or any information / documentation that you have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

What are the costs of participating in this research?

There are no costs involved. My estimate is that our interview will take **30 – 45 minutes**. Reading and preparing feedback may take another **15 – 20 minutes**. Therefore, over a period of 2 – 3 weeks, this would take a **max of 1 hour of your time.**

Additionally, when you (or your staff members) want to participate in a round-table discussion with (4-8) other main stakeholders from other companies: this will take 1.50 hours. However, as this might not be compulsory even though the discussion may bring great value, I plan to hold such discussion on central location such as in AUT premises, Auckland.

What opportunity do I have to consider this invitation?

Assuming you will have to organise the meeting and perhaps some documentation: I would like to hear from you within a week. Please allow me to contact you after 14 days in case I have not received a response from you.

Will I receive feedback on the results of this research?

I would like to stay into contact and hear your opinion on my research findings. Please indicate on the Consent Form in case you want no feedback on this research. You will receive summarized interview or discussion findings and the result of the analysis of the interaction of the stakeholders in each project case study.

Your subsequent written or oral comments are very much welcomed.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the supervisor, **Dr Ali Ghafarahoseini,** email …**ali.ghafarahoseini@aut.ac.nz**, Phone +**649219999**………ext. **7968**

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O’Connor, ethics@aut.ac.nz, Phone +649219999 ext. 6038

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Mr Anthony Okakpu

aokakpu@aut.ac.nz**; +64212108082**

PhD researcher

School of Engineering, Computer and Mathematical Sciences

Project Supervisor Contact Details:

Dr Ali Ghafarahoseini

Supervisor

Phone:

School of Engineering, Computer and Mathematical Sciences

Approved by the Auckland University of Technology Ethics Committee on …………., AUTEC Reference number ………………..

Participant Information Sheet for Interview

For Interview

Date Information Sheet Produced:

13 July, 2017

Project Title

Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand

What are the environmental factors that influence stakeholders' interaction and the benefits between traditional method and BIM methods

An Invitation

Dear [insert name]

You received this document [email] as I would like to invite you to participate in an interview/focus group/survey [Modify].

I currently work as a PhD researcher at the AUT within the School of Engineering. My supervisors are Dr. Ali GhaffarianHoseini, Professor John Tookey, and Professor Jarrod Haar. I have industry and academic backgrounds in civil engineering construction in oversea, but do not have New Zealand construction experience.

At the AUT, my study is investigating the effectiveness of adopting BIM for complex refurbishment projects in New Zealand. In New Zealand, the current execution of refurbishment projects is by traditional method. In the literatures, the main barriers are related to the influence of the environmental factors on stakeholders in construction industry. Therefore, we would like to discuss the current state of the interactions of the stakeholders, the risks and how it can be optimised to enable BIM adoption. We will also discuss the likely effects or clear benefits that BIM could offer in such a venture.

We can learn from text books the clear benefits of adopting BIM for construction projects. But we don't know how effective the adoption of BIM will offer refurbishment projects in New Zealand based on its environmental factors. We do not know if the interaction process of stakeholders and project procurement hinder BIM adoption at the current state.

Although I highly value your potential contribution, please do not feel obliged to participate in this research. You may withdraw at any time. Your participation will be voluntary and will be organised as efficiently as possible.

But then, I again like to stress that I'd very much want you to participate in this research.

Interviews are planned between August and November at a moment convenient to you. They can be via Skype but preferably at your workspace.

I look forward to your response. Please feel free to contact me for any questions.

The rest of this document gives extra information

Best regards,

(Mr) Anthony Okakpu
PhD research candidate
Phone: 0212108082
Email: aokakpu@aut.ac.nz

What is the purpose of this research?

In this research, I want to discuss the interaction of stakeholders in a case study refurbishment project and their BIM perceptions with the identified main stakeholders through interview and focus group meeting.

If you want to, you will receive summaries of my intermediate research findings. In a later phase, I first want to present (anonymised) results at the conference or in a journal and then want to publish my thesis. You can receive PDF copies of my publications, or follow my website.

How was I identified and why am I being invited to participate in this research?

I have selected you as I understand you previously in one way or the other participated in a refurbishment project at Auckland university of technology in the city centre, hence, I assume you have knowledge with refurbishment projects here in New Zealand.

I am particularly interested in discussing the topic when you have (more than 2 years of) experience in relevant procurement activities or refurbishment activities or innovation activities. Hence, I expect that we can have a good discussion on the stakeholders' role and interaction with their environment, and how it enhances or inhibit the adoption of BIM in New Zealand.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

During the interview, we will discuss a set of questions. Firstly, we will identify the internal and external stakeholders. Secondly, we will identify their roles and their likely interactions. Thirdly, we discuss the most environmental factors that influence the interaction of stakeholders. We will learn the most technology that is used for refurbishment projects and the perceptions of the benefits of adopting BIM for complex refurbishment projects.

What are the discomforts and risks?

There are no discomforts or risks. (Please see Consent Form). You will not disclose any information that may harm your company, your position or others. The names of stakeholders, their companies will remain confidential in my research findings.

What are the benefits?

