# Enhancing Green Star Certification by Improving BIM Uptake through System Dynamics Modelling

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By

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# Abstract


The construction industry has been criticised for its undesirable characteristics and its negative impacts on the environment. In New Zealand, low construction productivity and high levels of construction and demolition waste have been pressing concerns. BIM and Green Star uptake could mitigate these problems. However, they are still in their early stages in New Zealand. Understanding insights into BIM and Green Star is necessary for successful BIM and Green Star development. This research examines the characteristics of BIM and Green Star in New Zealand. It aims to provide a platform to enhance Green Star certification uptake by improving BIM uptake.

Interviews were conducted with construction experts concerning BIM adoption. Construction productivity or efficiency and sustainability improvement were highlighted as possible benefits of using BIM. A lack of understanding was suggested as the most significant challenge preventing BIM implementation. Providing education/training was suggested as a solution.

Green Star characteristics and its relationship with BIM were investigated through the mixed methods approach. Implementing Green Star offers benefits to the environment. However, the lack of understanding, cost perception, lack of benchmark projects, and complex administration of Green Star have deterred Green Star users. Similar to BIM, providing education is critical to address those challenges. A questionnaire survey confirmed that integrating BIM with Green Star is a practical solution. However, the low level of BIM development was perceived as one of the serious challenges and executing BIM correctly could solve those challenges.

A BIM adoption framework was developed to improve understanding and adoption. 7 main categories and 39 indicators affecting BIM adoption were determined from the data and three well-known Business Excellence Models (BEMs). Structural equation modelling (SEM) was adopted for validation and to measure the impacts of each category on each other. Leadership, Clients & Other Stakeholders, Strategic Planning, Resources, People, Process, and Results are the main categories of the framework.

A BIM-Green Star system dynamics (SD) model was developed and validated to provide insights into BIM and Green Star. The results indicate that it takes 8 years for an organisation in New Zealand to achieve BIM level 3 from BIM level 0 and 5 years to reach BIM level 2. It also reveals that an organisation would take 9 years to integrate BIM with Green Star appropriately. Different strategies towards BIM adoption along with the integration of BIM and Green Star were tested. Leadership was identified as the most significant category and could help organisations achieve BIM level 3 quicker.

The research provides insights into the characteristics of BIM and Green Star, confirms the challenges, and provides solutions for BIM and Green Star development. Also, a set of categories and indicators to assess the BIM practice was provided. The government, local authorities, and construction organisations could use the results as guidelines to improve their BIM and Green Star practice. They can adapt the developed SD model to test the effectiveness of their strategies towards BIM and Green Star over time; the positive direction for BIM and Green Star development can be achieved.

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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 (except where explicitly defined in the acknowledgements), 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.

Dat Tien Doan

09 May 2019

# List of Publications

## Journal Articles

Doan, D. T., GhaffarianHoseini, A., Naismith, N., Zhang, T., Tookey, J., & GhaffarianHoseini, AH. (2019). Examining critical perspectives on BIM adoption in New Zealand. *Journal of Construction Engineering and Management* (Under review): Chapter 2 .

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Doan, D. T., GhaffarianHoseini, A., Naismith, N., Zhang, T., Rehman, A., Tookey, J., & GhaffarianHoseini, AH. (2018). "What is BIM? A need for a unique BIM definition." *MATEC Web of Conf., 266, 05005: Proceedings of the Inaugural International Conference on the Built Environment and Engineering (IConBEE2018)*, 29-30 October 2018, Johor Bahru, Malaysia.

# Co-Authored Works and Declaration of Collaboration

Statement from co-authors confirming the authorship contribution of the PhD candidate:

As co-authors of the research “Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling,” we confirm that Mr. Dat Tien Doan contributed over 80% of the research. Mr. Dat Tien Doan is responsible for writing, ideas, and the content of the research.

Supervisors, Dr Ali GhaffarianHoseini, Assoc. Prof. Nicola Naismith, and Dr Amirhosein Ghaffarianhoseini, and the mentor, Prof. John Tookey, provided guidance and support to improve the quality of the research.

Colleagues, Mr. Tongrui Zhang and Mr. Attiq Rehman, provided their expertise and advice as construction experts to support the research.

Contribution of the authors to each journal article:

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# Chapter 1 Introduction

## 1.1 Overview

Chapter 1 outlines the background to this research. It provides descriptions and characteristics of the New Zealand construction industry, Building Information Modelling (BIM), Green Star, and previous research working on those topics. Next, the problem statement, research aim, research objectives, and research questions are presented. Research methods used in this study are then described before providing the research contribution to the construction industry. Also, the structure of the research is provided with a summary of the objectives, methods, activities, and brief results of the next chapters.

## 1.2 New Zealand Construction Industry

The construction industry plays an essential role in providing the needs of society and enhancing the quality of life (Kucukvar & Tatari, 2013; Rahman, Memon, & Karim, 2013). It is one of the key drivers to the New Zealand economy, accounting for 4% of New Zealand's GDP (Carson & Abbott, 2012) and employing 8% of the total employees in the country (Noktehdan, Shahbazpour, & Wilkinson, 2015). Based on the data provided by StatsNZ (2018), figureNZ (2018) analysed and indicated that the construction industry is in the top 4 sectors contributing highest to GDP in New Zealand, with NZ$16,895 million.

Despite its crucial role in the development of New Zealand, still many aspects of the construction industry could be improved. Infrastructure development in New Zealand lags behind other Organisation for Economic Co-operation and Development (OECD) countries, which could be due to the low construction productivity (Liu & Wilkinson, 2011). Low productivity is also explained as a reason why New Zealand's incomes are below the OECD average (Barker, 2017). It has been attached to the construction industry, and it has been well-recognised by the New Zealand society (Noktehdan et al., 2015). New Zealand has a low level of construction productivity compared to other countries (Lessing, Thurnell, & Durdyev, 2017). An increase of 1% in construction productivity could lead to an increase of 2% in the country' gross domestic product (Haji Karimian, Mbachu, Egbelakin, & Shahzad, 2019). This forced the establishment of the Building and Construction Sector Productivity Partnership to increase 20%

productivity by 2020 (Noktehdan et al., 2015) to manage the existing building stock, worth of NZ$388 billion (Durdyev & Mbachu, 2011).

It is undeniable that the construction industry is still amongst the lowest sectors in innovations (Noktehdan et al., 2015). Lack of innovation or faulty innovation is one of the identified reasons for low construction productivity (Carson & Abbott, 2012). The expenditure for R&D in the New Zealand construction industry just accounts for 5% of the total expenditure of the sector (Noktehdan et al., 2015). New Zealand just spent 1.2% GDP on R&D compared to 2.4% on average of the OECD countries, standing at the 28$^{th}$/34$^{th}$ place (StatsNZ, 2014). A lack of competition due to the remote area is explained as a reason why R&D has not been focused in New Zealand (Barker, 2017). In other words, New Zealand is sluggish to adopt new innovative approaches despite their substantial impacts on the construction industry in general and on the productivity in particular (Barker, 2017; Hampson, Kraatz, & Sanchez, 2014).

According to Hampson et al. (2014), a significant amount of waste is another undesirable characteristic of the construction industry besides low innovation and productivity. It has been seen as a significant contributor to environmental degradation (N. Wang, 2014). It is responsible for consuming a third of global resources, a quarter of wood harvested, 40% of raw materials, and one-sixth of global freshwater (Doan et al., 2017). As a result, a massive amount of construction and demolition waste has been created, constituting of around 40% of the solid waste in developed countries (Doan et al., 2017). Interestingly, 40% is also the figure of construction and demolition waste of all waste disposing of in landfills in New Zealand (Auckland-Council, 2018), which is believed to be higher, at around 50% of all waste created in New Zealand, in reality (Auckland-Council, 2018; Taylor & Field, 2007). The figure is in line with the one that Hampson et al. (2014) revealed, which ranges from 30% to 60%.

Realising the enormous waste created, Low Carbon Action Plan was developed by the Auckland Council focusing on improving the environment (Auckland-Council, 2018). Specifically, the plan aims to divert 30% of waste to landfills by 2020, 60% by 2030, and zero waste to landfills by 2040 (Auckland-Council, 2018). However, whether the plan will be effective is a question. As mentioned by Storey and Pedersen (2014) that the

New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand 2002 was released in the past to reduce 50% of construction and demolition waste to landfills by 2008; and the construction and demolition waste at that time just accounted for 17% of municipal solid waste generation. Also, the Territorial Authorities in New Zealand declared to aim for zero waste by 2015 (Storey & Pedersen, 2014). However, 40% of the total waste is construction and demolition waste currently (Auckland-Council, 2018). One of the suggested solutions to mitigate the enormous amount of waste is innovation (Storey & Pedersen, 2014). The Waste Minimisation and Innovation Fund (WMIF) is trying to encourage innovation by providing millions of dollars for waste minimisation projects (Auckland-Council, 2018).

In summary, low productivity and construction and demolition waste are the significant problems in the New Zealand construction industry in which innovation is one of the remarkably effective solutions to mitigate those problems. The government and local authorities should focus heavily on R&D, and encourage the industry to adopt innovative solutions. The next section presents one of the innovative solutions for the construction industry development that has been devoted attention by global governments, construction practitioners, and researchers recently.

## 1.3 Building Information Modelling (BIM)

BIM is defined by the International Organisation for Standardization as "shared digital representation of physical and functional characteristics of any built object (including buildings, bridges, roads, etc.) which forms a reliable basis for decisions" (ISO, 2010). BIM has been mentioned recently in New Zealand as one of the innovative building industry technologies that could transform the building industry (Harrison & Thurnell, 2015; Seadon & Tookey, 2019; S. Wilkinson et al., 2010). It has been recognised as an effective solution to most of the existing problems of the construction industry because of its wide range of benefits that could "fundamental change in the way buildings are designed, constructed, and operated" (GhaffarianHoseini, Tien Doan, Naismith, Tookey, & GhaffarianHoseini, 2017). Tulubas Gokuc and Arditi (2017) revealed 18 benefits of BIM adoption (e.g., improving design productivity and reducing waste) leading to the reducing overall project time and cost along with improving overall project quality. As a result, BIM has been planned or mandated for all public sector buildings or government projects in Finland, Norway, Denmark, Netherlands, and the UK (Smith, 2014b).

In contrast, a lack of government direction or mandate was revealed as one of the significant challenges for BIM adoption in New Zealand (EBOSS, 2018). Besides, very few studies focusing on BIM adoption in New Zealand has been conducted. Only three journal papers, except the papers belonging to this research, were found on Scopus database with the keywords *"BIM" + "New Zealand"* in *Engineering* subject area including "Making friends with Frankenstein: Hybrid practice in BIM" (Davies, McMeel, & Wilkinson, 2017), "BIM implementation in a New Zealand consulting quantity surveying practice" (Harrison & Thurnell, 2015), and "Potential of building information modelling for seismic risk mitigation in buildings" (Welch, Sullivan, & Filiatrault, 2014). This suggests that BIM adoption in New Zealand is still in its early stages, which was also stated by Boon and Prigg (2012).

It is clear that the level of BIM adoption in New Zealand is still low compared to other countries. For example, different types of resources have been provided in the UK to plan mandated BIM level 2 since 2016, see Figure 1.1. Whereas, only two documents including International BIM Object Standard (Masterspec, 2016) and New Zealand BIM Handbook (BAC, 2016) were developed for BIM implementation in New Zealand.

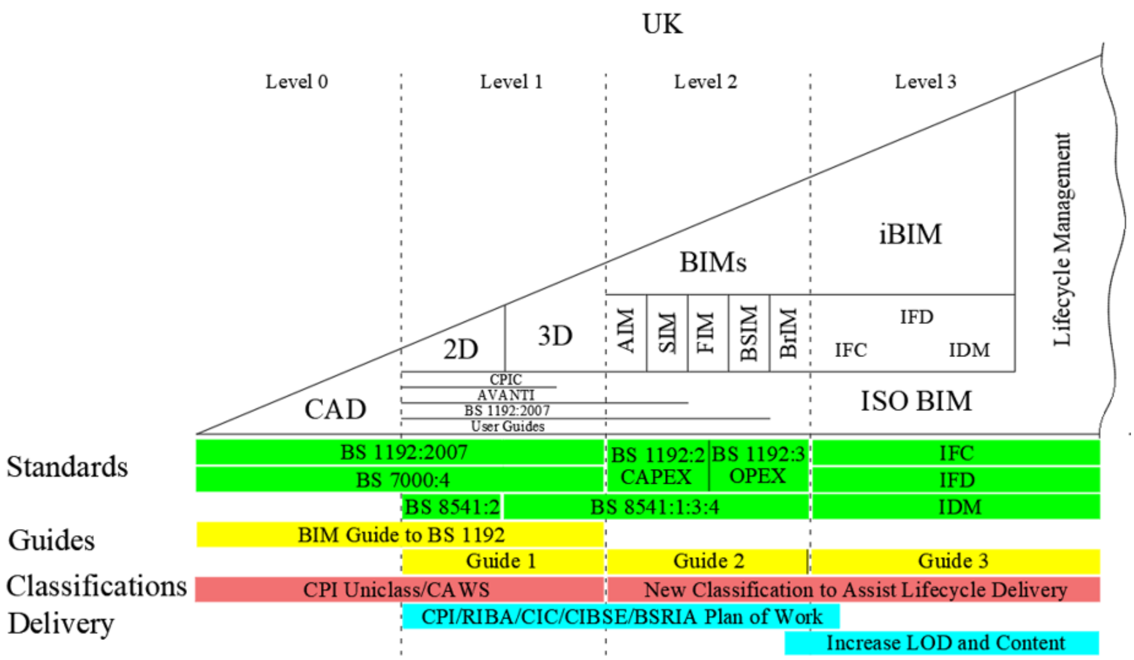



Figure 1.1. Resources for BIM adoption in the UK

(Bew & Richards, 2008)

## 1.4 Green Star

Green Star was established by the New Zealand Green Building Council in 2007 to promote the benefits of sustainable development, motivate and reward sustainable construction projects (NZGBC, 2019b). It evaluates the sustainability of a project through management, indoor environment quality, energy, transport, water, materials, land use & ecology, emissions, and innovation (NZGBC, 2017b). Although the benefits and development of green buildings are well recognised globally, they are not considered top priority in New Zealand currently (Green Star used to be mandated by the New Zealand government by 2010 (Bennet & Halvitigala, 2013)).

Adopting Green Star is considered as a solution to minimise the undesirable characteristics of the New Zealand construction industry, which were mentioned above. Indoor environment quality is one of the most important criteria of not only Green Star but also BREEAM (Building Research Establishment Assessment Method), LEED (Leadership in Energy and Environmental Design), and CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) with major credits, weightings, and sub-categories (Doan et al., 2017). Improving indoor environment quality could improve the performance of the employees by 8% or even 18% (WGBC, 2014). An increase of 1% productivity equals saving €51.5 billion per year for the European offices (Kockat, Dorizas, Volt, & Staniaszek, 2018). Fisk (2000) found out that improving indoor environment quality leading to the increase in productivity could save a minimum of $38 billion for the US. Furthermore, a considerable amount of construction and demolition waste could be reused, reduced, and recycled with Green Star certification uptake (Inglis, 2007). Amongst nine Green Star certified buildings investigated by Prins (2013), a minimum of 50% of waste was recycled by seven of them. It is noticed that the Christchurch Civic Building, a 6 Green Star rating building, reused and recycled at least 86.9% construction and demolition waste (CCC, 2011).

In Zealand, however, Green Star is only encouraged by several local authorities currently. Green Star was included in the Proposed Unitary Plan in Auckland (NZGBC, 2014) while 50% remission of levies has been offered by Wellington City Council for 5 Star or higher Green Star certified projects (WCC, 2015). This could be part of the reason why the number of Green Star certified projects is still modest in New Zealand, with 254 projects since 2007 (NZGBC, 2019c). Besides, similar with BIM, Green Star has not been an attractive topic to the New Zealand researchers, with only three journal papers, except the papers belonging to this research, in Scopus database including "Why are naturally ventilated office spaces not popular in New Zealand?" (Rasheed, Byrd, Money, Mbachu, & Egbelakin, 2017), "The productivity paradox in green buildings" (Byrd & Rasheed, 2016), and "Construction costs comparison between green and conventional office buildings" (Rehm & Ade, 2013). This highlights the need for further research on Green Star owing to its potential benefits to the construction industry (e.g., improving the productivity, reducing the construction and demolition waste).

## 1.5 Problem Statement

In recent years, BIM and green buildings have been attracted attention from global researchers owing to their potential benefits to the construction industry (Yalcinkaya & Singh, 2015; Zuo & Zhao, 2014). Undesirable characteristics of the construction industry revealed by Hampson et al. (2014) could be reduced with widespread BIM adoption and green building certification uptake (Azhar, 2011; J. K. W. Wong & Zhou, 2015; Yudelson, 2010). In contrast with other OECD countries, R&D in New Zealand has still been ignored (StatsNZ, 2014). As a result, BIM and Green Star, considered as the primary certification for green buildings in New Zealand supported by Auckland and Wellington Councils (NZGBC, 2014; WCC, 2015), are still in their early stages with very few publications.

Amongst three studies found in Scopus database with the keywords *"BIM" + "New Zealand,"* only one study focused on the New Zealand context. Harrison and Thurnell (2015) examined the benefits and challenges of BIM adoption to quantity surveying practice in New Zealand. Although Davies et al. (2017) revealed the reasons leading to the hybrid BIM practice, the study did not separate the results between Australia and New Zealand. In other words, the results from Davies et al. (2017) study may not appropriate for the New Zealand context because the authors have not proved the similarity of the characteristics between these two countries. It is noticed that the Australian construction industry is ahead of the New Zealand construction industry especially regarding the skills and average labour productivity (Barker, 2017; Eaqub, 2012; G. Mason, 2013; S. Wilkinson et al., 2010). Whereas, New Zealand was just mentioned in Welch et al. (2014) study to remind the Christchurch earthquake in 2011.

It is clear from the previous BIM studies in New Zealand that BIM adoption has not been fully investigated until now.