FOR YOU: You may get deeper insights in your company's refurbishment project execution process, the performance of stakeholders' roles and interactions that may help your organisations to be more successful, and be able to develop a BIM platform for your organisation BIM execution

FOR OTHERS: Improved know-how on the relationships of stakeholders in a project execution, beneficial for construction companies, increases the knowledge on factors that influence adoption of BIM for complex refurbishment in New Zealand, clients, and students and for the wider community.

FOR ME: Your participation helps me to develop knowledge and insights for my PhD thesis.

How will my privacy be protected?

The Consent Form (Please find attached) describes how your confidentiality will be protected. All information (relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential and will only be used for academic purposes. The AUT and I will keep all information and identities of participants confidential. You may withdraw yourself or any information / documentation that you have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

What are the costs of participating in this research?

There are no costs involved. My estimate is that our interview will take **45 – 60 minutes**. Reading and preparing feedback may take another **15 – 30 minutes**. Therefore, over a period of 2 – 3 weeks, this would take **1 to max 2 hours of your time.**

Additionally, when you (or your staff members) want to participate in a round-table discussion with (4-8) other main stakeholders from other companies: this will take 3 hours. However, as this might not be compulsory even though the discussion may bring great value, I plan to hold such discussion on central location such as in AUT premises, Auckland.

What opportunity do I have to consider this invitation?

Assuming you will have to organise the meeting and perhaps some documentation: I would like to hear from you within a week. Please allow me to contact you after 14 days in case I have not received a response from you.

Will I receive feedback on the results of this research?

I would like to stay into contact and hear your opinion on my research findings. Please indicate on the Consent Form in case you want no feedback on this research. You will receive summarized interview or discussion findings and the result of the analysis of the interaction of the stakeholders in each project case study.

Your subsequent written or oral comments are very much welcomed.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the project supervisor, Dr Ali Ghafarahoseini, email …ali.ghafarahoseini@aut.ac.nz, Phone +649219999………ext. 7968

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz, Phone +649219999 ext. 6038

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Mr Anthony Okakpu

aokakpu@aut.ac.nz**; +64212108082**

PhD researcher

School of Engineering, Computer and Mathematical Sciences

Project Supervisor Contact Details:

Dr Ali Ghafarahoseini

Supervisor

Phone:

School of Engineering, Computer and Mathematical Sciences

Approved by the Auckland University of Technology Ethics Committee on type the date final ethics approval was granted, AUTEC Reference number type the reference number.

Participant Information Sheet for Survey

For Survey

Date Information Sheet Produced:

13 July 2017

Project Title

Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment buildings in New Zealand

What are the environmental factors that influence stakeholders' interaction and the benefits between traditional method and BIM methods

An Invitation

Dear [insert name]

You received this document [email] as I would like to invite you to participate in a survey

I currently work as a PhD researcher at the AUT within the School of Engineering. My supervisors are Dr. Ali GhaffarianHoseini, Professor John Tookey, and Professor Jarrod Haar. I have industry and academic backgrounds in civil engineering construction in oversea, but do not have New Zealand construction experience.

At the AUT, my study is investigating the effectiveness of adopting BIM for complex refurbishment projects in New Zealand. In New Zealand, the majority of execution of refurbishment projects is by traditional method. In the literatures, the main barriers are related to stakeholders in construction industry. Therefore, we would like to discuss the current state of the interactions of the stakeholders, the risks and how it can be optimised to enable BIM adoption. We will also discuss the likely effects or clear benefits that BIM could offer in such a venture.

In the identified case study project, we would like to model a visual representation of the interactions (collaboration and information sharing) of the stakeholders in this project. This is to enable my research to develop an optimise BIM platform system for BIM adoption. But we don't know how effective the adoption of BIM would offer refurbishment projects in New Zealand. We do not know if there are environmental factors that influence the interaction process of stakeholders and project procurement to enable BIM adoption at the current state including the BIM perception of the stakeholders.

My estimate is that you have a wide industry experience in refurbishment work. This project is adopted for my research case studies. That is why I like to invite you for my research.

If you would accept the invitation, your participation will be in the period of October to November 2017. I think that your contribution will have relevant insights which will help construction companies and the industry forward.

I would highly value your contribution but please do not obliged to participate. Your participation will be anonymised in my research results, and will be organised as efficient as possible.

I look forward to your response. Please feel free to contact me for any questions.

Best regards,

(Mr) Anthony Okakpu
PhD research candidate
Phone: 0212108082
Email: aokakpu@aut.ac.nz

What is the purpose of this research?

In this research, I want to discuss the environmental influence on the interaction of stakeholders in a case study refurbishment project and their BIM perceptions and BIM benefits with the identified main stakeholders through interview and focus group meeting.

If you want to, you will receive summaries of my intermediate research findings. In a later phase, I first want to present (anonymised) results at the conference or in a journal and then want to publish my thesis. You can receive PDF copies of my publications, or follow my website.

How was I identified and why am I being invited to participate in this research?

I have selected you as I understand you previously in one way or the other participated in a refurbishment project at Auckland university of technology in the city centre, hence, I assume you have knowledge with refurbishment projects here in New Zealand.