Regarding three journal papers found in Scopus database mentioned Green Star in New Zealand, Rasheed et al. (2017) and Byrd and Rasheed (2016) focused on indoor environment quality criterion of Green Star. Whereas, a comparison of Green Star buildings and conventional buildings was made by Rehm and Ade (2013) to examine the difference in terms of construction costs between these two types of buildings. As a result of the limited studies on Green Star, the current situation of Green Star practice in New Zealand is still ambiguous while the number of Green Star certifications is still modest (NZGBC, 2019c).

According to Zuo and Zhao (2014), BIM can be a powerful tool to facilitate the green building certification process. K.-d. Wong and Fan (2013) indicated that BIM could provide the best sustainable building design that can reduce energy and resources consumption. Whereas, Azhar, Carlton, Olsen, and Ahmad (2011) revealed that 17 LEED credits and 2 prerequisites could be linked directly to BIM. Based on Gandhi and Jupp (2014), most of the Australian Green Star credits could be achieved with the implementation of BIM. In the UK, the Royal Institute of British Architects (RIBA) (2011) developed a plan of work to link the construction stages into sustainability checkpoints in which BIM is an appropriate tool to deliver sustainability aims. In New Zealand, however, BIM is not a major focus when BIM is indicated as one of the “possible trends the NZRAB may need to be aware” by the New Zealand Registered Architects Board (NZRAB) (2018). In other words, insights into BIM and Green Star practices have not been explored in New Zealand. Also, the relationship between BIM and Green Star has not been studied yet.

## 1.6 Research Aim

This research aims to provide a platform to enhance Green Star certification uptake in the New Zealand context by improving BIM uptake.

### 1.6.1 Objective 1: Examine the characteristics of BIM adoption in New Zealand

As mentioned above, BIM adoption in New Zealand has not been fully investigated by academics, their characteristics have not been found out. Identifying the benefits of

BIM adoption in New Zealand is necessary as it could improve BIM understanding amongst construction practitioners and encourage them to adopt BIM. Also, barriers/challenges to BIM adoption should be determined before proposing effective solutions to improve the quality of BIM projects and BIM adoption rate. Furthermore, 'what BIM is' should be highlighted because it is still an ambiguous term in the construction industry (Aranda-Mena, Crawford, Chevez, & Froese, 2009; Jaradat & Sexton, 2016).

As a result, four research questions are expected to be answered to achieve this objective, including:

1) What is BIM?;

2) What are the benefits of BIM adoption?;

3) What are the barriers/challenges to BIM adoption?;

4) What are the solutions for BIM adoption? (see Figure 1.2).

### 1.6.2 Objective 2: Examine the characteristics of Green Star uptake in New Zealand

Similar to BIM, the characteristics of Green Star, including the benefits, barriers/challenges, and solutions, in New Zealand have not been fully identified. Therefore, this objective aims to determine the benefits, barriers/challenges, and solutions for Green Star certification uptake.

Three research questions need to be addressed to achieve this objective are as follows:

1) What are the benefits of Green Star uptake?;

2) What are the barriers/challenges to Green Star uptake?;

3) What are the solutions for Green Star uptake?.

### 1.6.3 Objective 3: Explore the relationship between BIM and Green Star in New Zealand

This objective aims to examine how BIM adoption could affect Green Star certification uptake and how Green Star certification could affect BIM adoption in New Zealand.

Also, the barriers/challenges to the integration between BIM and Green Star are identified. Then, solutions for integration are suggested.

To achieve this objective, three research questions are planned to be solved, including:

1) What is the relationship between BIM and Green Star?;

2) What are the barriers/challenges to the integration of BIM and Green Star?;

3) What are the solutions for the integration of BIM and Green Star?.

### 1.6.4 Objective 4: Develop and validate a BIM adoption framework to improve BIM understanding and BIM practice in New Zealand

After identifying the characteristics of BIM adoption and the relationship between BIM and Green Star in New Zealand, a BIM adoption framework will be developed. Besides highlighting the critical factors affecting BIM adoption, the framework also reveals the relationships amongst those factors. As a result, it can be used as a guideline for BIM adoption in New Zealand.

Three research questions as follows are expected to be answered:

1) What are the critical categories affecting BIM adoption?;

2) What are the critical indicators of each category affecting BIM adoption?;

3) What are the relationships amongst those critical categories affecting BIM adoption?.

### 1.6.5 Objective 5: Develop and validate a BIM-Green Star system dynamics (SD) model to improve BIM and Green Star understanding and BIM and Green Star practice in New Zealand

The BIM-Green Star SD model will be developed and validated based on the characteristics and relationship between BIM and Green Star. It aims to provide insights into how BIM could affect Green Star. The model will reveal the impacts of significant factors of BIM adoption on Green Star. As a result, construction professionals can adjust their BIM strategies to have BIM most effective on Green Star certification uptake.

Three research questions are planned to be answered, including:

1) What are the critical categories affecting BIM and Green Star uptake?;

2) How do those categories affect BIM and Green Star uptake?;

3) What is the most important category affecting BIM and Green Star uptake?.

Figure 1.2 summarises the research aim, research questions, and expected outcomes of the research.

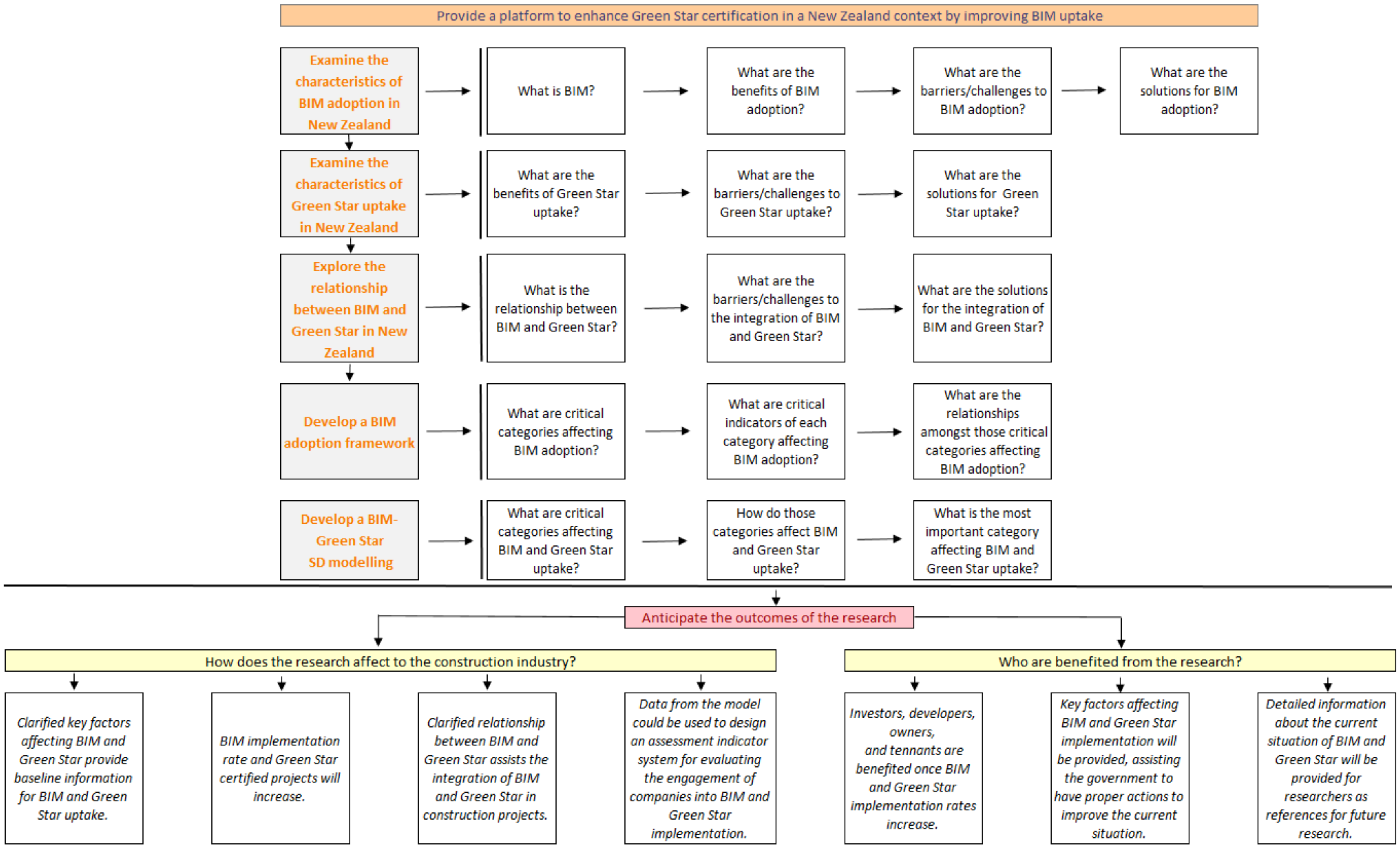



Figure 1.2. Research aim, questions, and expected outcomes

## 1.7 Research Contribution

The research proposes an innovative approach in which BIM and Green Star practice could be improved simultaneously. Specifically, the research aims to enhance Green Star certification uptake by improving BIM adoption. This will help the construction industry to tackle existing problems regarding low construction productivity, a considerable amount of construction and demolition waste, environmental degradation. The results of the research are expected to provide insights into BIM and Green Star certification uptake in New Zealand. Key factors affecting BIM and Green Star will be determined to improve construction practitioners' understanding. Also, the interrelationships amongst the critical factors affecting BIM and Green Star will be identified. Consequently, a set of assessment indicators will be provided to evaluate the development of BIM and Green Star implementation. Then, appropriate strategies and actions towards BIM and Green Star could be planned to improve the BIM adoption rate, the quality of BIM projects, and the number of Green Star certified projects.

Recently, New Zealand has established several strategic plans to improve the construction industry. For example, an increase of 20% of productivity was planned to be achieved by 2020 (Noktehdan et al., 2015) while 30% of waste to landfills was planned to be reduced by 2020 (Auckland-Council, 2018). This research could play an essential role to those plans as it provides an innovative approach to improve BIM and Green Star in New Zealand; BIM and Green Star uptake are expected to be solutions for the low construction productivity and negatives impacts of the construction industry on the environment.

Currently, little research focuses on BIM and Green Star in New Zealand. By providing insights into current BIM and Green Star practice, the research results could be used by other researchers as references for future research.

## 1.8 Research Methods

This study adopts the mixed methods approach, combining qualitative and quantitative data. Specifically, exploratory sequential mixed methods will be conducted. In this kind of method, a qualitative research phase will assist to explore the views of participants first to specify variables that need to go into a follow-up quantitative phase (Creswell & Creswell, 2017) (see Figure 1.3).

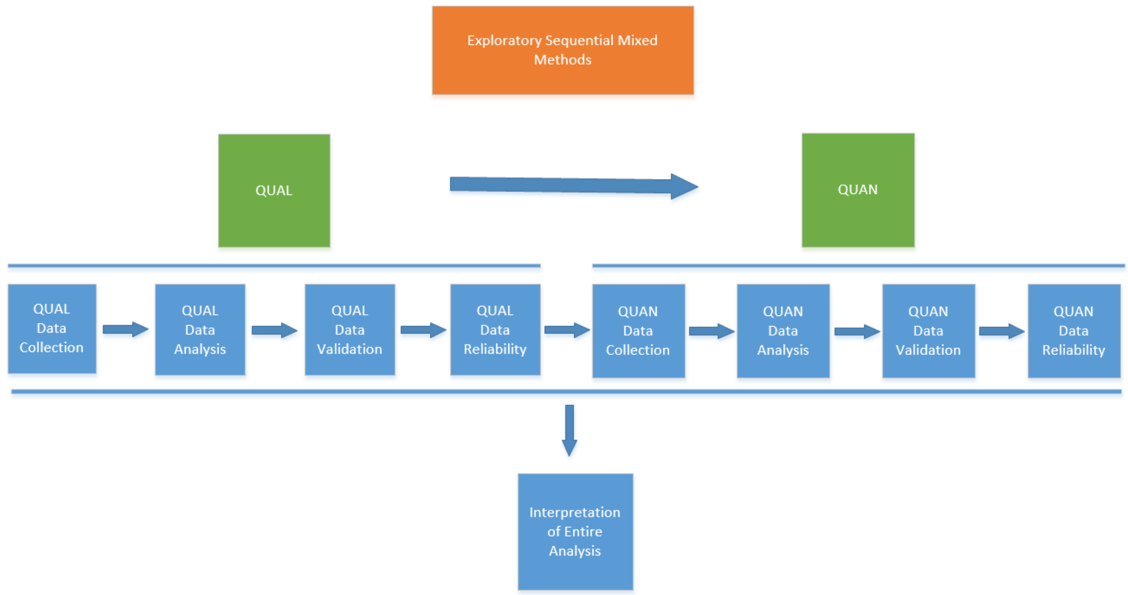



Figure 1.3. Sequential exploratory design

(adapted from Creswell and Creswell (2017))

Because of the limited research on both BIM and Green Star in New Zealand, the exploratory sequential mixed methods are considered appropriate. Mixed methods are selected as the qualitative method provides "deep, rich observational data" (Onwuegbuzie & Leech, 2005; Sieber, 1973) while the quantitative method provides "the virtues of hard, generalizable survey data" (Onwuegbuzie & Leech, 2005; Sieber, 1973). This method has "the potential to provide new insights into, and enhanced understanding of, phenomena being investigated" (Krivokapic-Skoko & O'neill, 2011). It also provides "rich data, lead to new lines of thinking, and by intentionally engaging multiple perspectives and presenting a greater diversity of views," and can be "inclusive, pluralistic and complementary" (Krivokapic-Skoko & O'neill, 2011). Johnson, Onwuegbuzie, and Turner (2007) stated that mixed methods "recognise the importance of traditional quantitative and qualitative research but also offers a powerful third paradigm choice that often will provide the most informative, complete, balanced, and useful research results." Mixed methods are a complementary approach in which qualitative research and quantitative research supplement its weakness and strength (Amaratunga, Baldry, Sarshar, & Newton, 2002; Johnson & Onwuegbuzie, 2004).

This study focuses on the relationship between BIM and Green Star, along with the solutions to minimise the barriers and enhance the benefits of BIM and Green Star. SD is based on an "endogenous feedback view of system causes and effects" (Zagonel, 2002); and solutions to the perceived problem will be "revealed through feedback thinking, the key expertise offered" (Forrester, 1961; J. D. Sterman, 1994; Zagonel, 2002). SD modelling could be used to enhance knowledge and understanding of the system, and to discover strategies that improve system behaviour (Albin, Forrester, & Breierova, 2001; Richardson & Pugh III, 1981). It focuses on "feedback structure and the resultant behaviour to understand a complex system in a holistic manner" (Shin, Lee, Park, Moon, & Han, 2014; J. Sterman & Sterman, 2000). Also, complex management problems and long-term behaviour of real-world systems could be analysed by SD adoption (J. L. Hao, Hill, & Shen, 2008). It is stated as a useful method to modellers which could provide insights quickly with low cost (Pienaar, Brent, & Musango, 2015).

Furthermore, data from the literature review, qualitative, and quantitative phases are identified as three sources of information for building an SD model (Forrester, 1987). In other words, SD modelling describes the system and understanding with qualitative and quantitative models (W. Wang & Cheong, 2005). The model "draws primarily upon the mental database (observation and experience) to reflect knowledge of organisational policies and system structure" (Forrester, 1987, 1994). This is considered appropriate for this study as the aim of the study also focus mainly on qualitative data by adopting exploratory sequential mixed methods. Besides, numerous studies have adopted SD in the construction industry (Chapman, 1998; J. L. Hao et al., 2008; Love, Holt, Shen, Li, & Irani, 2002; Ogunlana, Li, & Sukhera, 2003). From all of the provided information, SD modelling is considered as the appropriate method in this study.

Amongst a number of popular software programs used for SD modelling such as Vensim, Dynamo, and AnyLogic, iThink is selected for this research. This is because it is considered as a powerful tool to simulate the interdependencies between processes and problems (HP Yuan, Shen, Hao, & Lu, 2011). It has been used to model and gain insights into the complex systems (Ashayeri, Keij, & Bröker, 1998). Furthermore, it has been known as software that provides an intuitive icon-based interface assisting the mapping and modelling stages (J. L. J. Hao, Tam, Yuan, Wang, & Li, 2010).

Figure 1.4 shows the research framework designed with clear objectives and methods to guide the research efforts, which is described as follows:

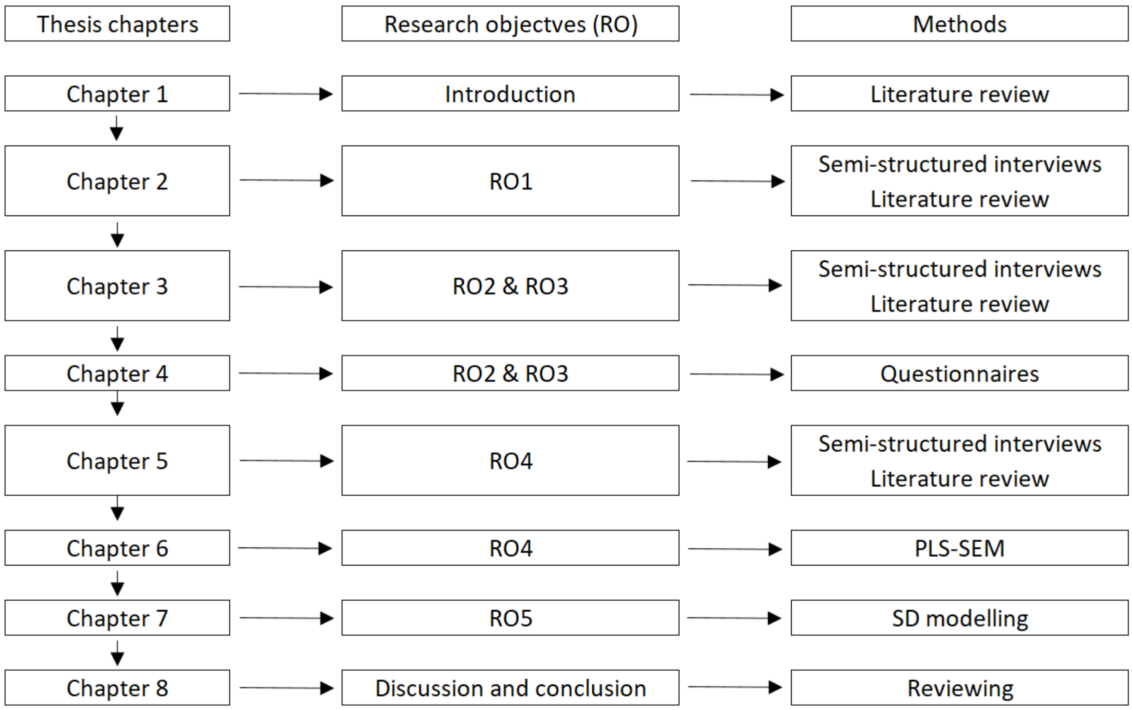



Figure 1.4. Research framework

Chapter 2 addresses the first research objective. By conducting semi-structured interviews with construction specialists in New Zealand, what BIM is, the benefits, barriers/challenges, and solutions for BIM adoption in the New Zealand context are determined. The results of Chapter 2 provide a foundation for further examination in the rest chapters. Sustainability improvement is revealed as one of the identified benefits of BIM adoption in New Zealand providing the rationale for examining the relationship between BIM and Green Star presented in Chapter 3 . To enhance the reliability and validity of the results, a combination of seven strategies are adopted including 1) maximum variation; 2) adequate engagement; 3) accurate transcribing; 4) accurate coding; 5) member checking 6) peer review; and 7) triangulation. Triangulation approach is mainly focused on comprehensively reviewing literature both in New Zealand and overseas.