I am particularly interested in discussing the topic when you have (more than 2 years of) experience in relevant procurement activities or refurbishment activities or innovation activities. Hence, I expect that we can have a good discussion on the stakeholders' role and interaction with their environment, and how it enhances or inhibit the adoption of BIM in New Zealand.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

During the survey, we will rate how different environmental factors could affect your role in the project. You will have a space for comments. You will also identify the stakeholders you exchanged information with and who you gave. The idea about this is to model interaction network for visualization which will help to improve collaboration and information sharing in the project. In this network, a Building Information modelling will be implemented (tested) and simulated. Then the results will be discussed through the focus group and receive feedbacks for optimisation of the network. This will help us to identify the real benefits of adopting BIM and how environmental factors could influence the decision to adopt BIM

What are the discomforts and risks?

There are no discomforts or risks. (Please see Consent Form). You will not disclose any information that may harm your company, your position or others. The names of stakeholders, their companies will remain confidential in my research findings.

What are the benefits?

FOR YOU: You may get deeper insights in your company's refurbishment project execution process, the performance of stakeholders' roles and interactions that may help your organisations to be more successful, and be able to develop a BIM platform for your organisation BIM execution

FOR OTHERS: Improved know-how on the relationships of stakeholders in a project execution, beneficial for construction companies, increases the knowledge on factors that influence adoption of BIM for complex refurbishment in New Zealand, clients, and students and for the wider community.

FOR ME: Your participation helps me to develop knowledge and insights for my PhD thesis.

How will my privacy be protected?

The Consent Form (Please find attached) describes how your confidentiality will be protected. All information (relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential and will only be used for academic purposes. The AUT and I will keep all information and identities of participants confidential. You may withdraw yourself or any information / documentation that you have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

What are the costs of participating in this research?

There are no costs involved. My estimate is that our interview will take **45 – 60 minutes**. Reading and preparing feedback may take another **15 – 30 minutes**. Therefore, over a period of 2 – 3 weeks, this would take **1 to max 2 hours of your time.**

Additionally, when you (or your staff members) want to participate in a round-table discussion with (4-8) other main stakeholders from other companies: this will take 3 hours. However, as this might not be compulsory even though the discussion may bring great value, I plan to hold such discussion on central location such as in AUT premises, Auckland.

What opportunity do I have to consider this invitation?

Assuming you will have to organise the meeting and perhaps some documentation: I would like to hear from you within a week. Please allow me to contact you after 14 days in case I have not received a response from you.

Will I receive feedback on the results of this research?

I would like to stay into contact and hear your opinion on my research findings. Please indicate on the Consent Form in case you want no feedback on this research. You will receive summarized interview or discussion findings and the result of the analysis of the interaction of the stakeholders in each project case study.

Your subsequent written or oral comments are very much welcomed.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the supervisor, Dr Ali Ghafarahoseini, email …ali.ghafarahoseini@aut.ac.nz, Phone +649219999………ext. 7968

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz, Phone +649219999 ext. 6038

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Mr Anthony Okakpu

aokakpu@aut.ac.nz**; +64212108082**

PhD researcher

School of Engineering, Computer and Mathematical Sciences

Project Supervisor Contact Details:

Dr Ali Ghafarahoseini

Supervisor

Phone:

School of Engineering, Computer and Mathematical Sciences

Approved by the Auckland University of Technology Ethics Committee on type the date final ethics approval was granted, AUTEC Reference number type the reference number.

Date Information Sheet Produced:

13 July, 2017

Project Title

Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand

What are the environmental factors that influence stakeholders' interaction and the benefits between traditional method and BIM methods

An Invitation

Dear [insert name]

You received this document [email] as I would like to invite you to participate in a focus group

I currently work as a PhD researcher at the AUT within the School of Engineering. My supervisors are Dr. Ali GhaffarianHoseini, Professor John Tookey, and Professor Jarrod Haar. I have industry and academic backgrounds in civil engineering construction in oversea, but do not have New Zealand construction experience.

At the AUT, my study is investigating the effectiveness of adopting BIM for complex refurbishment projects in New Zealand. In New Zealand, the current execution of refurbishment projects is by traditional method. In the literatures, the main barriers are related to the influence of the environmental factors on stakeholders in construction industry. Therefore, we would like to discuss the current state of the interactions of the stakeholders, the risks and how it can be optimised to enable BIM adoption. We will also discuss the likely effects or clear benefits that BIM could offer in such a venture.

We can learn from text books the clear benefits of adopting BIM for construction projects. But we don't know how effective the adoption of BIM will offer refurbishment projects in New Zealand based on the influence of its environmental factors. We do not know if the interaction process of stakeholders and project procurement hinder BIM adoption at the current state.

Although I highly value your potential contribution, please do not feel obliged to participate in this research. You may withdraw at any time. Your participation will be voluntary and will be organised as efficiently as possible.

But then, I again like to stress that I'd very much want you to participate in this research.

The round table meeting is planned between November and December 2017 at a moment convenient to you. They can be via Skype but preferably at AUT city campus.

I look forward to your response. Please feel free to contact me for any questions.

The rest of this document gives extra information

Best regards,

(Mr) Anthony Okakpu
PhD research candidate
Phone: 0212108082
Email: aokakpu@aut.ac.nz

What is the purpose of this research?

In this research, I want to discuss the interaction of stakeholders in a case study refurbishment project and their BIM perceptions with the identified main stakeholders through interview and focus group meeting. In addition, we will discuss the results obtained from the visualization of traditional method and when BIM is implemented. We will suggest how the current traditional method would be optimised to enable BIM implementation if possible. We will also suggest solution on how to deal with some important environmental factors in New Zealand context.

If you want to, you will receive summaries of my intermediate research findings. In a later phase, I first want to present (anonymised) results at the conference or in a journal and then want to publish my thesis. You can receive PDF copies of my publications, or follow my website.

How was I identified and why am I being invited to participate in this research?

I have selected you as I understand you previously in one way or the other participated in a refurbishment project at Auckland university of technology buildings in the city centre, hence, I assume you have knowledge with refurbishment projects here in New Zealand.

I am particularly interested in discussing the topic when you have (more than 2 years of) experience in relevant procurement activities or refurbishment activities or innovation activities and as well as BIM knowledge. Hence, I expect that we can have a good discussion on the stakeholders' role and interaction with their environment, and how it enhances or inhibit the adoption of BIM in New Zealand.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

During the focus group meeting, we will discuss a set of questions. Firstly, we will identify the difference between the networks with BIM and non-BIM. Secondly, we will identify the important stakeholders to move decisions to adopt BIM, we will identify their roles and their likely interactions from the result analysis. Thirdly, we discuss the most environmental factors that influence the interaction of stakeholders. We will learn the most technology that is used for refurbishment projects and the perceptions of the benefits of adopting BIM for complex refurbishment projects. We will expect recommendation on how to move forward from the current state.

What are the discomforts and risks?

There are no discomforts or risks. (Please see Consent Form). You will not disclose any information that may harm your company, your position or others. The names of stakeholders, their companies will remain confidential in my research findings.

What are the benefits?

FOR YOU: You may get deeper insights in your company's refurbishment project execution process, the performance of stakeholders' roles and interactions that may help your organisations to be more successful, and be able to develop a BIM platform for your organisation BIM execution

FOR OTHERS: Improved know-how on the relationships of stakeholders in a project execution, beneficial for construction companies, increases the knowledge on factors that influence adoption of BIM for complex refurbishment in New Zealand, clients, and students and for the wider community.

FOR ME: Your participation helps me to develop knowledge and insights for my PhD thesis.

How will my privacy be protected?

You will not be identified in my result and your contribution will remain anonymous even though you are to see each other during the meeting. Additionally, the Consent Form (Please find attached) describes how your confidentiality will be protected. All information (relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential and will only be used for academic purposes. The AUT and I will keep all information and identities of participants confidential. You may withdraw yourself or any information / documentation that you have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way

What are the costs of participating in this research?

There are no costs involved. My estimate is that our meeting will take **45 – 60 minutes**. Reading and preparing feedback may take another **30 – 45 minutes**. Therefore, over a period of 2 – 3 weeks, this would take **2 to max 3 hours of your time.**

Additionally, when you (or your staff members) want to participate in a round-table discussion with (4-8) other main stakeholders from other companies: this will take 3 hours. However, as this might not be compulsory even though the discussion may bring great value, I plan to hold such discussion on central location such as in AUT premises, Auckland.

What opportunity do I have to consider this invitation?

Assuming you will have to organise the meeting and perhaps some documentation: I would like to hear from you within a week. Please allow me to contact you after 14 days in case I have not received a response from you.

Will I receive feedback on the results of this research?

I would like to stay into contact and hear your opinion on my research findings. Please indicate on the Consent Form in case you want no feedback on this research. You will receive summarized interview or discussion findings and the result of the analysis of the interaction of the stakeholders in each project case study.

Your subsequent written or oral comments are very much welcomed.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the supervisor, Dr Ali Ghafarahoseini, email …ali.ghafarahoseini@aut.ac.nz, Phone +649219999………ext. 7968

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O’Connor, ethics@aut.ac.nz, Phone +649219999 ext. 6038

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Mr Anthony Okakpu

aokakpu@aut.ac.nz**; +64212108082**

PhD researcher

School of Engineering, Computer and Mathematical Sciences

Project Supervisor Contact Details:

Dr Ali Ghafarahoseini

Supervisor

Phone:

School of Engineering, Computer and Mathematical Sciences

Approved by the Auckland University of Technology Ethics Committee on……., AUTEC Reference number ……………..

CONSENT FORM (for preliminary interview)

Project title: **Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand**

Project Supervisor: ***Dr Ali GhaffarianHoseini, Prof John Tookey, Prof Jarrod Haar***

Researcher: ***Mr Anthony Okakpu***

○ I have read and understood the information provided about this research project in the Information Sheet dated 13 July, 2017.

o I understand that I must not disclose any information that may harm my company, my position or others. I will contribute to trust, confidentiality and professional behaviour of participants and myself

o All company information (industry-relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential. I understand that the AUT and the researcher will keep such information and identities confidential and only use for academic purposes.

○ I understand that the researcher may ask to be referred to additional participants within or outside my company. I have the right to contact such additional participants and ask whether they would be interested in such participation. If so, they will contact the researcher.

○ I understand that the researcher may ask for additional documentation to be analysed for the academic purposes of the case study project. However, I am not obliged to provide any such documentation.