Chapter 3 addresses the second and third objectives in which the characteristics of Green Star and the relationship between BIM and Green Star are determined. Similar to Chapter 2 , semi-structured interviews are selected as the primary method to explore the current practice of Green Star and its relationship with BIM adoption. Because Green Star is still in its early stages with a few Green Star certified projects and Green Star studies, it is a challenge to adopt the triangulation approach to validate the results of Chapter 3 . Therefore, the questionnaire is carried out in Chapter 4 to confirm the results of Chapter 3 . Data is collected and analysed using Statistical Package for the Social Sciences (SPSS). Statistical tests including Cronbach's Alpha to evaluate the reliability and internal consistency and one-sample *t*-test to determine the significance of the collected data are conducted. Chapter 3 and Chapter 4 provide the rationale for the rest chapters in which BIM adoption framework is developed to improve the BIM maturity level.

Chapter 5 addresses the fourth objective in which the BIM adoption framework is established based on the characteristics of BIM adoption in New Zealand found out in Chapter 2 . By reanalysing the data collected from the interviews in Chapter 2 along with making a comparison with the three most global well-known Business Excellence Models (BEMs), important categories and factors affecting BIM adoption in New Zealand are identified. Also, hypotheses regarding the relationship amongst the identified categories are proposed. To validate the results of Chapter 5 , questionnaires are distributed, and the collected data is analysed using the partial least squares structural equation modelling (PLS-SEM), which is presented in Chapter 6 . Chapter 5 and Chapter 6 provide a foundation for Chapter 7 in which all the key factors and categories having significant impacts on BIM adoption are revealed.

Chapter 7 addresses the final objective in which the BIM-Green Star SD model is developed and validated. SD modelling is adopted owing to its benefits in terms of clarifying knowledge and understanding of the system to explore policies that could improve or minimise the system behaviour. Obtaining the results of how the categories of the BIM adoption framework relate to each other, the research suggests that it is the top priority category that should be focused to improve BIM adoption and Green Star uptake in New Zealand. Also, the SD model predicts that it takes at least 8 years for a company to have their BIM maturity level reaching level 3 which is also the time when BIM and Green Star could be appropriately integrated.

## 1.9 Thesis Organisation

This PhD thesis is organised into eight chapters as follows:

Chapter 1 introduces the research in which the characteristics of the New Zealand construction industry, BIM, Green Star, and previous research focusing on BIM and Green Star in New Zealand are provided. It outlines the need for adopting an innovative method to improve the New Zealand construction industry where BIM has the most potential benefit. Green Star is also highlighted to be a factor minimising the negative impacts of the New Zealand construction industry on the environment. The problem statement is then presented indicating the research gap and the potential benefits of integrating BIM with Green Star. Next, the research aim and research objectives are described, which are followed by the research contribution, research methods, and thesis organisation.

Chapter 2 identifies the characteristics of BIM adoption in New Zealand focusing on the definitions of BIM, the benefits, barriers/challenges to BIM adoption; solutions for BIM development are also suggested. After conducting 21 semi-structured interviews with industry experts, an inconsistency of BIM definitions in New Zealand is revealed in which 4 different definitions of BIM are found. Also, 14 benefits and 10 barriers/challenges to BIM adoption are determined. Sustainability improvement is one of the 14 identified benefits of BIM adoption indicating the potential of integrating BIM with Green Star. After reviewing the literature towards global BIM adoption, it is found out that characteristics of BIM adoption are similar between countries. Therefore, it would be helpful for New Zealand to learn the lessons from pioneer countries towards BIM adoption. Also, the role of the government to the small and medium enterprises (SMEs), contractors, and those who do not have much experience in BIM adoption is significant to BIM development. As a result, the New Zealand government is recommended to be more active towards BIM adoption.

Chapter 3 explores the perspectives of the key stakeholders in the New Zealand construction industry towards Green Star and its relationship with BIM. After analysing the data collected from 21 semi-structured interviews, 6 benefits, 5 barriers/challenges, and 6 solutions for Green Star uptake were determined. Amongst the 6 solutions suggested for Green Star uptake, BIM is mentioned as an innovative method confirming the potential relationship between BIM and Green Star. Although over a half of the industry experts believed that the relationship between BIM and Green Star does not exist currently, almost all of them recognised the potential of integrating BIM with Green Star for Green Star development. Industry experts reveal 5 barriers/challenges preventing the integration of BIM and Green Star in which low BIM maturity level is determined as one of the crucial ones. Executing BIM properly is then suggested as a significant solution for both BIM and Green Star development.

Chapter 4 validates the results in Chapter 3 using questionnaires. Because Green Star has been focused by only a few studies, literature review from other green rating systems such as BREEAM and LEED was used in Chapter 3 to confirm the results, known as triangulation method. A further validation stage, therefore, is needed as the characteristics of Green Star could be not completely similar to other green rating systems. As a result, in Chapter 4 , questionnaires are distributed to construction practitioners in New Zealand to discover their perspectives towards Green Star uptake and its relationship with BIM adoption. After conducting the descriptive statistics and statistical statistics, the results confirm the accuracy of all of the findings in Chapter 3 . BIM is confirmed as one of the solutions for Green Star uptake while improving BIM maturity level has a significant impact on integrating BIM with Green Star.

Chapter 5 develops a BIM adoption framework to measure the success of a BIM project. Results in Chapter 4 indicate that BIM practice in New Zealand is still in its early stages with low BIM maturity level while lack of understanding and lack of benchmark projects are determined as the barriers/challenges to BIM adoption in New Zealand in Chapter 2 . This urges the need to have a system containing all crucial factors affecting BIM adoption in New Zealand to provide insights into BIM and to provide the ability to assess the maturity level of a BIM project. After reanalysing the results collected from 21 semi-structured interviews in Chapter 2 along with referencing three global well-known BEMs, the BIM adoption framework is established with 7 main categories and 39 indicators. Leadership is considered as the most significant category affecting the rest categories. Also, how the categories impact each other is hypothesised in this chapter.

Chapter 6 validates the BIM adoption framework developed in Chapter 5 along with the five hypotheses. The research adopts PLS-SEM to assess the measurement model and the structural model of the framework based on the data collected from 66 construction practitioners who have been involved in BIM projects in New Zealand. After conducting two rounds evaluating the accuracy of the developed framework and those five hypotheses, 8 indicators are removed due to their insignificance to the framework. In other words, the BIM adoption framework with 7 categories and 31 indicators are confirmed accuracy for measuring the success of a BIM project. Furthermore, the most effective indicator in each category and how the categories impact each other are revealed which is helpful for BIM adopters to have effective strategies to improve their BIM projects.

Chapter 7 develops and validates a BIM-Green Star SD model to forecast the development of BIM adoption and when BIM and Green Star could be appropriately integrated in New Zealand. Based on the results in Chapter 6 , the BIM adoption framework with 7 categories is modelled using SD modelling. By taking advantage of SD modelling in which the structure behaves over time, how the categories affect BIM adoption and Green Star uptake over the years can be understood. Then, alternative policies could be tested to provide the best solution for the research problem.

The results show that at least 8 years should be spent by a construction company to achieve BIM level 3 from BIM level 0 in normal circumstance. Whereas, at the end of year 9 is the perfect time to have BIM integrated with Green Star. Furthermore, Leadership is revealed as the most significant category affecting both BIM and Green Star uptake. It, therefore, is suggested that Leadership should be the principal focus in which having a clear BIM leadership role, the most effective indicator of Leadership, should be achieved. By focusing more on Leadership, BIM adopters can achieve BIM level 3 in a shorter time. By providing the BIM-Green Star SD model with 7 main categories affecting BIM and 31 indicators in the BIM adoption framework found out after conducting PLS-SEM in Chapter 6 , construction companies can adjust and run the model using their statistics to predict their BIM development in the future. The model, categories, indicators provided in this research could be the guideline for construction companies to plan for their BIM adoption and Green Star uptake.

Chapter 8 discusses the research aim, research objectives, and how they are achieved. It is then concluded with the recommendations for the New Zealand construction industry, research contribution, limitations, and future research.

To strengthen the contribution of the research results to the current knowledge, thesis by publications or Pathway 2 is selected. Pathway 2 is a term to describe a thesis with publications. It is becoming popular globally owing to its benefits to students and universities (Barry, Woods, Warnecke, Stirling, & Martin, 2018; S. Mason, 2018). It allows PhD candidates to publish journal articles which is considered as de facto standard to secure their jobs “in a highly competitive international doctor market” (East, Hajdukova, Carr, Evans, & Hornby, 2017; Matas, 2012). Also, it improves the quality of the universities’ students enabling them to consolidate and expand their market (Matas, 2012).

Furthermore, the quality of the research could be ensured by adopting this approach (Matas, 2012). It is also noticed that the thesis examiners today “require a thesis to be publishable research” (Golding, Sharmini, & Lazarovitch, 2014; Merga, 2015). In addition, it is undeniable the high status of journal articles that “they are attributed in local, national, and transnational evaluation systems” (Lillis & Curry, 2013). As a result, Pathway 2 is considered as the appropriate approach for this research. In other words, thesis chapters, with research aims and objectives, are prepared as articles for high-quality journals to seek advice from the experts through the peer-review process. The results and contribution of each chapter of this thesis have been validated and confirmed.

# Chapter 2 Examining Critical Perspectives on Building Information Modelling (BIM) Adoption in New Zealand

## 2.1 Prelude

This chapter aims to provide insights into BIM adoption in New Zealand. What is BIM?; What are the benefits of BIM adoption?; What are the barriers/challenges to BIM adoption?; and What are the solutions for BIM adoption? were answered in this chapter. A qualitative approach using 21 semi-structured interviews with industry experts was adopted. The results raise a question concerning whether the New Zealand construction industry needs a unique definition of BIM to achieve a clear and consistent understanding amongst the construction practitioners. Fourteen potential benefits and ten barriers/challenges to BIM adoption were identified. Specifically, time-saving was considered as the most benefit of BIM adoption. Efficiency and sustainability improvement were also highlighted as the potential benefits that can be achieved by BIM adopters. However, a lack of understanding was pointed out as the most significant challenge preventing construction practitioners from implementing BIM. Providing education/training, therefore, is necessary to address the BIM challenges. The research provided valuable insights into BIM understanding as well as recommendations regarding BIM adoption in New Zealand. The results could be considered baseline information for the government and construction organisation to have effective strategies towards BIM adoption.

## 2.2 Introduction

Recently, an intense interest in BIM, which is generally defined as Building Information Modelling (Mordue, Swaddle, & Philp, 2015), has been developed because of its potential benefits to the current practices of the construction industry. The construction industry is still amongst the lowest sectors in innovation (Kenley, Harfield,

& Behnam, 2016; Kim & Park, 2016; Kuiper & Holzer, 2013; S. J. Wilkinson & Jupp, 2016). With BIM implementation, extensive changes can occur that enhance performance on construction projects during the entire lifecycle (Ryan, Miller, & Wilkinson, 2013). Benefits of BIM adoption have been researched to prove its ability to reforming the existing situation of the construction industry. Nine main benefits were identified by Newton and Chileshe (2012) in South Australia while 18 BIM drivers were pointed out by Eadie, Odeyinka, Browne, McKeown, and Yohanis (2013). Also, Ghaffarianhoseini, Tookey, et al. (2017) divided benefits of BIM adoption into 9 groups due to its “wide range of clear and current benefits associated with the use of BIM” (Ghaffarianhoseini, Tookey, et al., 2017). Besides, 35 cases using BIM in 8 different countries were investigated to identify the BIM impacts on those results (Bryde, Broquetas, & Volm, 2013). Because of its benefits, BIM implementation has come high on the agenda in many countries. For example, BIM has been mandated for all public sector buildings or government projects in Finland, Norway, Denmark, Netherlands, and the UK (Smith, 2014b).

Despite the increased global interest in BIM development, BIM adoption in New Zealand is still in its early stages with low uptake levels (Miller, Sharma, Donald, & Amor, 2013) and insufficient attention from researchers (Amor, Jiang, & Chen, 2007), leading to a very few BIM publications. Based on the Scopus database, only three journal papers mentioning BIM in New Zealand are available with the keywords (“BIM” + “New Zealand”) limited to the *engineer* area and *journals* type. However, BIM as a key topic was just researched by other researchers in two papers including “Making friends with Frankenstein: Hybrid practice in BIM” (Davies et al., 2017), and “BIM implementation in a New Zealand consulting quantity surveying practice” (Harrison &

Thurnell, 2015). Harrison and Thurnell (2015) examined the potential effect of BIM implementation on quantity surveyors (QS) in the use of 5D BIM. Whereas, factors leading to “hybrid practice in BIM” in Australia and New Zealand were identified by Davies et al. (2017). It is noticed that Davies et al. (2017) did not separate the results of BIM practice between Australia and New Zealand. Furthermore, attempts are being made to enhance BIM uptake in New Zealand such as the BIM Acceleration Committee, established as the driving force towards BIM adoption (BAC, 2019a), or the National BIM Education Working Group, formed with the involvement of nine fundamental construction tertiary educators to deliver the future workforce possessing adequate BIM skills (BAC, 2019b). However, only a few guidelines and resources were provided by the BIM Acceleration Committee. There is still a need for further research on BIM adoption in the New Zealand construction industry.

This research aims to identify and explore the perspectives of the key stakeholders in the New Zealand construction industry towards BIM adoption. Four different themes of BIM adoption were examined, including: what is BIM?; BIM knowledge and understanding; the benefits of BIM adoption; and the challenges/barriers associated with BIM adoption. Based on the research results, further discussion is presented while the solutions for BIM adoption in New Zealand are implied from the revealed challenges/barriers to BIM adoption. The research provides insights into BIM understanding as well as recommendations regarding BIM adoption. The next section describes the methods used for data collection and the analysis process.

## 2.3 Research Methodology

This research is a part of a more extensive study examining the relationship between BIM adoption and Green Star certification uptake in New Zealand; it adopted a qualitative approach using semi-structured interviews to explore the BIM perspectives of a wide range of industry participants who are key actors in the New Zealand construction industry. The approach was considered appropriate due to its primary benefits providing "deep, rich observational data" (Onwuegbuzie & Leech, 2005; Sieber, 1973). Also, gaining familiarity with the topic and generating insights for future research could be achieved with the qualitative approach (Eisenhardt, 1989; Haussner, Maemura, & Matous, 2018; Scott, 1965). Reliable and comparable qualitative data could be gained through the use of semi-structured interviews "allowing respondents the freedom to actively engage in sharing their views in their terms" (Cohen & Crabtree, 2006; Galletta, 2013; Harrell & Bradley, 2009).

A combination of two different sampling methods was used to recruit the participants, see Figure 2.1. Firstly, purposive sampling was applied to ensure the desirable criteria, in which the interviewees have to be working in the construction industry for at least five years and have been involved in BIM projects and/or Green Star projects in New Zealand. Due to the shortage of BIM specialist in the New Zealand construction industry, snowball sampling was adopted next to identify the key stakeholders. Multiple sampling techniques using in particular research are not uncommon in the qualitative studies (Teddlie & Yu, 2007; Tongco, 2007). The LinkedIn source was used to approach the initial interviewees because it is a powerful professional networking tool providing an extensive database of business professionals (Albrecht, 2011; Schneiderman, 2016). Then, suggestions were provided by them to locate further participants.