○ I understand that although the researcher or other participants may have suggestions that can be beneficial for my company, implementing such suggestions is my own commercial responsibility

○ I understand that the identification and nomination of stakeholders is for the purpose of modeling visual interaction within the project

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

○ I agree to take part in this research.

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: ....……………………………………………………

Participant's name: ....……………………………………………………

Participant's email address:………………………………………………………………………………

Participants position………………………………………………………………………………………..

Participants organisation……………………………………………………………………………………..

Date & Place……………………………………………………………………………………………..

Approved by the Auckland University of Technology Ethics Committee on…….AUTEC Reference number……….

Note: The Participant should retain a copy of this form.

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Project title: **Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand**

Project Supervisor: ***Dr Ali GhaffarianHoseini, Prof John Tookey, Prof Jarrod Haar***

Researcher: ***Mr Anthony Okakpu***

○ I have read and understood the information provided about this research project in the Information Sheet dated 13 July, 2017.

o I understand that I must not disclose any information that may harm my company, my position or others. I will contribute to trust, confidentiality and professional behaviour of participants and myself

o All company information (industry-relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential. I understand that the AUT and the researcher will keep such information and identities confidential and only use for academic purposes.

○ I understand that the researcher may ask to be referred to additional participants within or outside my company. I have the right to contact such additional participants and ask whether they would be interested in such participation. If so, they will contact the researcher.

○ I understand that the researcher may ask for additional documentation to be analysed for the academic purposes of the case study project. However, I am not obliged to provide any such documentation.

○ I understand that although the researcher or other participants may have suggestions that can be beneficial for my company, implementing such suggestions is my own commercial responsibility

○ I understand that the identification and nomination of stakeholders is for the purpose of modeling visual interaction within the project

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

○ I agree to take part in this research.

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: ....……………………………………………………

Participant's name: ....……………………………………………………

Participant's email address:………………………………………………………………………………

Participants position………………………………………………………………………………..

Participants organisation…………………………………………………………………………………………..

Date & Place…………………………………………………………………………………………..

Approved by the Auckland University of Technology Ethics Committee on…….AUTEC Reference number………..

Note: The Participant should retain a copy of this form.

For Quantitative interview

Project title: **Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand**

Project Supervisor: ***Dr Ali GhaffarianHoseini, Prof John Tookey, Prof Jarrod Haar***

Researcher: ***Mr Anthony Okakpu***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 13 July, 2017.

- o I understand that I must not disclose any information that may harm my company, my position or others. I will contribute to trust, confidentiality and professional behaviour of participants and myself

- o All company information (industry-relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential. I understand that the AUT and the researcher will keep such information and identities confidential and only use for academic purposes.

- ○ I understand that the researcher may ask to be referred to additional participants within or outside my company. I have the right to contact such additional participants and ask whether they would be interested in such participation. If so, they will contact the researcher.

- ○ I understand that the researcher may ask for additional documentation to be analysed for the academic purposes of the case study project. However, I am not obliged to provide any such documentation.

- ○ I understand that although the researcher or other participants may have suggestions that can be beneficial for my company, implementing such suggestions is my own commercial responsibility

- ○ I understand that the identification and nomination of stakeholders is for the purpose of modeling visual interaction within the project

- ○ I have had an opportunity to ask questions and to have them answered.

- ○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.

- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

- ○ I agree to take part in this research.

- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: ....……………………………………………………

Participant's name: ....……………………………………………………

Participant's email address:………………………………………………………………………………

Participants position……………………………………………………………………………………..

Participants organisation……………………………………………………………………………………..

Date & Place……………………………………………………………………………………..

Approved by the Auckland University of Technology Ethics Committee on…….AUTEC Reference number………..

Note: The Participant should retain a copy of this form.

Consent Form

For Focus Group meeting

Project title: **Investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand**

Project Supervisor: ***Dr Ali GhaffarianHoseini, Prof John Tookey, Prof Jarrod Haar***

Researcher: ***Mr Anthony Okakpu***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 13 July, 2017.
- o I understand that I must not disclose any information that may harm my company, my position or others. I will contribute to trust, confidentiality and professional behaviour of participants and myself
- o All company information (industry-relations, data, trends, insights) which is not known to others and which is commercially or technical sensitive is considered confidential. I understand that the AUT and the researcher will keep such information and identities confidential and only use for academic purposes.
- ○ I understand that the researcher may ask to be referred to additional participants within or outside my company. I have the right to contact such additional participants and ask whether they would be interested in such participation. If so, they will contact the researcher.
- ○ I understand that the researcher may ask for additional documentation to be analysed for the academic purposes of the case study project. However, I am not obliged to provide any such documentation.
- ○ I understand that although the researcher or other participants may have suggestions that can be beneficial for my company, implementing such suggestions is my own commercial responsibility
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: ....……………………………………………………

Participant's name: ....……………………………………………………

Participant's email address:………………………………………………………………………………

Participants position……………………………………………………………………………………..

Participants
organisation……………………………………………………………………………………..

Date & Place……………………………………………………………………………………..

Approved by the Auckland University of Technology Ethics Committee on…….AUTEC Reference number………..

Note: The Participant should retain a copy of this form.

Investigating the effectiveness of adopting building information modelling for complex refurbishment building: Case of auckland

My name is Anthony Okakpu, A PhD student of Auckland University of Technology Auckland, under the supervision of Dr Ali GhaffarianHoseini, Prof John Tookey and Prof Jarrod Haar. We are conducting a study on investigating the effectiveness of adopting Building Information Modelling for complex refurbishment projects in New Zealand. There are environmental factors that influence the adoption of BIM. We are seeking to identify these factors and the collaboration processes within the project so that its effects on stakeholders' activities will be optimized to enable a platform to adopt BIM for refurbishment project. That is why we are asking for your participation.

This involves completing the following survey which is expected to take most people 30 minutes to complete. Your participation in this research is completely voluntary. I am NOT collecting your personal name or work place so you will never be personally identified – this means that you will be totally anonymous and your anonymity will not be compromised.

Please be aware there are no right or wrong questions to the questions asked. Just answer to the response that is closest to what you feel or agree/disagree with. Choosing not to answer a question does not exclude answering subsequent questions.

With thanks.

Anthony Okakpu

School of Engineering, Computer and Mathematics Science

Auckland University of Technology

Auckland.

To begin the survey, please turn to the following page >>

SURVEY QUESTIONS

Section I. Stakeholder Concerns in refurbishment project

Q1. The following table shows the stakeholder concerns in the Project. Please rate the relative importance of the following concerns to you based on your experience from 1-5, where "1" represents "least important", "5" represents "most important" and "N/A" represents "the concern is not related to me at all".

Social Factors

How does the following factors concern you when executing refurbishment project? (please circle one number for each row)

		N/A	Less		←→		Most
1	Occupants attitude ……………………………………….	0	1	2	3	4	5
2	Comfort requirement ……………………………………..	0	1	2	3	4	5
3	Access to control ………………………………………….	0	1	2	3	4	5
4	Management and alignment ……………………………….	0	1	2	3	4	5
5	Maintenance ……………………………………………….	0	1	2	3	4	5
6	Occupancy regimes ………………………………………..	0	1	2	3	4	5
7	Public awareness ………………………………………….	0	1	2	3	4	5
8	Social safety ……………………………………………….	0	1	2	3	4	5
9	Assess to education ………………………………………..	0	1	2	3	4	5
10	Collaboration ………………………………………………	0	1	2	3	4	5

11	Regulations and standards …………………………………	0	1	2	3	4	5

Space for comments…

Retrofit technologies

Would you rate the following factors according to your <u>main concern</u> based on your day to day project execution

		N/A	Less	←	→		Most
1	Economic payback of tool uses ……..	0	1	2	3	4	5
2	Complicated tool …………………….	0	1	2	3	4	5
3	Ease of tool implementation ……….	0	1	2	3	4	5
4	Energy saving technologies ……….	0	1	2	3	4	5
5	Renewable systems use …………….	0	1	2	3	4	5
6	Energy consumption patterns ……….	0	1	2	3	4	5
7	Adopting new technologies ………….	0	1	2	3	4	5

8	Compatibility with BIM software …	0	1	2	3	4	5
9	Coordination/clash detection tool ….	0	1	2	3	4	5
10	Integration tools ……………………	0	1	2	3	4	5
11	Collaboration tools …………………	0	1	2	3	4	5
12	Communication tools ………………	0	1	2	3	4	5
13	Interoperability tools ……………….	0	1	2	3	4	5

Space for comments…..

Daily Activities

To what degree does the following factors influence your activities with other team members? *(please tick one for each row)*

Stakeholder concerns	**1**	**2**	**3**	**4**	**5**	**N/A**
Investment decision	☐	☐	☐	☐	☐	☐
Payback period	☐	☐	☐	☐	☐	☐
Refurbish with energy conservation measures	☐	☐	☐	☐	☐	☐
Policies in construction works	☐	☐	☐	☐	☐	☐
Energy efficiency standard	☐	☐	☐	☐	☐	☐
Renovation consents	☐	☐	☐	☐	☐	☐
BIM Standards	☐	☐	☐	☐	☐	☐
Behavioural norms of a team member	☐	☐	☐	☐	☐	☐
Cultural heritage	☐	☐	☐	☐	☐	☐

Mission	☐	☐	☐	☐	☐	☐
Adaptability	☐	☐	☐	☐	☐	☐
Consistency	☐	☐	☐	☐	☐	☐
Involvement	☐	☐	☐	☐	☐	☐

Space for comments…..

Information sharing

To what extent does the following factors concern you when you share information with other project team members? (Circle one)

Stakeholder concern	Not at all	Slightly	Moderately	Quite a bit	Almo totall
Fair price …………………………..	**0**	**1**	**2**	**3**	**4**
Cost effective ………………………	**0**	**1**	**2**	**3**	**4**
Good service ……………………….	**0**	**1**	**2**	**3**	**4**
Energy saving reliability …………..	**0**	**1**	**2**	**3**	**4**