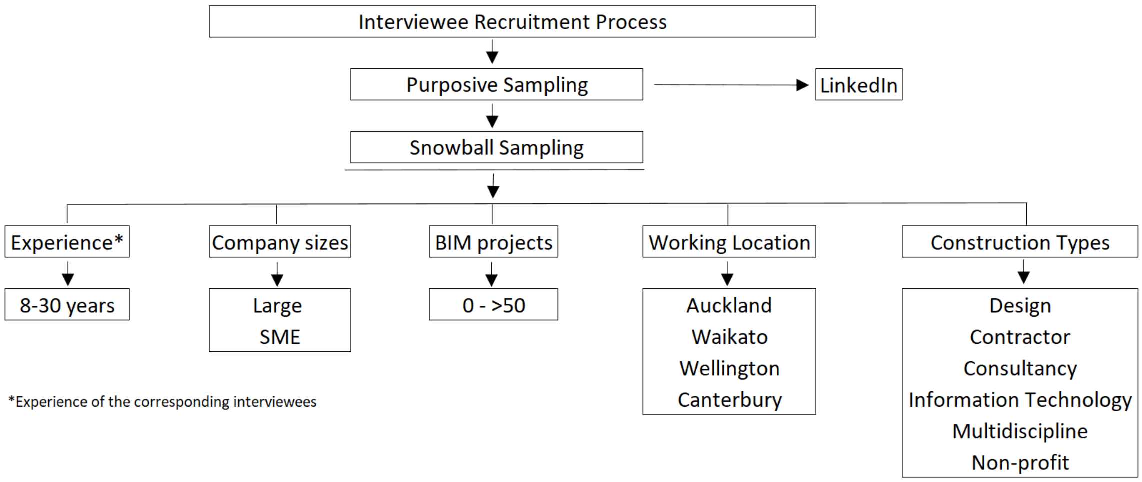



Figure 2.1. The process of interviewee recruitment

The interviews were conducted between November and December 2017. The data were obtained from 19 face-to-face interviews and 3 telephone interviews with a total of 26 interviewees coming from a range of sectors; and all of them are considered as the experts in the construction industry in terms of the position held and length of time working within the industry, see Table 2.1. It is noted that the interviews 6, 12, 13, and 20 were conducted with 2 interviewees each, which were recommended by the corresponding interviewees. The sample size is considered appropriate compared to the nature of qualitative research supported by the following studies. According to Galvin (2015) and Guest, Bunce, and Johnson (2006), 12 interviews are sufficed to achieve saturation, in which no new information is found after the 12$^{th}$ interview, while the figure for Crouch and McKenzie (2006) research is less than 20, and 15±10 for Kvale and Brinkmann (2009) research. Furthermore, previous qualitative studies were also published with similar sample sizes in the construction field (Hurlimann, Browne, Warren-Myers, & Francis, 2018; Sacilotto & Loosemore, 2018).

Table 2.1. Interviewees demographics

| Interviewee | Construction Position | Experience (Years) | Construction Type | Company Size | BIM Projects |
|---|---|---|---|---|---|
| #01 | Senior QS | 10 | Contractor | Large | 01 |
| #02 | BIM Manager & GSAP[1] | 14 | Design | Large | >50 |
| #03 | Director, Building Scientist,<br>Green Star Assessor, & GSAP | 12 | Consultancy | Large | >50 |
| #04 | Senior Architect, GSAP, & Green Star Assessor | 15 | Design | Large | 30 |
| #05 | Technical Services Manager, Design Manager, GSAP, &<br>Green Star Assessor | 22 | Contractor | Large | 06 |
| #06 | 1) Director & Building Surveyor2<br>2) Building Surveyor | 14<br>04 | Consultancy | SME | 15 |
| #07 | Principal & Designer | 30 | Design | SME | 04 |
| #08 | Senior Cost Manager | 20 | Consultancy | Large | 01 |
| #09 | Project Director | 23 | Contractor | Large | 11 |
| #10 | Building Services Technical Leader | 08 | Consultancy | Large | 07 |
| #11 | Director & Building Performance Expert | 19 | Consultancy | SME | 01 |
| #12 | 1) BIM Manager[2]<br>2) Building Scientist | 22<br>03 | Design | Large | >50 |
| #13 | 1) Associate & Structural Engineer[2]<br>2) Drawing Office Manager | 10<br>19 | Design | Large | >50 |
| #14 | Structural Technician | 08 | Design | Large | 01 |
| #15 | Sustainability Leader, Green Star Assessor, & GSAP | 13 | Design | Large | >50 |
| #16 | BIM Construction Manager | 11 | Contractor | Large | 40 |

| Interviewee | Construction Position | Experience (Years) | Construction Type | Company Size | BIM Projects |
|---|---|---|---|---|---|
| #17 | Technical Lead & Senior QS | 12 | Multidiscipline | Large | >50 |
| #18 | BIM Consultant, Application Engineer, & Business Analyst | 17 | Information Technology | SME | >50 |
| #19 | Associate Senior Architect | 11 | Design | Large | >50 |
| #20 | 1) BIM Development Engineer[2]<br>2) Senior Structural and Sustainable Engineer, & GSAP | 20<br>08 | Consultancy | Large | 50 |
| #21 | Principal QS | 08 | Multidiscipline | Large | 02 |
| #22 | GSAP & Green Star Assessor | 10 | Non-profit | Large | 00 |

Note: [1]Green Star Accredited Professional
[2]The corresponding interviewees

The interviewees came from 21 different companies, 17 large companies, and 4 small and medium companies. According to the New Zealand Ministries (MBIE, 2017; MED, 2011), large enterprises were defined as having a total number of employees equal to or higher than 20, and small and medium-sized enterprises (SMEs) have less than 20 employees. Table 2.1 demonstrates a wide variety of organisational types including design companies, contractor companies, consultancy companies, as well as 1 information technology company, 1 non-profit organisation, and 2 multidiscipline companies. The study was primarily based in Auckland with 4 of the 22 interviews based outside of Auckland (Canterbury: 1, Wellington: 2, Waikato: 1). All of these characteristics can ensure the diversity of the interviewees allowing for an exploration of different BIM perspectives, given the qualitative nature of the study.

Ethics Approval was sought from the Auckland University of Technology Ethics Committee "to ensure that the privacy, safety, health, social sensitivities and welfare of human participants are adequately protected" (AUT, 2018) before conducting the interviews. The interviewees were informed about the research purpose, the agreement to participate in the research, how the interview is conducted, how the discomforts and risks are alleviated, the benefits of the participants, how the privacy is protected and recording the interviews.

The interview questions are shown in Appendix A and focused on the following themes: what is BIM?; BIM knowledge and understanding; the benefits of BIM adoption; and the challenges/barriers associated with BIM adoption. The interviews were recorded and transcribed before conducting the thematic analysis using NVivo 11. Because "hand-coding is a laborious and time-consuming process, even for data from a few individuals" (Creswell & Creswell, 2017), NVivo was adopted to deal with hundreds of pages produced after the transcribing step. It is frequently used in the qualitative method because of its benefits regarding efficiency, multiplicity, and transparency (Hoover & Koerber, 2011). Amongst different types of analysis such as content analysis and grounded theory, thematic analysis was selected to conduct the interview analysis. This is because it has been identified as "a foundational method for qualitative analysis" producing accurate and insightful findings (Braun & Clarke, 2006; Nowell, Norris, White, & Moules, 2017); it is the best method to examine the perspectives of different interviewees generating unanticipated insights (Braun & Clarke, 2006; Joffe, 2012; Nowell et al., 2017).

The research followed the six-stage process suggested by Braun and Clarke (2006), see Figure 2.2. It was noted that during the transcribing stage, sound issues were detected while recording the interview with participant 9 leading to the inaudible problem. The transcript of participant 9 was then removed to ensure the accuracy of the findings. In other words, 21 transcripts were thematically analysed.

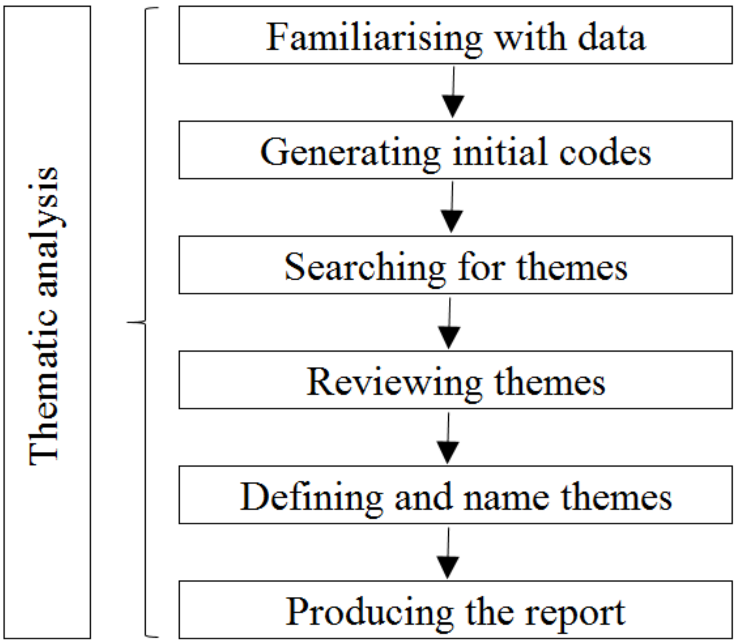



Figure 2.2. The process of thematic analysis

(adapted from Braun and Clarke (2006) and Vaismoradi, Turunen, and Bondas (2013))

To counter the weaknesses of the snowball sampling, a combination of seven different strategies was adopted to promote the validity and reliability of the findings, see Figure 2.3. Firstly, a wide range of characteristics of participants was purposely collected to satisfy the maximum variation of the participants' demographics, see Table 2.1. With the maximum variation, the research results could be transferred to the readers effectively (Merriam & Tisdell, 2015; Patton, 2015). The saturation of the data was achieved with adequate engagement in which sufficient time was spent on each interviewee (Merriam & Tisdell, 2015). Similar to the suggestions from Galvin (2015) and Guest et al. (2006), the findings of this research were saturated after the 12th interview where the nine interviews that followed provided more explanations for the findings rather than new themes.

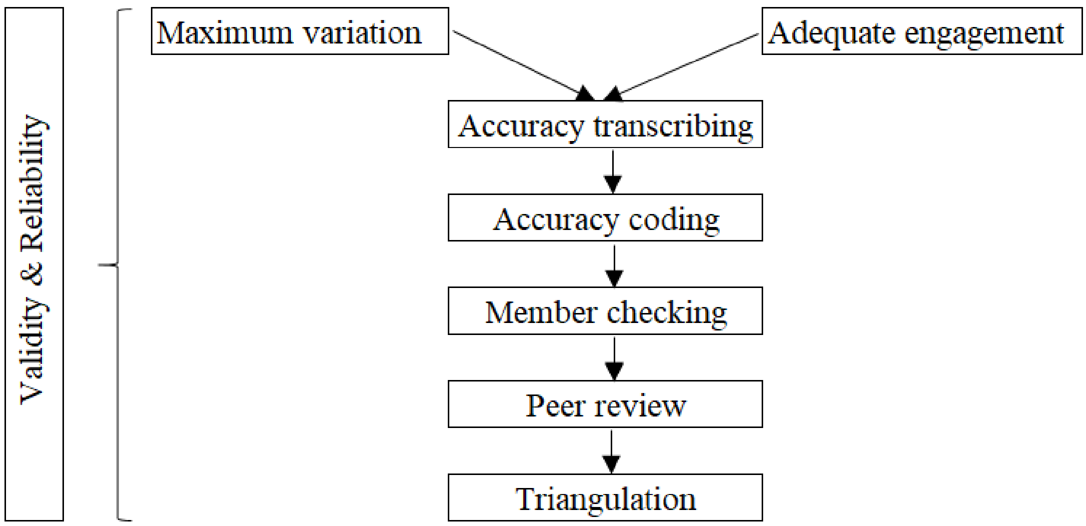



Figure 2.3. The process of promoting validity and reliability

The transcripts and codes were then checked to detect mistakes during the transcribing stage as well as to ensure that the codes were appropriately grouped and consistent across all the interviews (Creswell & Creswell, 2017; Gibbs, 2018; Longhofer, Floersch, & Hoy, 2012). After going through the analysis process step, the data was returned to the interviewees to validate, verify, and assess the trustworthiness of what has been recorded and transcribed, which is known as member checking (Birt, Scott, Cavers, Campbell, & Walter, 2016). Next, the agreement with the findings was concluded after conducting the data evaluating process with the interviewees (Merriam & Tisdell, 2015). Finally, triangulation using multiple sources of data to confirm the findings was carried out (Barbour, 2001; Merriam & Tisdell, 2015; Silverman & Patterson, 2014). The triangulation stage presented in the discussion section.

## 2.4 Results and Discussion

Four main themes were analysed and are discussed including: what is BIM?; BIM knowledge and understanding; the benefits of BIM adoption; and the challenges/barriers to BIM adoption.

### 2.4.1 What is BIM?

Interviewees were asked to explain from their perspective how they defined BIM. “A digital representation of a physical as-built real-world environment” (#1) or Building Information Model was considered as one of the definitions of BIM, which is “the best sort of recognised definition” (#16). Building Information Modelling was most commonly mentioned by the interviewees by a total of 16 interviewees. Interviewee 5 suggested that “BIM is not just a 3D model; it is a completely collaborative working environment.” While others suggested that BIM is Building Information Management; interviewee 13 stated that “Building Information Management is a big workflow which starts from client concept through to architectural concept, structural concept, detailed design, and then through to construction.” Software/technology was also mentioned as an interpretation of the definition of BIM. Three interviewees confirmed that “when I think of BIM, I think of Revit” (#15), whereas the rest of the group discussed the fact that typically other construction practitioners in New Zealand suggest that “I am doing BIM because I am using Revit” (#19).

The findings are consistent with existing literature. Building Information Model, Building Information Modelling, and Building Information Management were referred by Turk (2016) and Hjelseth (2017). Whereas, Eastman, Eastman, Teicholz, and Sacks (2011) analysed the difference between Building Information Model and Building Information Modelling. A misunderstanding of BIM as Revit was also mentioned by M. King (2011) and Hongming, Huilong, Wenjing, and Rui (2017).

Table 2.2 summarises the findings of what BIM is. Building Information Model, Building Information Modelling, and Building Information Management were almost equally explained as BIM by the industry experts. It is clear from Table 2.2 that the perspectives of the experts towards the definition of BIM are similar despite the different construction types and company sizes that the experts are working for. Regarding the number of BIM projects and their years of experience, those who have been involved in equal or greater than 15 projects and those have at least 15 years’ experience provided more than one definition of BIM.

Table 2.2. BIM definitions summary

| BIM Definition Theme | No of Response | Construction Type | | | | Company Size | | No of BIM Projects | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥15 | <15 | ≥15 | <15 |
| Building Information Model | 15/21 | 7/8 | 3/3 | 3/6 | 2/4 | 13/17 | 2/4 | 9/12 | 6/9 | 5/8 | 10/13 |
| Building Information Modelling | 16/21 | 7/8 | 3/3 | 4/6 | 2/4 | 13/17 | 3/4 | 10/12 | 6/9 | 6/8 | 10/13 |
| Building Information Management | 14/21 | 7/8 | 2/3 | 2/6 | 3/4 | 12/17 | 2/4 | 10/12 | 4/9 | 7/8 | 07/13 |
| Software/Technology | 09/21 | 4/8 | 1/3 | 2/6 | 2/4 | 08/17 | 1/4 | 04/12 | 5/9 | 4/8 | 05/13 |

It is noted that each of the interviewees (apart from three people) provided at least two different definitions, confirming that there is currently no unified interpretation of BIM. This is considered as a factor leading to the fallacies of the definition which are “overly broad, use obscure or ambiguous language, or contain circular reasoning” (Gibbon, 2013; Kak, 2018; van Eemeren et al., 2014). Consequently, it could cause a significant problem regarding what BIM stands for. For example, a result of 57% of projects using BIM in New Zealand from the New Zealand BIM Survey (EBOSS, 2018) was disagreed by most of the interviewees. For example, interviewee 12 stated that “it never defined what BIM is.” This suggests that there is a wide range of opinion within the industry as to what the definition of BIM is. Industry experts have a wide range of perceptions on the topic and there is no one size fits all definition currently being utilised. This raises the questions concerning whether there is a need to have a unique definition of BIM to achieve a clear and consistent understanding amongst the construction practitioners in New Zealand.

### 2.4.2 BIM knowledge and understanding

To develop an understanding of the level of BIM adoption in the existing industry, the interviewees were asked about their perception concerning construction practitioners’ level of awareness of BIM. Half of them discussed a lack of general awareness in the industry currently. They remarked that BIM is “a quite new concept” (#1). Only two interviewees thought that most construction practitioners are well-aware of BIM; interviewee 5 suggested that “we have got some key project managers and consultants to work with BIM, and most of the top tier contractors are fully aware of what BIM can offer.” However, the interviewees that are employed by top tiers contractors pointed out that “BIM is not very common yet” (#16). All the interviewees from SMEs agreed with this lack of knowledge. SMEs dominate the construction industry in New Zealand with 97% of the total companies (MBIE, 2017). This finding is consistent with the view of Rodgers, Hosseini, Chileshe, and Rameezdeen (2015) implying that the low level of BIM awareness is remained due to the operations of the SMEs making up the significant part of the industry.

Interviewees were also asked about the current level of BIM awareness of specific key stakeholders. The design and consultant sides were seen as the leading teams in BIM adoption in New Zealand. Specifically, “most architects are leading the way, followed by structural engineers, and services engineers” (#13). Interviewees generally suggested that the size of the companies relates the level of BIM understanding and adoption. The interviewees went on to confirm that most of the QSs, contractors and supply chain companies are still delivering the projects with traditional methods without utilising other innovative methods. Interviewee 5 went on to describe contractors and the supply chains stating that “contractors are slowly getting on board, or slowly getting to a stage where they can leverage the information they have been given, and start getting into a stage where they can model to manufacture as well … there are a lot of supply chains who still do not really work in this space.”

The findings have parallels to the existing literature. According to S. Wu, Wood, Ginige, and Jong (2014) and Rodgers et al. (2015), contractors are lagging behind architects and designers in BIM adoption. Services engineers and architects were considered as the stakeholders who possess the highest level of competency compared to the rest (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2015). While structural engineers were identified as the ones who are well-aware of BIM with the highest frequent application of BIM levels (Eadie, Browne, et al., 2015).

In contrast, supply chain and QS firms have been showing a very poor engagement in BIM adoption due to the high economic investment required (Aibinu & Venkatesh, 2013; Navendren, Manu, Shelbourn, & Mahamadu, 2014; Smith, 2014a). Regarding the view of the SMEs in BIM adoption, it is undeniable that the level of BIM adoption in the SMEs is very low compared to the large-sized firms (M Reza Hosseini et al., 2016). This is because of the nature of the SMEs with limited personnel, finance, and knowledge relevant to management which prevents them from embracing innovation and technological advancement (M Reza Hosseini et al., 2016; T. T. Lam, Mahdjoubi, & Mason, 2017). Furthermore, the policymakers, the industry, and researchers have not paid much attention to the SMEs regarding BIM adoption despite their dominant role in the industry (Dainty, Leiringer, Fernie, & Harty, 2017; M Reza Hosseini et al., 2016; T. T. Lam et al., 2017). However, it is unquestionable that there are still advantages towards BIM adoption to the SMEs (Arayici et al., 2011). The contractors, QSs, supply chains, and SMEs, therefore, should have more interest from the government, industry, and researchers to orientate them towards BIM adoption.