project completion time ……………	**0**	**1**	**2**	**3**	**4**
Construction materials management..	**0**	**1**	**2**	**3**	**4**
Waste minimization ………………...	**0**	**1**	**2**	**3**	**4**
Energy minimization ………………	**0**	**1**	**2**	**3**	**4**
Noise management ………………..	**0**	**1**	**2**	**3**	**4**
Pollution management ……………	**0**	**1**	**2**	**3**	**4**
Use of land ………………………..	**0**	**1**	**2**	**3**	**4**
Health management ………………	**0**	**1**	**2**	**3**	**4**
Air quality management …………	**0**	**1**	**2**	**3**	**4**
Type of comfort ………………….	**0**	**1**	**2**	**3**	**4**
Aesthetics ………………………..	**0**	**1**	**2**	**3**	**4**
Decoration ……………………….	**0**	**1**	**2**	**3**	**4**
Environment purposes …………..	**0**	**1**	**2**	**3**	**4**
Buildings purposes ………………	**0**	**1**	**2**	**3**	**4**
Level of detail ……………………	**0**	**1**	**2**	**3**	**4**
Schedule and time model ………..	**0**	**1**	**2**	**3**	**4**
Operation and maintenance model..	**0**	**1**	**2**	**3**	**4**
Sustainability model ………………	**0**	**1**	**2**	**3**	**4**
Resources and cost model ………..	**0**	**1**	**2**	**3**	**4**

Space for comments……

Project attribute

How would you rate the following factors according to how it influences your decisions with your team members when you carry out refurbishment projects

		N/A	Least important ←				Very important →
		0	1	2	3	4	5
1	Data richness	☐	☐	☐	☐	☐	☐
2	Life-cycle views	☐	☐	☐	☐	☐	☐
3	Change management	☐	☐	☐	☐	☐	☐
4	Delivery method	☐	☐	☐	☐	☐	☐
5	Role of disciplines	☐	☐	☐	☐	☐	☐
6	Timeliness/response	☐	☐	☐	☐	☐	☐
7	Graphical information	☐	☐	☐	☐	☐	☐

8	Spatial capability	☐	☐	☐	☐	☐	☐
9	Interoperability/IFC support	☐	☐	☐	☐	☐	☐
10	Information accuracy	☐	☐	☐	☐	☐	☐
11	BIM contents library	☐	☐	☐	☐	☐	☐
12	Size and complexity of project	☐	☐	☐	☐	☐	☐
13	BIM capability	☐	☐	☐	☐	☐	☐

Space for comments…….

Organisational influences

When working on a group project, how would you rate the following factors based on its impact on your role in the project? (Please mark one for each row)

		N/A	Negatively				Positively
1	Organizational structure	0	1	2	3	4	5

2	Strategy	0	1	2	3	4	5
3	Mechanisms and procedures to manage changes	0	1	2	3	4	5
4	Accomodating cultural variations between project team members	0	1	2	3	4	5
5	Resources	0	1	2	3	4	5
6	Engineering method	0	1	2	3	4	5
7	Information sharing	0	1	2	3	4	5
8	BIM scope	0	1	2	3	4	5
9	Coordinating with interfacing construction projects	0	1	2	3	4	5
10	Previous experience of the project team in undertaking similar construction projects	0	1	2	3	4	5
11	Enterprise integration	0	1	2	3	4	5
12	functionality/capability	0	1	2	3	4	5
13	Physical accuracy of model	0	1	2	3	4	5
14	Content creation	0	1	2	3	4	5
15	Location awareness	0	1	2	3	4	5
16	IPD methodology	0	1	2	3	4	5
17	Calculation Mentality	0	1	2	3	4	5

18	Establishing trust, common understanding and mutual goals between client, contractors and consultants	0	1	2	3	4	5
19	Implement refurbishment project with BIM	0	1	2	3	4	5
		N/A	Negatively ←			→ Positively	
20	Storage device (computer hardware)	0	1	2	3	4	5
21	Input device (processing device/motherboard)	0	1	2	3	4	5
22	Output device (computer hardware)	0	1	2	3	4	5
23	Networking hardware	0	1	2	3	4	5
24	Confidence with traditional method	0	1	2	3	4	5

Space for comments……………

Risk influences

1) We are interested to learn the importance of **Software compatibility** risk to adoption of BIM. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

2) We are interested to learn the importance of **transition workflow** risk to adoption of BIM. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

3) We are interested to learn the importance of **management process change** risk to adoption of BIM. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

4) We are interested to learn the importance of **who controls the entry of data** risk to BIM adoption. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

5) We are interested to learn the importance of **Increase in short term work load** risk to your role in the project. Please shade the number below that describes social impact on your role in the project

0 1 2 3 4 5

6) We are interested to learn the importance of **unclear legal liabilities** risk to your role in the project. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

7) We are interested to learn the importance of **additional expenditures** risk to your role in the project. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4

8) We are interested to learn the importance of **BIM standard** risk to your role in the project. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

9) We are interested to learn the importance of **available skill personnel** risk to your role in the project. Please shade the number below that describes this impact on your role in the project

0 1 2 3 4 5

Section 11. Information exchange relationship

This section collects your opinions regarding your information exchange relationships with each of the stakeholders in the Project.

Definition of information

In this survey, information refers to: (1) any information which is related to the stakeholder concerns shown in Section II, and (2) any information whose transmission can help or is essential for the stakeholders to understand or address these concerns.

Definition of information exchange

Information is exchanged in two directions. In one direction, you OBTAIN information from a set of stakeholders to help in understanding/addressing stakeholder concerns (please refer to Q2). In the opposite direction, you PROVIDE information to a set of stakeholders to facilitate them in understanding/addressing stakeholder concerns (please refer to Q3).

Instructions

In Q2 and Q3, please firstly identify the stakeholders who have information flow relationships with you (a Stakeholder List is provided in the Appendix for your reference). Information flow includes two directions: Q2 considers you as the information recipient; Q3 considers you as the information provider.

Then, in Q2 and Q3, please evaluate your information flow relationships with each of the identified stakeholders according to three relationship attributes (frequency, access, and information quality) using a numerical scale of 1-5. The numerical scale is defined below.

Numerical scale

(i) Frequency:	“1” = “less than once a month”, “2” = “biweekly to monthly”, “3” = “weekly”, “4” = “several times a week”, and “5” = “at least once per day”
(ii) Access:	“1” = “very untimely access”, “2” = “untimely access”, “3” = “fairly timely access”, “4” = “timely access”, and “5” = “very timely access”
(iii) Information quality:	“1” = “very low quality”, “2” = “low quality”, “3” = “fair quality”, “4” = “good quality”, and “5” = “very good quality”

Note: Definitions of the above relationship attributes will be given in Q2 and Q3.

Q2. From which stakeholders do you **OBTAIN** information to assist in understanding/addressing the stakeholder concerns shown in Section II?
Please list these stakeholders and their project role in Q2a.

For each identified stakeholder, please rate the following items from 1-5 according to the numerical scale shown in Page 4:

(i) Frequency: **How often** do you obtain information from the identified stakeholder? Please rate in Q2b;
(ii) Access: Do you obtain information from the identified stakeholder **in a timely manner**? Please rate in Q2c;
(iii) Information quality: What is the **quality of the information** obtained (e.g. correctness, completeness and comprehensibility)? Please rate in Q2d.

From which stakeholder(s) do you **OBTAIN** information?		2b Frequency					2c Access					2d information quality				
Stakeholders	Role in the project	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
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		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
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Note: (i) Please identify as many stakeholders as possible. Stakeholders not identified are considered as having no relationships with you.
(ii) Please feel free to add more rows if necessary.

Q3. To which stakeholders do you **PROVIDE** information to assist them in understanding/addressing the stakeholder concerns shown in Section II?

Please list these stakeholders and their project role in Q3a.
For each identified stakeholder, please rate the following items from 1-5 according to the numerical scale shown in Page 4:
(i) *Frequency:* **How often** do you provide information to the identified stakeholder? Please rate in Q3b;
(ii) *Access:* Do you provide information to the identified stakeholder **in a timely manner**? Please rate in Q3c;
(iii) *Information quality:* What is the **quality of information** transferred by you (e.g. correctness, completeness and comprehensibility)?
Please rate in Q3e.

To which stakeholder(s) do you **PROVIDE** information?		3b Frequency					3c Access					3d information quality				
Stakeholder	Role in the project	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**

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Note: (i) Please identify as many stakeholders as possible. Stakeholders not identified are considered as having no relationships with you.
(ii) Please feel free to add more rows if necessary.

Section III.

General Information *(Only overall statistical data will be compiled, i.e. individual information not disclosed)*

Q111a. Name of your organization:

Q111b. Stakeholder role of your organization in the Project:

Q111c. Your position in the organization:

Q1d. Scope of work of your department and organization in the Project:

Q111e. Your work experience:

 5 years or below, 6-10 years , 11-15 years, 16-20 years, Over 20 years

Age differences

 20 years or below, 21-35 years , 36-49 years, 50-65 years, Over 65 years

Gender

 Male, Female , Neutral

Appendix: ***Stakeholder List for Reference***

The table below shows the stakeholders of this Project. You may refer to this list when you identify stakeholders in Q2 and Q3.

Code	Role in the project	Stakeholder
S1		
S2		
S3		
S4	(Not disclosed herein due to the issue of confidentiality)	(Not disclosed herein due to the issue of confidentiality)
….		
Sn		

Where "S" denotes the stakeholder while "n" denotes the total number of stakeholder identified through the project document and by classical base method.

(End)

Thank you for your kind cooperation and valuable assistance in participating in this survey

THE RECENT REFURBISHMENT STAKEHOLDERS FOR XXX BUILDING AT AUT CITY CENTRE, WE

Auckland University of Technology is known for many things in the field of research but one thing that we pride ourselves in is diversity and inclusion of student and staff diversity communities in this university.

My name is Anthony Okakpu, I am a PhD student of Auckland University of Technology Auckland. My topic is investigating the effectiveness of adopting building information modelling for complex refurbishment buildings. The aim of this research is to motivate the adoption of Building Information Modelling (BIM) for complex refurbishment projects by addressing the potential benefits of BIM adoption for refurbishment projects. This will be achieved by analysing the interaction of refurbishment stakeholders in a traditional method of refurbishment and BIM method to compare the real benefits. We hope that this research will provide;

1) **key determinant factors that influence the decision to adopt BIM for refurbishment projects in New Zealand.**
2) **Real benefits between the traditional method and the BIM method.**
3) **The level of perception of BIM adoption by refurbishment stakeholders in Auckland**

If you are interested, contact us on:

Project supervisor: *ali.ghafarahoseini@aut.ac.nz/+649219999………ext. 7968*

Researcher: *ifectony@yahoo.com/+64212108082*

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