### 2.4.3 Benefits of BIM adoption

A range of benefits associated with BIM adoption was discussed. All of the interviewees agreed that BIM could bring many potential benefits to the construction projects. Time-saving for the projects was indicated as a significant benefit of BIM adoption by most of the interviewees. Interviewees also felt that the time-saving benefit of BIM is linked to other benefits of BIM including the collaboration/coordination improvement, rework reduction, visualisation improvement, risk reduction, clash detection, and variations reduction. Additional benefits discussed were improvements to efficiency, costs and client satisfaction.

Time-saving was indicated as a significant benefit of BIM adoption by 16 interviewees. The collaboration amongst stakeholders leads to a shorter time for clash detection and checking and verifying things. “Having all their information is stored centrally as well as all of the other project information in one place, it works extremely fast because you are not doing anything that will be aborted” (#11). Interviewee 13 explained the significance of the time-saving confirming that “saving in time with regards to resolving it on a computer screen might take 5 to 10 minutes, while on-site, it takes days if not weeks.”

BIM is believed to improve collaboration/coordination. Interviewee 2 stated that “BIM allows better collaboration between the architects, engineers, clients, project managers, all that kind of stuff. Regarding design, you can pretty much see the 3D assembling of the whole thing, visualisation, coordination, collaboration, and transparency.” Interviewees suggested that information management was another benefit of BIM as the data can be shared and managed effectively. By improving collaboration/coordination and information management, this can lead to rework reduction. The improvement in visualisation was also expressed as a benefit of adopting BIM. Interviewees suggested that it means that the project can be presented accurately and encourages collaboration. Interviewee 21 went on to discuss the visualisation aiding risk management “we have the ability to visualise documentation … we can process, understand the risks, and communicate the risks through the project more efficiently and effectively.” It was suggested that the clash reduction and risk reduction are two of the factors that could lead to variation reduction in construction projects.

Efficiency or productivity improvement was also identified as one of the significant BIM benefits. Interviewee 10 explained that “everyone is working on the same information; everything is current … So, I think efficiency that can be gained from the systems that are in place. I would say efficiency is number one.” Cost improvement is a perceived benefit of using BIM by 14 interviewees, as it can lead to better coordination and less cost and fewer variations. As a result of cost and time savings from BIM adoption, 7 interviewees felt that BIM adoption could improve client satisfaction. Interviewee 5 believed that “you should get your client satisfaction improved.” Competitiveness improvement was revealed as another benefit of BIM adoption. It is “seen as a marketing tool” (#6) which “decently sells a project better to a client” (#4). Regarding the environment, BIM adoption is believed to improve the sustainability of the project. “It is going to make it easier for modelling … things like heating, ventilation, and air conditioning (HVAC), daylight, etc., which are some of the environmental things. In that sense, it is going to improve sustainability” (#5). Besides, BIM was also stated that it could improve health and safety by “looking at the 3D model … to spot the dangerous areas” (#7).

Table 2.3 summarises the potential benefits of BIM. It is noted that the understanding of BIM benefits is similar amongst the interviewees despite the different construction types, company sizes, the number of BIM projects that they have been involved in, and years of experience. This could be because all of the interviewees have been working in the construction industry for at least eight years, and they have been holding significant positions in their companies. Therefore, they obtained specific knowledge about BIM. The BIM benefits raised here align with the existing literature. The topic related to the BIM benefits has been attracting attention globally from researchers.

Clash reduction and visualisation improvements are the most and second well-acknowledged benefits of BIM adoption in the UK and Australia respectively (Eadie, Odeyinka, et al., 2013; Newton & Chileshe, 2012). According to Khosrowshahi and Arayici (2012), information management and efficiency improvements were identified as major benefits of BIM adoption along with the minor ones including rework reduction, risk reduction, and sustainability improvement, etc. Interestingly, the competitiveness improvement has the same rank, 7th, regarding the important level of the BIM benefits in both the UK and Australia (Eadie, Odeyinka, et al., 2013; Newton & Chileshe, 2012); besides, collaboration/coordination, health and safety, and client satisfaction improvements, time and cost savings were also remarked as the BIM benefits in these two studies (Eadie, Odeyinka, et al., 2013; Newton & Chileshe, 2012). Whereas, Sebastian and van Berlo (2010) mentioned the capability of BIM which could minimise the variations of the project.

Table 2.3. BIM benefits summary

| BIM Benefit | No of Response | Construction Type | | | | Company Size | | No of BIM Projects | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥15 | <15 | ≥15 | <15 |
| Reduce Clash | 15/21 | 5/8 | 2/3 | 6/6 | 2/4 | 12/17 | 3/4 | 08/12 | 7/9 | 7/8 | 08/13 |
| Reduce Rework | 13/21 | 5/8 | 2/3 | 5/6 | 1/4 | 10/17 | 3/4 | 07/12 | 6/9 | 6/8 | 07/13 |
| Reduce Risk | 15/21 | 6/8 | 3/3 | 4/6 | 2/4 | 12/17 | 3/4 | 08/12 | 7/9 | 6/8 | 09/13 |
| Reduce Variation | 6/21 | 2/8 | 1/3 | 1/6 | 2/4 | 05/17 | 1/4 | 04/12 | 2/9 | 1/8 | 05/13 |
| Improve Collaboration and Coordination | 16/21 | 6/8 | 2/3 | 6/6 | 2/4 | 12/17 | 4/4 | 10/12 | 6/9 | 7/8 | 09/13 |
| Improve Information Management | 12/21 | 4/8 | 2/3 | 4/6 | 2/4 | 10/17 | 2/4 | 06/12 | 6/9 | 6/8 | 06/13 |
| Improve Visualisation | 14/21 | 5/8 | 2/3 | 5/6 | 2/4 | 11/17 | 3/4 | 07/12 | 7/9 | 7/8 | 07/13 |
| Improve Efficiency | 15/21 | 6/8 | 2/3 | 5/6 | 2/4 | 12/17 | 3/4 | 08/12 | 7/9 | 7/8 | 08/13 |
| Improve Sustainability | 05/21 | 2/8 | 1/3 | 1/6 | 1/4 | 05/17 | 0/4 | 03/12 | 2/9 | 2/8 | 03/13 |
| Improve Health and Safety | 07/21 | 3/8 | 2/3 | 2/6 | 0/4 | 05/17 | 2/4 | 03/12 | 4/9 | 4/8 | 03/13 |
| Improve Competitiveness | 09/21 | 5/8 | 1/3 | 2/6 | 1/4 | 07/17 | 2/4 | 07/12 | 2/9 | 5/8 | 04/13 |
| Improve Client Satisfaction | 07/21 | 3/8 | 2/3 | 2/6 | 0/4 | 06/17 | 1/4 | 03/12 | 4/9 | 4/8 | 03/13 |
| Save Time | 16/21 | 6/8 | 2/3 | 5/6 | 3/4 | 13/17 | 3/4 | 08/12 | 8/9 | 6/8 | 10/13 |
| Save Cost | 14/21 | 5/8 | 2/3 | 5/6 | 2/4 | 11/17 | 3/4 | 08/12 | 6/9 | 5/8 | 09/13 |

### 2.4.4 Barriers/challenges of BIM adoption

Interviewees were also asked about the barriers/challenges preventing the construction practitioners from implementing BIM. The five most significant barriers/challenges were identified as: lack of BIM understanding; lack of expertise, high economic investment; lack of collaboration and coordination; and legal issues.

BIM understanding was identified as one of the significant barriers by most of the interviewees. Interviewee 10 stated that "lack of understanding is probably the biggest barrier, like knowledge about what it is, what the benefits are, how the process can be used." There are two different themes for lack of BIM understanding, amongst clients, and amongst other stakeholders. Regarding clients, "to a lot of them, when you mention the word BIM, they do not know what it means, how to achieve it, and what to do with it." (#20). Amongst other stakeholders, interviewee 5 described the current situation that "it is always the perception of what people mean by BIM. They can just do 3D modelling, and they said they are doing BIM. It is missing a whole lot of what BIM is, but they said they are doing BIM." The findings in New Zealand are supported by Alabdulqader, Panuwatwanich, and Doh (2013), Alreshidi, Mourshed, and Rezgui (2017), and Khosrowshahi and Arayici (2012). The lack of BIM understanding is always one of the first challenges/barriers to BIM adoption in their findings proving its essential role which needs to be solved for BIM development.

Interviewees also confirmed that a lack of knowledge concerning BIM means that they are unable to determine the benefits of using it. In other words, "if somebody experiences no benefits, they are going to be reluctant to do it" (#14). Additionally, we do not have BIM benchmark projects for BIM adoption in New Zealand. BIM benchmark projects have been steadily realised because of its essential role in BIM adoption. For example, a multination data centre project used to record BIM best practices was awarded in the BIM Excellence category by ICEA (Irish Construction Excellence Awards) (ICEA, 2018).

The high economic investment including software, hardware, training, specialist recruitment, etc. was also identified as a barrier/challenge to BIM adoption. Interviewee 3 explained the issue of staff and recruitment, “it is a high investment if you have to hire a BIM manager or hire a brand new staff member ... Those people tend to ask for quite high salaries because they are in demand.” Interviewee 1 also outlined the issue of investment, “the investment in hardware and software, changing workstreams and the need to restructure construction company skills composition and service offerings that is a significant capital investment cost and change management risk.” Interestingly, not only BIM practitioners in New Zealand but also those in the UK and Australia have the same view about the high economic investment for BIM adoption (Alabdulqader et al., 2013; Alreshidi et al., 2017; Khosrowshahi & Arayici, 2012). A cost model developed by Olatunji (2011) indicated that software, training, and hardware are the three highest costs for BIM adoption for the SMEs.

Interviewees confirmed that the lack of expertise is a significant challenge to BIM adoption associating with the cost. “Lack of expertise, yes. That is right, the knowledge pool and the people that are able to do the work. BIM managers, BIM coordinators, they are all like hen's teeth. They are rare, and it is hard to find those people” (#5). Interviewee 20 went on to state “definitely, we are desperately short of good expertise.” Interviewee 3 mentioned about contractors that “the contractors, in particular, do not necessarily have any BIM technicality, so it is just upskilling which is missing.” The finding reflects the view of Zhao, Pienaar, and Gao (2016) indicating that the lack of BIM competency or BIM expertise is one of the critical risks regarding BIM adoption.

A lack of client demand was identified as the next most significant barrier/challenge to BIM adoption. Interviewee 16 explained that “the clients are sort of lacking behind on saying they want a BIM project … it has to do with the fact that potentially architects and structural engineers, they sell BIM as being more expensive; and the client will say no to that.” Moreover, less interest in FM (facility management) from the owners is also a factor leading to the lack of client demand for BIM adoption. It is noted that the lack of client demand is not only a problem to BIM adoption in New Zealand but also around the world such as in the Middle East (Gerges et al., 2017), Sweden (Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth, 2017), and Hong Kong (Chan, 2015), etc.

Cultural resistance was also revealed as a barrier/challenge to BIM adoption. “I do not believe the industry currently wants it to be because they want to keep the status quo; they are afraid of change” (#1). “People like to stay in their comfort zone” (#14). The cultural resistance is a result of the combination of the lack of understanding, expertise, benchmark projects, and the incapacity of the industry. The results reported here are in line with the existing literature finding that cultural resistance is one of the most common and essential challenges/barriers to BIM adoption, which should be paid more attention to achieve the optimal solution (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013; Gerges et al., 2017; Zhao et al., 2016).

Legal issues such as intellectual property (IP), liability and contractual requirements were also considered as major barriers/challenges to BIM adoption. Interviewee 5 explained that “people do not want to give out information because they feel like they are losing IP.” These findings support the work of Arensman and Ozbek (2012) and

Eadie, McLernon, and Patton (2015). This proves that there is a need for further research in legal issues to BIM adoption to improve the transparency of the BIM process, along with the confidence of the BIM users to share their information willingly.

Eadie, Browne, et al. (2013) pointed out that the collaboration amongst stakeholders has the highest impact towards BIM adoption, one of the top three critical barriers/challenges affecting the BIM implementation is that lack of collaboration (Zhao et al., 2016). In this research, the lack of collaboration and coordination was also mentioned by the interviewees as a significant barrier/challenge. Currently, "the contractors are not taking the BIM model and using it necessarily to coordinate throughout the construction" (#3 ). Besides, "if we look at the supply chain, the supply chain that we get up for doing all the work we do, and how we want to gather and collect the information now, they are still not up to speed with all the requirements that we want" (#5). This has parallels to Chan (2015) and Bosch-Sijtsema et al. (2017) remarking that "BIM does not help if our counterparties are not using BIM."

Another challenge for BIM adoption relates to technical issues in terms of software, compatibility and interoperability. Interviewee 5 stated that "you need specialised software with certain characteristics, but it is a limited pool of what you can use currently." Interviewee 7 explained "what happens is when you use one package like ArchiCAD, and you use the IFC protocol and read it, you then lose things in translation." Interviewee 8 also acknowledged that "the technologists still have to catch up a little bit in various aspects … people's computers and software requirements or capabilities are really lagging behind what it actually requires for this technology and process to kick off." The findings reflect the view of Elena, Sergey, and

Irina (2018) stating that “none of the BIM software can provide solutions to all specialised tasks”; whereas, IFC still fails to be a solution in order to overcome the current interoperability problems (Belsky, Sacks, & Brilakis, 2013; Benghi & Greenwood, 2018; Q. Chen, Harmanci, Ou, & De Soto, 2017). Tulenheimo (2015) also expressed the need for the strong power of computers to BIM adoption.

The lack of guidelines and standards was also discussed by the interviewees as a challenge. Most of the interviewees agreed that we need more guidelines and standards for BIM adoption. “There is probably no New Zealand standard; companies here follow those standards from Europe or the UK … The problem with European standards out there was set up for Europe which may not be 100% suitable for New Zealand” (#4). Interviewee 13 expressed the inconsistency of the standards applications in New Zealand, “BIM in the industry is in a little bit of a flux at the moment … In New Zealand, we do not have any standard at the moment. There is a little bit of lack of direction of what we are going to do. We want to do the same as the rest of the world, but the rest of the world have different standards.”

According to Edirisinghe and London (2015), there is a connection between BIM adoption and BIM standards, regulations, and policy initiatives. However, BIM adoption situations between European countries and New Zealand are different in which the European governments have been politically active leading the development of BIM adoption in their countries; BIM has been mandated for certain types or stages of the projects (Travaglini, Radujković, & Mancini, 2014), compared to the passive resistance from the New Zealand government. McAdam (2010) and Maradza, Whyte, and Larsen (2013) revealed that the BIM standards and regulations in the UK and US are hardly applicable to each other. This is because those standards are only perfectly suitable for certain regions owing to the different approaches pursued by each area (Maradza et al., 2013; McAdam, 2010). In other words, the BIM standards from different countries should be analysed, discussed, and amended before applying it. This is parallel to Sielker and Allmendinger (2018)'s suggestion in which the consistent national framework including handbooks, guidelines, standards, and regulations should be established to have a successful BIM implementation.

In Canada, for example, a national BIM strategy, standards, guidelines, protocols, technical codes were planned to develop to ensure consistency of the BIM implementation process (buildingSMART, 2014). Although the Ministry of Education in New Zealand realised the vital role of the BIM standards and planned for its development (Cunningham, 2015), the current BIM resources are still modest. Compared to the UK, with many standards, guidelines, classification, and delivery created for BIM adoption, only two documents including International BIM Object Standard (Masterspec, 2016) and New Zealand BIM Handbook (BAC, 2016) were developed for BIM implementation in New Zealand, see Figure 2.4.

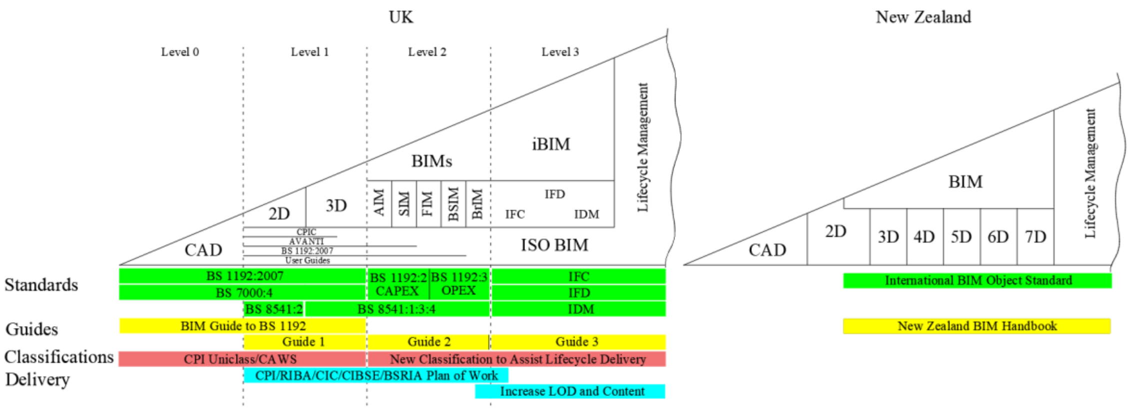



Figure 2.4. Standards and guidelines for BIM adoption in the UK and New Zealand (adapted from Bew and Richards (2008))

Table 2.4 shows the cross-case analysis conducted to examine whether the perspectives of the interviewees are different due to business types, company sizes, the number of BIM projects they have been involved in, and their experience. It is noted that they have the same view towards the barriers/challenges to BIM adoption despite their experience and their business types. Regarding the company sizes, the data from the interviewees working in the SMEs shows that they expressed more barriers/challenges compared to their counterparts, especially in the high economic investment, lack of expertise, cultural resistance, legal issues, and lack of collaboration and coordination. The findings here are consistent with the results and existing literature shown in section 2.4.2.

Table 2.4. BIM barriers/challenges summary

| BIM Barrier/challenge | No of Response | Construction Type | | | | Company Size | | No of BIM Projects | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥15 | <15 | ≥15 | <15 |
| Lack of Understanding | 20/21 | 8/8 | 3/3 | 6/6 | 3/4 | 16/17 | 4/4 | 12/12 | 8/9 | 8/8 | 12/13 |
| Lack of Benchmark Projects | 13/21 | 6/8 | 2/3 | 4/6 | 1/4 | 10/17 | 3/4 | 06/12 | 7/9 | 5/8 | 08/13 |
| High Economic Investment | 15/21 | 5/8 | 3/3 | 5/6 | 2/4 | 11/17 | 4/4 | 10/12 | 5/9 | 6/8 | 09/13 |
| Lack of Expertise | 17/21 | 5/8 | 3/3 | 6/6 | 3/4 | 13/17 | 4/4 | 10/12 | 7/9 | 7/8 | 10/13 |
| Lack of Client Demand | 11/21 | 4/8 | 2/3 | 3/6 | 2/4 | 08/17 | 3/4 | 06/12 | 5/9 | 5/8 | 06/13 |
| Cultural Resistance | 14/21 | 4/8 | 2/3 | 6/6 | 2/4 | 10/17 | 4/4 | 07/12 | 7/9 | 6/8 | 08/13 |
| Legal Issues | 14/21 | 6/8 | 2/3 | 4/6 | 2/4 | 10/17 | 4/4 | 08/12 | 6/9 | 6/8 | 08/13 |
| Lack of Standards and Guidelines | 09/21 | 5/8 | 1/3 | 3/6 | 0/4 | 07/17 | 2/4 | 05/12 | 4/9 | 4/8 | 05/13 |
| Lack of Collaboration and Coordination | 15/21 | 6/8 | 2/3 | 6/6 | 1/4 | 11/17 | 4/4 | 08/12 | 7/9 | 7/8 | 08/13 |
| Technical Problems | 12/21 | 6/8 | 2/3 | 4/6 | 0/4 | 09/17 | 3/4 | 05/12 | 7/9 | 5/8 | 07/13 |

Regarding the number of BIM projects, those who have been involved in less than 15 BIM projects are struggling with BIM badly in comparison with the ones participating in equal or higher than 15 BIM projects, especially with the lack of benchmark projects, technical issues, and lack of collaboration and coordination. This could be because the latter group gains much more BIM experience (by joining in many BIM projects), so they came up with solutions that could minimise the technical issues along with the collaboration and coordination problems.

Based upon the lack of guidelines and standards in New Zealand, interviewees were asked for their perspectives concerning the idea of BIM mandate in New Zealand. Interviewees were of differing views. A third of them believe that the government will mandate BIM. In terms of timing of a possible mandate, interviewees did not think it would happen quickly. In contrast, half of the interviewees stated that BIM would not be mandated in New Zealand. It is due to a number of reasons including the capacity of the industry; interviewee 14 stated that "we are too early to mandate the process, and I think it does get a lot of time before you can start that." Also, the benefits of BIM have not been proved yet in New Zealand and that politicians lack knowledge concerning the construction industry or buildings, so the concept of BIM could be lost on them. When asked whether the government should mandate BIM in New Zealand, the group were divided equally. Half felt that the government should mandate BIM because "BIM mandate would make a difference … They would get the industry doing more than just talking about it" (#20). Whereas, the other half felt that it should be business driven, "BIM should be a business solution … In the way of the commercial competitiveness, if you make BIM mandatory, people tend to become lazy" (#2).

### 2.4.5 Further discussion

BIM adoption in New Zealand is still in its early stages in which the level of depth of BIM definition as well as its understanding is not being achieved sufficiently. It is, therefore, necessary to collect, analyse, and learn the lessons from pioneer countries who have been managing to succeed at a certain level of BIM adoption. After identifying and analysing the benefits and barriers/challenges to BIM adoption in New Zealand, they were compared with the benefits and barriers/challenges to BIM adoption around the world, see Table 2.5.

Table 2.5. Benefits and barriers/challenges to BIM adoption amongst the countries and regions

| Benefits | UK | Australia | US | Singapore | China | Middle East | Finland | Turkey | Indonesia | Malaysia |
|---|---|---|---|---|---|---|---|---|---|---|
| RC | (Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | (Teo, Ofori, Tjandra, & Kim, 2015) | (Jin et al., 2017) | | (Gerbov, Singh, & Herva, 2018) | (Aladag, Demirdögen, & Isık, 2016) | | (Rodgers et al., 2015) |
| RRW | (Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | | (Jin et al., 2017) | | (Gerbov et al., 2018) | (Aladag et al., 2016) | | |
| RR | (Khosrowshahi & Arayici, 2012) | (Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | (Teo et al., 2015) | (Jin et al., 2017) | | (Gerbov et al., 2018) | (Aladag et al., 2016) | | |
| RV | | | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | | | | | (Aladag et al., 2016) | | (Rodgers et al., 2015) |
| ICC | (Eadie, Browne, et al., 2013) | (Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | (Teo et al., 2015) | (Jin et al., 2017) | (Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | (Chandra, Nugraha, & Putra, 2017) | (Rodgers et al., 2015) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IIM | (Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | (Teo et al., 2015) | | (Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | | |
| IV | | (Alabdulqader et al., 2013; Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | (Teo et al., 2015) | | | (Gerbov et al., 2018) | (Aladag et al., 2016) | | (Rodgers et al., 2015) |
| IE | (Khosrowshahi & Arayici, 2012) | | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | | | (Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | (Chandra et al., 2017) | |
| IS | (Khosrowshahi & Arayici, 2012) | (Newton & Chileshe, 2012) | (Tulubas Gokuc & Arditi, 2017) | (Teo et al., 2015) | | | | (Aladag et al., 2016) | | |
| IHS | | | | (Teo et al., 2015) | | | | (Aladag et al., 2016) | | |
| ICS | (Eadie, Browne, et al., 2013) | (Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | | (Jin et al., 2017) | (Venkatachalam, 2017) | | (Aladag et al., 2016) | (Chandra et al., 2017) | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IC | (Eadie, Browne, et al., 2013) | (Newton & Chileshe, 2012) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | (Teo et al., 2015) | (Jin et al., 2017) | (Venkatachalam, 2017) | | | (Chandra et al., 2017) | |
| ST | (Eadie, Browne, et al., 2013) | (Alabdulqader et al., 2013) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | | (Jin et al., 2017) | (Venkatachalam, 2017) | | (Aladag et al., 2016) | (Chandra et al., 2017) | (Rodgers et al., 2015) |
| SC | (Eadie, Browne, et al., 2013) | (Alabdulqader et al., 2013) | (Azhar, 2011; Tulubas Gokuc & Arditi, 2017) | | (Jin et al., 2017) | (Venkatachalam, 2017) | | (Aladag et al., 2016) | (Chandra et al., 2017) | (Rodgers et al., 2015) |
| Barriers | UK | Australia | US | Singapore | China | Middle East | Finland | Turkey | Indonesia | Malaysia |
| LU | (Alreshidi et al., 2017; Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Alabdulqader et al., 2013; Mohammad Reza Hosseini, Pärn, Edwards, Papadonikolaki, & Oraee, 2018) | (Ku & Taiebat, 2011) | | (Jin et al., 2017) | (Gerges et al., 2017; Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | (Chandra et al., 2017) | |
| LBP | (Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | | | (Teo et al., 2015) | | (Venkatachalam, 2017) | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEI | (Alreshidi et al., 2017; Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Alabdulqader et al., 2013; Mohammad Reza Hosseini et al., 2018) | (Ku & Taiebat, 2011) | (Teo et al., 2015) | (Jin et al., 2017) | (Gerges et al., 2017; Venkatachalam, 2017) | | (Aladag et al., 2016) | (Chandra et al., 2017) | (Hamid, Taib, Razak, & Embi, 2018) |
| LE | (Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Alabdulqader et al., 2013; Mohammad Reza Hosseini et al., 2018) | (Ku & Taiebat, 2011) | (Teo et al., 2015) | (Jin et al., 2017) | (Gerges et al., 2017; Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | (Chandra et al., 2017) | (Rodgers et al., 2015) |
| LCD | (Alreshidi et al., 2017; Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Mohammad Reza Hosseini et al., 2018) | | (Teo et al., 2015) | (Jin et al., 2017) | (Gerges et al., 2017; Venkatachalam, 2017) | | (Aladag et al., 2016) | | |
| CR | (Alreshidi et al., 2017; Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Alabdulqader et al., 2013) | (Ku & Taiebat, 2011) | | | (Gerges et al., 2017; Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | (Chandra et al., 2017) | |
| LI | (Alreshidi et al., 2017; Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | (Alabdulqader et al., 2013) | (Ku & Taiebat, 2011) | | | (Venkatachalam, 2017) | | | (Chandra et al., 2017) | (Hamid et al., 2018) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LSG | | | (Ku & Taiebat, 2011) | (Teo et al., 2015) | (Jin et al., 2017) | (Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | | (Hamid et al., 2018) |
| LCC | (Alreshidi et al., 2017; Eadie, Browne, et al., 2013; Khosrowshahi & Arayici, 2012) | | (Ku & Taiebat, 2011) | | | | | (Aladag et al., 2016) | | |
| TP | (Alreshidi et al., 2017) | (Alabdulqader et al., 2013; Mohammad Reza Hosseini et al., 2018) | (Ku & Taiebat, 2011) | | | (Gerges et al., 2017; Venkatachalam, 2017) | (Gerbov et al., 2018) | (Aladag et al., 2016) | (Chandra et al., 2017) | (Hamid et al., 2018) |

Note: RC: reduce clash; RRW: reduce rework; RR: reduce risk; RV: reduce variation; ICC: improve collaboration and coordination; IIM: improve information management; IV: improve visualisation; IE: improve efficiency; IS: improve sustainability; IHS: improve health and safety; ICS: improve client satisfaction; IC: improve competitiveness; ST: save time; SC: save cost; LU: lack of understanding; LBP: lack of benchmark projects; HEI: high economic investment; LE: lack of expertise; LCD: lack of client demand; CR: cultural resistance; LI: legal issues; LSG: lack of standards and guidelines; LCC: lack of collaboration and coordination; TP: technical problems.

It is clear that those benefits and barriers/challenges identified in the New Zealand construction industry are common to BIM adoption around the world despite the unique characteristics of the industry in each region. This helps to confirm that the lessons and practices of BIM adoption around the world can be valuable and worth for examining and analysing for further BIM implementation in the New Zealand construction industry during the time waiting for the BIM research and practices conducted in the New Zealand context. It is, however, noted that those practices need to be carefully reviewed regarding their time-scale of BIM adoption and their distinctive characteristics. For example, there are two milestones to BIM adoption in the UK, 2011-2016 (BIM was planned to be mandated by 2016 by the UK government (CO, 2011)) and after 2016. The studies and practices of BIM in the UK should be examined rigorously between 2011-2016 rather than the period after that as an example of planning and preparing for BIM development in New Zealand.

Besides, the time-scale can also have a considerable impact on the research to BIM adoption. Taking the software and hardware costs for implementing BIM in Malaysia for example, they were not considered as the major barrier anymore despite its existing in the previous literature (Rogers, Chong, & Preece, 2015). Furthermore, the unique characteristics of the countries could also be taken into consideration. Compared to other countries around the world, the UK, Australia, and New Zealand have many things in common. “Australia, New Zealand, and the UK have a similar basis of law. They have a common democratic system, and they have the same types of legislation and regulations around investment and trade” (Scheer, 2017). It is, therefore, suggested that the plans, practices, and studies towards BIM implementation in the UK and Australia should be critically analysed for further BIM development in New Zealand. This suggestion reflects the view of interviewee 16, "we generally follow the UK, Australia, or America. I think we almost follow the UK more than Australia. So, if the UK mandated BIM, we will be more likely to follow what the UK did, and normally take whatever they have done, and recycle that, and legislate things that are quite similar to what they did." While analysing case studies in the UK on BIM projects could "help to inform the New Zealand law" for avoiding legal issues, suggested by interviewee 20.

Furthermore, several solutions were implied by the interviewers when barriers/challenges to BIM adoption in New Zealand were revealed. Providing education and training is necessary to mitigate the challenge of lack of understanding, lack of expertise, and lack of client demand. Also, benchmark projects should be showcased to cover the challenge of lack of benchmark projects. In addition, BIM guidelines and standards should be developed with the inputs of the government. Developing a BIM execution plan and investing in technology development could also be the solutions to improve BIM adoption in New Zealand.

## 2.5 Conclusion

This research examined the perspectives of the construction experts towards BIM adoption in the New Zealand construction industry. BIM definition, understanding, benefits, challenges/barriers, solutions for BIM adoption, along with mandating BIM in New Zealand were critically analysed to provide a full picture of the existing situation of BIM adoption. The data was collected by conducting 21 semi-structured interviews with 25 interviewees working in a wide range of positions, construction types, company sizes. The results revealed that the understanding of BIM definition varies, and it is inconsistent amongst the construction experts. Also, it is found that most of the construction practitioners in New Zealand are not well-aware of BIM, especially the contractors, QSs, supply chain companies, and the SMEs, see Figure 2.5.

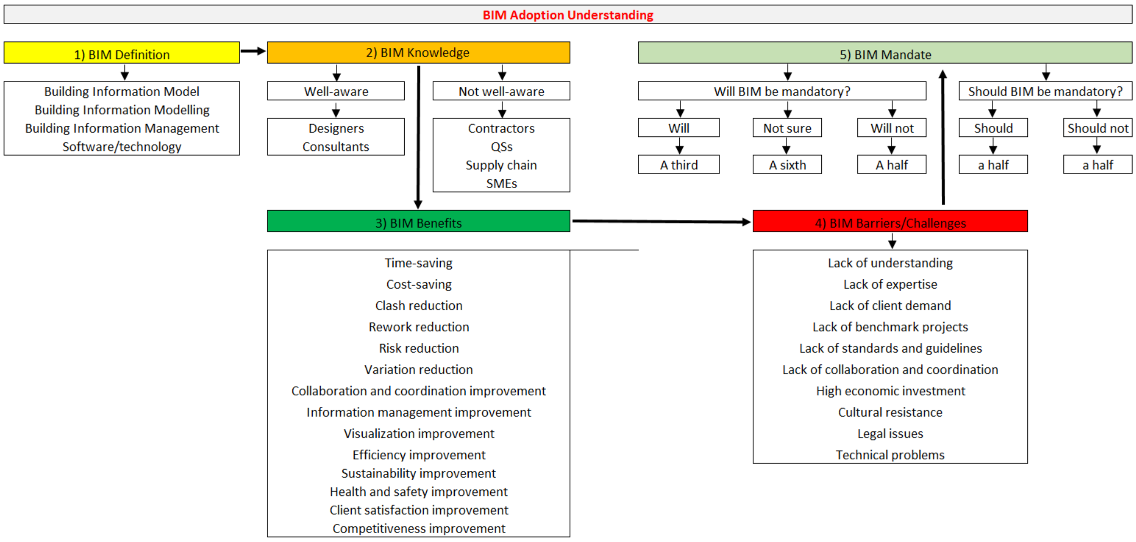


Figure 2.5. Results of the research

Regarding the benefits of BIM adoption, 14 potential benefits were identified by the interviewees. The five most significant barriers/challenges outlined were: lack of BIM understanding; lack of expertise; high economic investment; lack of collaboration and coordination; and legal issues. In contrast with the benefits, there is a division amongst the interviewees towards the barriers/challenges of BIM adoption. Those who have been working in the SMEs and have been involved in less than 15 BIM projects perceived more BIM barriers/challenges than their counterparts.

Whether New Zealand will or should mandate BIM was also analysed. While only one-third of the interviewees believed that BIM would be mandatory, half of them provided an opposite answer. However, more interviewees agreed that BIM should be mandatory in New Zealand compared to the "will" question. This could be because they have perceived the benefits of BIM adoption, but the construction industry is just not ready yet for the implementation because of the identified barriers/challenges. It is recommended that the government should be involved in finding out the role of BIM adoption towards the current practices of the construction industry instead of being inactive and standing outside of its development. The findings indicated that the government inputs into BIM implementation could be a significant solution to the SMEs, contractors, and those who do not have much experience in BIM adoption.

In summary, this research contributed to the existing body of knowledge in two key ways. Firstly, the research provided valuable insights into BIM understanding as well as recommendations regarding BIM adoption in New Zealand. Secondly, it was found out that characteristics such as benefits and barriers to BIM adoption amongst different countries could be similar. Therefore, it could be useful to analyse the studies, strategies, and practices of the pioneer countries in BIM adoption for the implementation. To be more specific, BIM adoption in the UK and Australia could provide valuable lessons for the New Zealand construction industry owing to the similar basis of law, democratic system, legislation, and regulations.

The data collection was conducted mainly in Auckland. Therefore, a more extensive study examining perceptions in other regions in New Zealand is suggested for future work. Also, the statistics of the BIM adoption rate were not collected due to the different understanding towards BIM definition of each interviewee. This research is the first stage of a larger project examing the relationship between BIM adoption and Green Star certification uptake in New Zealand. The next research will investigate the benefits, barriers/challenges, and solution of Green Star certification before establishing the connection between BIM adoption and Green Star certification uptake. It is clear from the results that sustainability improvement is one of the potential benefits of BIM adoption in New Zealand. Therefore, there might be a relationship between BIM and Green Star in New Zealand. Moreover, the findings in this research indicated that there is a lack of metrics to measure the success of BIM projects in the industry. Further studies will be conducted to develop a framework to analyse the factors having a significant impact on BIM adoption and to assess the success of the BIM projects.

# Chapter 3 Examining Green Star Certification Uptake and its Relationship with Building Information Modelling (BIM) Adoption in New Zealand

## 3.1 Prelude

This chapter aims to explore the perspectives of the key stakeholders in the New Zealand construction industry towards the use of Green Star. As indicated in Chapter 2 that adopting BIM could improve the sustainability of the project, the relationship between BIM and Green Star is also examined in this chapter. Specifically, six themes including 1) benefits of Green Star certification uptake; 2) challenges/barriers to Green Star certification uptake; 3) solutions for Green Star certification uptake; 4) the relationship between BIM adoption and Green Star certification uptake; 5) barriers/challenges to the integration of BIM between Green Star; and 6) solutions for the integration between BIM and Green Star were highlighted. The data was collected from 21 semi-structured interviews with industry experts. The results identified a range of benefits and barriers/challenges to the use of Green Star. The research offered a variety of suggestions to encourage Green Star development, with more extensive education playing a critical role, combined with greater integration of BIM with Green Star. The results could be considered baseline information for the construction professionals and academia to have effective strategies towards BIM and Green Star adoption.

## 3.2 Introduction

Green building has attracted significant attention recently due to the criticism against the construction industry for being responsible for environmental deterioration. Establishing and evaluating the green rating systems based on sustainable pillars to assess the environmental friendliness of the construction projects has been widely researched with 180 studies in 9 prestigious journals during 2008-2016 (Doan et al., 2017).

Hundreds of rating systems have been developed globally; however, BREEAM (Building Research Establishment Assessment Method) and LEED (Leadership in Energy and Environmental Design) are regarded as the two leading rating tools globally (Alwisy, BuHamdan, & Gül, 2018; Awadh, 2017; Doan et al., 2017). BREEAM is believed as having the most influence on the other rating systems (Mao, Lu, & Li, 2009), and it has the highest number of certified buildings compared to the other systems (Doan et al., 2017). Whereas, LEED has attracted the most attention from academia, and is seen as the most popular rating system based on the number of countries that have adopted it (Doan et al., 2017). CASBEE (Comprehensive Assessment System for Built Environment Efficiency) (Mattoni et al., 2018; Shan & Hwang, 2018) and Green Star are indicated as green rating systems in which they are usually compared to BREEAM and LEED (Alwisy et al., 2018; Doan et al., 2017; B. K. Nguyen & Altan, 2011).

Green Star New Zealand, is an adapted version of Green Star Australia, established in 2007 by the New Zealand Green Building Council (NZGBC) (NZGBC, 2019b). It has not held its strong attraction in academia, or to building developers and clients, with only 254 certified projects compared to over 2000 accredited projects of Green Star Australia (GBCA, 2019; NZGBC, 2019c). From the Scopus database with the keywords “Green Star” + “New Zealand,” only three journal articles were found focusing on Green Star in New Zealand. Byrd, Rasheed, and their research group contributed two papers concentrating mainly on the Indoor Environmental Quality (IEQ) category of Green Star (Byrd & Rasheed, 2016; Rasheed et al., 2017). Rehm and Ade (2013) compared the cost difference between green and conventional office buildings. None of these studies examined the current practice of Green Star certification, its benefits, barriers, or solutions.

Green Star manuals have been adapted and indirectly affected by BREEAM and LEED. However, it has weaknesses regarding sustainability assessment compared to both BREEAM and LEED (Doan et al., 2017). Green BIM has become a technical term recently with the idea of integrating BIM with the green rating systems (Azhar & Brown, 2009; Jalaei & Jrade, 2015; J. K.-W. Wong & Kuan, 2014). Integrating BIM with LEED allows designers to design the project easily and efficiently (Jalaei & Jrade, 2015). Automatic sustainability assessment can be achieved when BIM is integrated with BREEAM (Ilhan & Yaman, 2016). BIM is considered a powerful tool that could support green rating adopters to have their projects certified easier and quicker. However, whether the integration of BIM and green rating systems exists or it is workable in the current practice has not been explored.

This raises several questions; Whether Green Star uptake can bring benefits to the adopters, construction industry, and society in New Zealand? Why is the number of Green Star certified projects in New Zealand modest? And how can the current practice of Green Sar be improved? This research aims to explore the perceptions of the key construction professionals towards Green Star in New Zealand regarding its benefits, barriers/challenges, and the solutions for its development. Also, whether a relationship between BIM and Green Star exists in New Zealand. Barriers/challenges and resolution for the integration of BIM and Green Star will also be revealed.

## 3.3 Research Methodology

Semi-structured interviews, with key construction professionals, were used to examine Green Star perspectives and its relationship with BIM adoption in New Zealand. The method is suitable as it offers benefits of “deep, rich observational data”

(Onwuegbuzie & Leech, 2005; Sieber, 1973) providing insights for the research (Eisenhardt, 1989; Haussner et al., 2018; Scott, 1965). Also, the interviewees can share their opinions freely and actively creating reliable and comparable qualitative data (Cohen & Crabtree, 2006; Galletta, 2013; Harrell & Bradley, 2009).

Purposive sampling and snowball sampling techniques were used, see Figure 3.1. The respondents needed to have been working in the construction industry for at least five years with experience in either BIM or Green Star. "There are no hard-and-fast rules about the experience and ability to provide insights … five years is widely regarded by most professional institutions to be the period of time it takes to qualify as a full professional in the construction industry" (Brown & Loosemore, 2015).

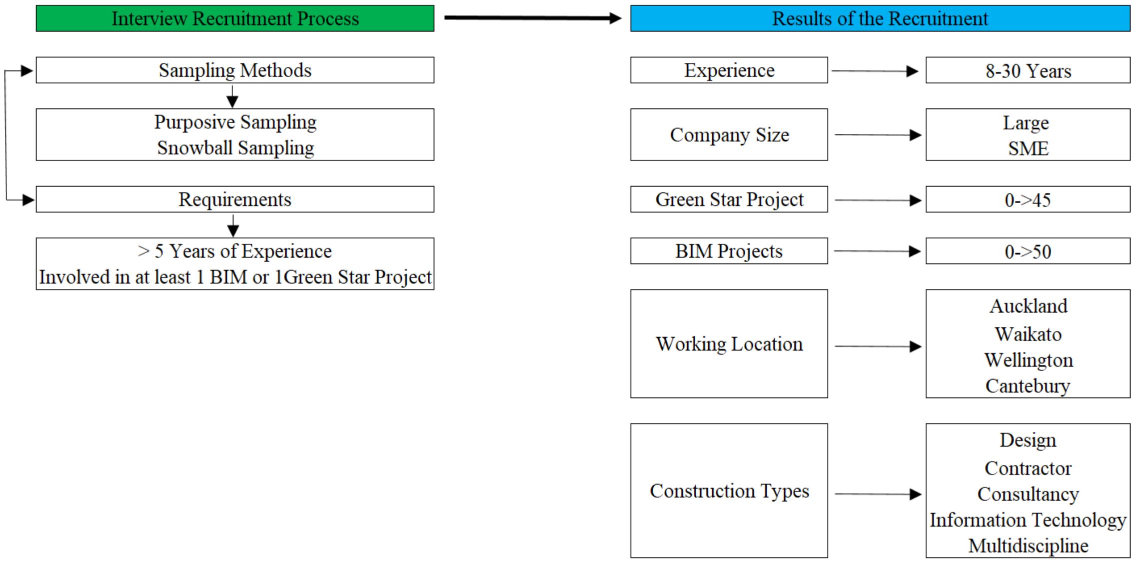



Figure 3.1. Interviewee recruitment process

19 face-to-face and 3 telephone interviews were carried out with 26 interviewees between November and December 2017, see Table 3.1. Interviewees in the interviews 6, 12, 13, and 20 recommended the presence of an additional interviewee to ensure the quality of the answers to the research questions. The sample size in this research is considered appropriate as the saturation point of the data was achieved. Based on the results of Galvin (2015), Guest et al. (2006), Crouch and McKenzie (2006), and Kvale

and Brinkmann (2009), and previously construction field qualitative studies (Hurlimann et al., 2018; Sacilotto & Loosemore, 2018), 12-15 interviews are appropriate to achieve the saturation.

Table 3.1. Demographics of interviewees

| Interviewee | Construction Position | Experience (years) | Construction Type | Company Size | BIM Projects | Green Star Projects |
|---|---|---|---|---|---|---|
| #01 | Senior QS | 10 | Contractor | Large | 01 | 01 |
| #02 | BIM Manager & GSAP[1] | 14 | Design | Large | >50 | 00 |
| #03 | Director, Building Scientist, Green Star Assessor, & GSAP | 12 | Consultancy | Large | >50 | 30 |
| #04 | Senior Architect, GSAP, & Green Star Assessor | 15 | Design | Large | 30 | >45 |
| #05 | Technical Services Manager, Design Manager, GSAP, & Green Star Assessor | 22 | Contractor | Large | 06 | 30 |
| #06 | 1) Director & Building Surveyor[2]<br>2) Building Surveyor | 14<br>04 | Consultancy | SME | 15 | 00 |
| #07 | Principal & Designer | 30 | Design | SME | 04 | 03 |
| #08 | Senior Cost Manager | 20 | Consultancy | Large | 01 | 02 (BREEAM) |
| #09 | Project Director | 23 | Contractor | Large | 11 | 03 |
| #10 | Building Services Technical Leader | 08 | Consultancy | Large | 07 | 01 |
| #11 | Director & Building Performance Expert | 19 | Consultancy | SME | 01 | 05 |
| #12 | 1) BIM Manager[2]<br>2) Building Scientist | 22<br>03 | Design | Large | >50 | 00 |
| #13 | 1) Associate & Structural Engineer[2]<br>2) Drawing Office Manager | 10<br>19 | Design | Large | >50 | 00 |
| #14 | Structural Technician | 08 | Design | Large | 01 | 00 |
| #15 | Sustainability Leader, Green Star Assessor, & GSAP | 13 | Design | Large | >50 | 20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| #16 | BIM Construction Manager | 11 | Contractor | Large | 40 | 00 |
| #17 | Technical Lead & Senior QS | 12 | Multidiscipline | Large | >50 | 00 |
| #18 | BIM Consultant, Application Engineer, & Business Analyst | 17 | Information Technology | SME | >50 | 01 |
| #19 | Associate Senior Architect | 11 | Design | Large | >50 | 01 (Green Star)<br>01 (Lotus)<br>01 (PBRS[3]) |
| #20 | 1) BIM Development Engineer[2]<br>2) Senior Structural and Sustainable Engineer, & GSAP | 20<br>08 | Consultancy | Large | 50 | 03 |
| #21 | Principal QS | 08 | Multidiscipline | Large | 02 | 00 |
| #22 | GSAP & Green Star Assessor | 10 | Non-profit | Large | 00 | 45 |

Note: [1]Green Star Accredited Professional
[2]Corresponding interviewee
[3]Pearl Building Rating System

Table 3.1 outlines that interviewees have at least 8 years of construction industry experience. They hold senior positions in companies, including design, contracting, consultancies, information technology, a non-profit organisation, and 2 multidisciplinaries, within small and medium-sized enterprises (SMEs) i.e. less than 20 employees (MBIE, 2017; MED, 2011) and large organisations. All interviewees have direct experience in BIM or Green Star; 14 of them had direct involvement in both (or equivalent) projects. 4 of the interviews were conducted outside of Auckland (Canterbury: 1, Wellington: 2, Waikato: 1).

Thematic analysis using NVivo 11 was adopted on 21 transcripts, as it is considered as "a foundational method for qualitative analysis" providing accurate and insightful findings (Braun & Clarke, 2006; Nowell et al., 2017). NVivo is frequently used because of its benefits regarding efficiency, multiplicity, and transparency (Hoover & Koerber, 2011). One transcript (participant 9) was discarded from the analysis due to poor sound quality.

To confirm the validity and reliability of the findings, three stages were adopted, see Figure 3.2. Maximum variation was ensured with the participation of the wide variety of the characteristics of the interviewees to enhance the transferability of the findings to readers (Merriam & Tisdell, 2015; Patton, 2015). Sufficient time was spent on each of the interviewees to achieve data saturation, i.e. adequate engagement (Merriam & Tisdell, 2015). Interestingly, the results of the research were saturated at the 12th interview, identical to Galvin (2015) and Guest et al. (2006)'s suggestions for the sample size. To avoid mistakes and errors, the transcripts and codes were checked thoroughly (Creswell & Creswell, 2017; Gibbs, 2018; Longhofer et al., 2012). Subsequently, member checking was carried out by returning the data and the initial analysis results to the interviewees to validate and revise if necessary (Birt et al., 2016). Peer review was ensured by extensively discussing the results of the analysis with the interviewees (Merriam & Tisdell, 2015). Finally, triangulation using multiple sources of data to confirm the findings was carried out (Barbour, 2001; Merriam & Tisdell, 2015; Silverman & Patterson, 2014).

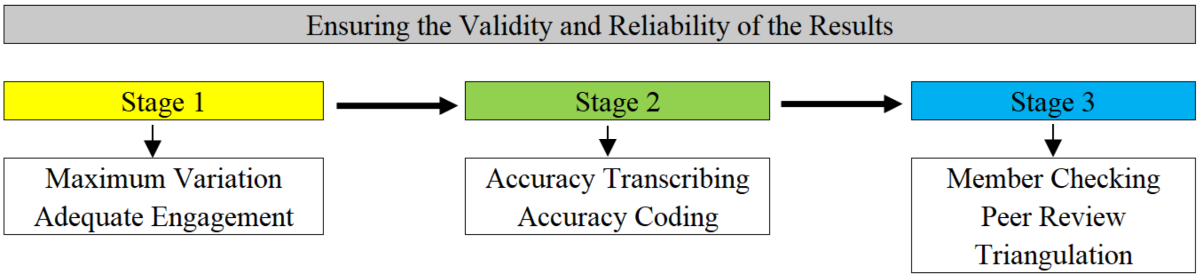



Figure 3.2. Promoting validity and reliability process

## 3.4 Results and Discussions

Six main themes were analysed and discussed including the benefits of Green Star certification uptake, the challenges/barriers to that uptake, and possible solutions for Green Star certification uptake. It also examined the relationship between BIM adoption and Green Star certification uptake, associated barriers/challenges to their integration, as well as possible integration solutions.

### 3.4.1 Benefits of Green Star certification uptake

All of the interviewees perceived many benefits associated with Green Star certification; "there are a lot of benefits towards a Green Star building. It is essentially a sustainable building" (#12). Most of the interviewees agreed that it could provide "obvious environmental benefits regarding the reduced impacts on the environment" (#5).

Regarding Green Star benefits to the occupants, it could provide "healthy office spaces" (#1) "with a better environment for the users" (#2). In other words, it "improves occupant comfort and occupant performance" (#22) leading to "the reduction in absenteeism and the increase in the productivity by getting through more work with fewer mistakes and fewer business risks from the employees" (#11).

As for the building developers, the interviewees revealed a range of benefits associated with Green Star certified buildings. These included having a positive impact on sales prices and perceived reputation, "if you also have portfolio projects that are Green Star rated ... you have got the perception and the reputation in the market of what you own" (#5). Furthermore, interviewee 17 stated that "Green Star is like a trademark … It is a good selling point that they are trying to sell office space to someone."

Regarding the owners, benefits suggested related to cost and energy saving. "It is the obvious benefits of the OPEX (operating expenditure) costs" (#5) because the Green Star certified building is "drawing from nature as much as possible" (#8). The building could be "efficient regarding energy usage and heat loss" (#6) by, for example, "taking the solar glare and solar gain out of the building and divert that heat into something that will actually heat water and provide power" (#8). In case the buildings are used for lease, "it is more attractive to tenants or maybe even charged more for rental" (#3).

A third of the respondents also indicated that Green Star certification uptake could raise social conscience regarding sustainability development. It potentially "drives the industry for change" (#15) and provides "a bit of a social conscience in environmental impacts" (#8). Finally, three interviewees remarked that Green Star could be considered as "a great benchmarking system" (#11), "the common language thing so that I can compare certain types of buildings" (#15).

The findings are consistent with existing literature. After reviewing and comparing studies in the US, the UK, and Canada with "a small amount of anecdotal evidence" in New Zealand, NZGBC (2010) identified that certified green buildings could be a benefit for tenants, developers, and owners. All the benefits revealed by the interviewees could be found in the NZGBC (2010) report. It is not unusual for selecting a rating system to be a property industry benchmark. For example, ENERGY STAR Portfolio Manager Tool, has been used by the United States Department of Energy (Bantanur, Mukherjee, & Shankar, 2012). In New Zealand, Green Star requirements are included in the Proposed Unitary Plan by the Auckland Council (Doan et al., 2017) while Wellington City Council offers 50% remission of levies to 5 Star or higher Green Star certified projects, since July 2015 (WCC, 2015). This is reflected by the interviewees suggesting Green Star as “a great benchmarking system” (#11).

However, the benefits of Green Star certification uptake were perceived unequally amongst the respondents. Reducing environmental impacts was highlighted by most of the interviewees, followed by the benefits to the occupants. However, less than a third of the respondents outlined the benefits to owners and developers. This could imply a question “are the current benefits of Green star attractive to the developers or the investors to pursue?” for further research.

A cross-case analysis was conducted to examine whether respondents’ demographic characteristics have any impacts on the results, see Table 3.2. It was found out that the benefits of Green Star certification uptake were perceived similarly across all interviewees’ types. However, those who have been involved in equal or higher than 20 Green Star projects pointed out much wider benefits of Green Star compared to their counterparts in terms of the benefits to developers and owners, as well as being seen as a benchmarking system. This is understandable because those interviewees are Green Star assessors, possessing remarkable skills and knowledge in green buildings.

Table 3.2. Green Star benefits summary

| Green Star Benefit | No of Response | Construction Type | | | | Company Size | | No of Green Star Projects | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥20 | <20 | ≥15 | <15 |
| Benefit to the Environment | 17/21 | 7/8 | 3/3 | 5/6 | 2/4 | 15/17 | 2/4 | 4/5 | 13/16 | 6/8 | 11/13 |
| Benefit to Occupants | 12/21 | 4/8 | 2/3 | 5/6 | 1/4 | 09/17 | 3/4 | 4/5 | 08/16 | 5/8 | 07/13 |
| Rasing Social Conscience | 07/21 | 2/8 | 1/3 | 1/6 | 3/4 | 06/17 | 1/4 | 2/5 | 05/16 | 2/8 | 05/13 |
| Benefit to Developers | 06/21 | 2/8 | 1/3 | 0/6 | 3/4 | 05/17 | 1/4 | 3/5 | 03/16 | 3/8 | 03/13 |
| Benefit to Owners | 04/21 | 1/8 | 1/3 | 1/6 | 1/4 | 04/17 | 0/4 | 3/5 | 01/16 | 2/8 | 02/13 |
| Being a Benchmarking System | 03/21 | 1/8 | 1/3 | 1/6 | 0/4 | 02/17 | 1/4 | 2/5 | 01/16 | 2/8 | 01/13 |

### 3.4.2 Challenges/barriers to Green Star certification uptake

Interviewees discussed the challenges/barriers associated with Green Star certification uptake. Significant ones were the lack of Green Star understanding, cost perception, lack of benchmark projects, lack of client demand, and the complex administration for Green Star registration and assessment.

Green Star understanding/skill was seen as the most significant barrier to Green Star uptake, revealed by over two-thirds of the interviewees. Interviewee 5 stated that “we still struggle with client awareness of what it means.” (#5). While the Green Star skills were mentioned by interviewee 7, “we have a lot of people learning, trying to learn how to do it, and not knowing how to do it.” Furthermore, “they do not actually understand the long-term cost savings from it (#19). Without exception, the lack of knowledge and skills is a problem identified by GBCA (Green Building Council Australia) to Green Star in Australia (BGCA, 2011).

Cost perception of Green Star uptake was also important. Interviewee 12 stated “there is a perception that green or sustainable buildings are more expensive”; “the cost associated with Green Star certification is the biggest barrier” for the uptake (#21). Interviewee 5 outlined “they still believe that to meet the requirements for Green Star, they have to put a significant capital expenditure into the building to upgrade the design to meet the benefits of Green Star.” Compared to traditional buildings, Green Star buildings are believed to cost up to 20% more (#2). As a result, “people do not want to pay to get it assessed” (#17).

These findings are consistent with existing literature. Dwaikat and Ali (2016) confirmed that the costs of the green buildings are around -0.4% (saving) to 46% compared to the traditional ones, but 80% of the reviewed studies provided the positive value for the green cost premium. Interestingly, 15 interviewees believed that a Green Star building would cost higher than or equal to a traditional building. This study reflects the results of the qualitative data analysis of Rehm and Ade (2013) research (similarly with 15 industry professionals in New Zealand).

The lack of benchmark projects regarding the Green Star benefits was a serious concern to half the interviewees. Interviewee 22 stated “those have not been proven in the New Zealand market, so I do not know if you could definitively say those are benefits of green building.” Interviewee 15 stated “the biggest challenge in my career is the evidence; there is not enough evidence.” The literature supports this too. NZGBC has made an effort to mitigate this issue by just officially releasing a new tool, Green Star Performance, last year, “we are currently seeking a handful of pilot projects to be the first in New Zealand to benchmark themselves against the Green Star Performance framework” (NZGBC, 2017a). However, no project has been certified with Green Star Performance in New Zealand until now (NZGBC, 2018). This problem has still not been solved yet.

A lack of client demand was indicated as the next barrier/challenge to Green Star uptake. “It really comes down to if the client has that sort of idea in mind and whether they push that” (#12). Interviewee 13 stated “we have not had requests from our clients to build, to design that unless it is a big warehouse or a multi-story building. We generally do not get a request.” This is seen as a significant problem to Green Star uptake. According to NZGBC (2019c), there are only 254 Green Star certified building from 2007-2019.

Complex administration was also described as a barrier by a third of the interviewees. “The administrative burden is one of the big barriers of Green Star” (#5). “It is almost too process-driven … It is too strict … They are concentrating not on having a really energy-efficient building” (#10). The problem aligns with the GhaffarianHoseini, Tien

Doan, et al. (2017) and BCI (2014) results highlighting the time-consuming nature as well as the difficulty of the Green Star certification process.

To explore whether the demographics of the interviewees could affect their perspectives, the results analysed further based on their demographic characteristics, see Table 3.3. Interestingly, their perceptions towards the barriers/challenges preventing people from uptaking Green Star showed little difference despite their company types, sizes and their experience in the industry. This could be because Green Star has been established for over a decade and green building has been an appealing topic recently. Also, the interviewees are those holding senior positions in their companies; they, therefore, are quite well-aware of the challenges/barriers to Green Star uptake. It is noticed that those have been involved in equal or greater than 20 Green Star projects highlighted the lack of understanding and cost perception as the most significant barriers/challenges to Green Star uptake. Based on the data collected from the interviewees, lack of understanding was indicated as the most significant barrier/challenge, followed by cost perception, which needs to be solved for Green Star development.

Table 3.3. Green Star barriers/challenges summary

| Green Star Barriers/Challenges | No of Response | Construction Type | | | | Company Size | | No of Green Star Projects | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥20 | <20 | ≥15 | <15 |
| Lack of Understanding | 16/21 | 6/8 | 2/3 | 5/6 | 3/4 | 12/17 | 4/4 | 5/5 | 11/16 | 8/8 | 08/13 |
| Cost Perception | 15/21 | 5/8 | 2/3 | 5/6 | 3/4 | 13/17 | 2/4 | 5/5 | 10/16 | 5/8 | 10/13 |
| Lack of Benchmark Projects | 09/21 | 4/8 | 1/3 | 2/6 | 2/4 | 06/17 | 3/4 | 2/5 | 07/16 | 5/8 | 04/13 |
| Lack of Client Demand | 07/21 | 3/8 | 1/3 | 3/6 | 0/4 | 05/17 | 2/4 | 2/5 | 05/16 | 4/8 | 03/13 |
| Complex Administration | 07/21 | 1/8 | 1/3 | 2/6 | 3/4 | 06/17 | 1/4 | 1/5 | 06/16 | 3/8 | 04/13 |

Interviewees were also asked for their perspectives around the idea of making Green Star mandatory in New Zealand. Two-thirds of the interviewees indicated that Green Star should or will be mandated. This is because “we are running out of natural resources” (#13). Interviewee 20 stated “we have the safety rating for cars, and we have the energy efficiency rating for our fridges, it should be the same for our buildings ... mandating Green Star rating system is a good idea.” While the rest of the interviewees indicated that “we can encourage it, but we can never force it” (#7). This could be the reason why only a few local authorities have been active in the Green Star development such as the Auckland Council and Wellington City Council (Doan et al., 2017; WCC, 2015).

### 3.4.3 Solutions for Green Star uptake

Education, in both continuing professional development and continuing education, was considered as one of the critical solutions to aid Green Star uptake by most of the interviewees. Interviewee 5 suggested “it is really just education of the building owners to understand what it is that they want, what they want to achieve with that building stock; and do they want to get the efficiency, understanding and getting the benefits of what Green Star is going to?” Also, the building developers need education about the benefits of Green Star as “they can get good clients when they deliver highly efficient buildings” (#20). This is also the solution mentioned by S.-C. Wong and Abe (2014) suggesting that raising the awareness of those who are potential project owners is crucial for CASBEE development.

Providing Green Star benchmark projects was also indicated as a practical solution. The clients will be willing to have their buildings certified once “we can prove the benefits of Green Star uptake, saying regarding money, a green building gets a little cost more, but the benefits are blah blah blah" (#2). NZGBC has been active with the release of Green Star Performance "which is good to provide the evidence" (#15).

Providing incentives for Green Star uptake was also suggested as an appropriate way to mitigate the barriers/challenges. Interviewee 13 stated "if the government gives tax incentives for the Green Star building, the client will get the percentage of the value of the building back." Interviewee 3 confirmed "in Wellington, we are very lucky because the council offers a discount to Green Star buildings, so we get a 50% discount on our development … That quite often makes Green Star very attractive."

Interestingly, integrating BIM with Green Star was seen as a solution for Green Star development. "If they can tie up with BIM which is good. They can integrate it; that is a better way to assess the building regarding materials, indoor environment quality, and that kind of stuff" (#2). Interviewee 1 explained "once 6D BIM is developed, the model will be linked to actual Green Star points and credits which could reduce the time for Green Star assessment." This reflects the contents of BIM Uses in the New Zealand BIM handbook mentioned the possibility of using BIM in a construction project for Green Star assessment (BAC, 2016).

The Green Star assessment process was also suggested to be optimised. Interviewee 5 proposed "making the manuals and the technical systems easier to use, using templates, etc., trying to make it easy on the administration." However, interviewee 18 highlighted "this evolution is missing, unfortunately." This is seen in Doan et al. (2017) results showing that Green Star has still many weaknesses regarding its credits assessment as well as the less updated versions compared to BREEAM and LEED. Reducing the costs for Green Star assessment was raised by interviewee 4 as a final solution. However, "how we can reduce it much? It needs to be rigorous in the assessment. Otherwise, it is just a simple checklist, and everybody will be doing it, but it will be worth nothing because it is going to be no kind of legitimacy … There is money involved in upgrading the project, money involved in the professional fees, and then also money involved in the documentary. I am not sure how much we can reduce each of those factors.”

It is noticed from the cross-case analysis that those who have been involved in equal or greater than 20 Green Star projects strongly indicated the idea of providing incentives for Green Star buildings compared to their counterpart, see Table 3.4. This could be because they have been involved in many Green Star projects, so they understood the vital role of the economic encouragement policies towards Green Star investors. Interestingly, those who have been working in the consultancy companies did not mention streamlining the Green Star process or integrating Green Star with BIM at all. This could be understandable because Green Star was released a decade ago; it, therefore, could be streamlined to a certain level; while BIM is still in early stages, preventing the integration between Green Star and BIM. As a result, providing education, showcasing Green Star benchmark projects, and offering incentives were pointed out frequently amongst the interviewees. Although reducing the registration cost was pointed out by one interviewee as a solution for Green Star uptake. This is because the one who suggested that the solution is a Green Star assessor who has been involved in more than 45 Green Star projects. In other words, the interview is well-aware of the Green Star practice in New Zealand.

Table 3.4. Green Star solutions summary

| Green Star Solutions | No of Response | Construction Type | | | | Company Size | | No of Green Star Projects | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥20 | <20 | ≥15 | <15 |
| Providing Education | 07/21 | 1/8 | 1/3 | 4/6 | 1/4 | 06/17 | 1/4 | 3/5 | 04/16 | 5/8 | 02/13 |
| Showcasing Benchmark Projects | 06/21 | 4/8 | 1/3 | 1/6 | 0/4 | 05/17 | 1/4 | 2/5 | 04/16 | 3/8 | 03/13 |
| Providing Incentives | 05/21 | 2/8 | 0/3 | 2/6 | 1/4 | 05/17 | 0/4 | 2/5 | 03/16 | 2/8 | 03/13 |
| Integrating with BIM | 04/21 | 2/8 | 1/3 | 1/6 | 0/4 | 03/17 | 1/4 | 1/5 | 03/16 | 2/8 | 02/13 |
| Optimising Administration | 03/21 | 1/8 | 1/3 | 0/6 | 1/4 | 01/17 | 2/4 | 1/5 | 02/16 | 3/8 | 00/13 |
| Reducing Registration Fees | 01/21 | 1/8 | 0/3 | 0/6 | 0/4 | 01/17 | 0/4 | 1/5 | 00/16 | 1/8 | 00/13 |

### 3.4.4 The relationship between BIM adoption and Green Star certification uptake

Thirteen interviewees stated that there is no relationship between BIM and Green Star currently. However, 20 of the interviewees felt that adopting BIM could potentially support Green Star certification uptake. Interviewee 1 explained, “the BIM model is linked to sustainability via 6D information where the Green Star credits are linked to the model.” This is because “potentially any information that Green Star needs can be held within the BIM workflow so that it could be any amount of information from the concept design to construction to implementation and facility management, and Green Star can get that information from BIM” (#13). This aligns with the ninth BIM Use, Sustainability (Green Star/NABERS) Evaluation, in the BIM handbook (BAC, 2016).

Interviewee 11 believed “adopting BIM could make the work of GSAP easier.” Interviewee 8 strongly confirmed that “if you can get efficiencies from BIM then that would surely help to gain Green Star certification.” As a result, “it should be possible to do the Green Star assessment almost purely by looking at the Revit model … all of that kind of stuff that was in there” (#3). An ideal way could be “an investment in developing a tool that has plugged into it” (#20), then “hopefully we can press a button, and it will tell us how many points our building is going to get” (#17). These findings have parallels to Ryu and Park (2016) results indicating the usefulness of implementing BIM for LEED energy simulation. Also, Ilhan and Yaman (2016) developed an IFC-based framework for the integration between BIM and sustainable data model with the BREEAM materials category assessment for validation. All of these implied the possibility of the BIM-Green Star integration offering efficient Green Star assessment, a potential solution to push the development of Green Star uptake.

Whether Green Star certification uptake could affect the BIM adoption rate was also explored during the interviews. Two-thirds of the interviewees believed that Green Star uptake could have impacts on BIM adoption for some aspects. Interviewee 2 shared “Green Star should affect BIM because Green Star offers better design, BIM is a tool to achieve the design, so Green Star should be leading, and BIM supports that.” In contrast, interviewee 5 perceived that “I do not think Green Star can influence the adoption of BIM … The design is still a driven process that sits outside of what the Green Star is, that does not drive the process.” The opinions shared were varied, and not many studies have researched the relationship between BIM and green rating systems. However, GhaffarianHoseini, Tien Doan, et al. (2017) developed the conceptual framework based on the potential benefits and challenges of BIM and Green Star adoption, which reflects the idea of Green Star uptake could have impacts on the BIM adoption rate.

### 3.4.5 Barriers/challenges to the integration between BIM and Green Star

To understand why there is no perceived relationship between BIM and Green Star currently, the interviewees were asked to determine the barriers/challenges to the integration. The BIM and Green Star certification processes were described as separate from each other by a third of the interviewees. “There are two models living … how my design process can marry up with the green process in a nice way” (#2). The interviewees’ perceptions are consistent with the existing literature. Azhar et al. (2011) indicated that only around one-third of the LEED credits could be achieved with BIM adoption, which is also the figure for BEAM (Building Environmental Assessment Method) Plus credits in J. K.-W. Wong and Kuan (2014) research.

Challenges to integration outlined by interviewees were very similar to challenges associated with Green Star as a stand-alone system, ranging from a lack of BIM and

Green Star understanding, the need for extensive information required and the cost perception. Interviewee 14 shared “it is a combination of lacking awareness and costs, but I think it is more about the fear of costs, and the fear of what they do not quite understand.” “Understanding what information we need out of the model to provide for the Green Star outputs” was remarked by interviewee 12.

Lack of client demand was also highlighted as a significant barrier/challenge to the integration. Interviewee 11 explained the opinion by asking rhetorical questions, “how many projects out there in New Zealand that have required BIM? How many projects out there in New Zealand that have required Green Star? And how many for both? That is a huge barrier if you cannot get uptake in either BIM or Green Star to get them to happen at the same time. So, that is both at the point where not many projects have been done yet until you start to get some overlap.” In other words, BIM and Green Star projects are not the common focus in New Zealand currently. Interviewee 6 shared the practices in his company that “we never look for the Green Star rating.” This reflects the modest number of Green Star registered projects from 2007-2019, with only 254 projects (NZGBC, 2019c).

Green Star submission requirements were indicated as the next barriers/challenges. Interviewee 20 shared “NZGBC is working on the traditional base, sort of the tick boxes, filling forms, it is straightforward.” Therefore, “there is no real advantage to a BIM project over somebody using 2D AutoCAD because the documentation is assessed in the same way.” “So at the moment, there is not necessarily any advantage regarding the green building assessment” (#3). Furthermore, “NZGBC requires it to be a contract document, you would have to show that the Revit model is a contract document” (#4) which is not happening yet.

The low level of BIM development in New Zealand was also identified as a crucial barrier/challenge. Interviewee 3 suggested that the LOD (level of development) should be up to 400 or 500, and the BIM maturity level should reach the highest level to have "all that information loaded in"; then, "it should, in theory, be possible to do your Green Star assessment almost purely by looking at the Revit model."

Table 3.5 summarises the barriers/challenges to the integration of BIM and Green Star. Two different processes and lack of understanding were perceived as the most significant barriers/challenges. Interestingly, interviewees who have been working in large companies provided more barriers/challenges compared to SMEs. It could be because they have participated in the projects required both BIM and Green Star and are knowledgeable on this topic.

Table 3.5. Barriers/challenges to the integration of BIM and Green Star summary

| Green Star & BIM Barriers/Challenges | No of Response | Construction Type | | | | Company Size | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥15 | <15 |
| Two Different Processes | 07/21 | 2/8 | 2/3 | 2/6 | 1/4 | 07/17 | 0/4 | 3/8 | 04/13 |
| Lack of Understanding | 07/21 | 5/8 | 0/3 | 1/6 | 1/4 | 06/17 | 1/4 | 3/8 | 04/13 |
| Lack of Client Demand | 06/21 | 1/8 | 0/3 | 5/6 | 0/4 | 04/17 | 2/4 | 4/8 | 02/13 |
| Green Star Submission Requirement | 04/21 | 2/8 | 0/3 | 2/6 | 0/4 | 03/17 | 1/4 | 3/8 | 01/13 |
| Low Level of BIM Development | 04/21 | 2/8 | 1/3 | 1/6 | 0/4 | 04/17 | 0/4 | 0/8 | 04/13 |

### 3.4.6 Solutions for the integration between BIM and Green Star

Before the interviewees were asked about the solutions to have BIM and Green Star processes integrated, they strongly indicated the potential of this action. Interviewee 5 stated "as soon as we can link that data, then you can see huge benefits in actually improving certifications, and because the administrative burden was one of the drawbacks of Green Star … this will drastically reduce that."

NZGBC, then, was suggested to be more active in this integration. Instead of using the tradition process with 2D documents, they could "take on the whole digitising their processes, make the processes better, IT savvy and that kind of stuff" (#2). Interviewee 7 suggested that NZGBC could "supply a template to Navisworks because it is clever enough that you can actually pull it off the schedule area." Furthermore, NZGBC should collaborate with other stakeholders to have the integration worked effectively. Interviewee 17 talked about NZGBC and supplier relationships, stating that "NZGBC as an organisation would need to start setting up points within different objects; they would have to work with certain suppliers … However, the collaboration amongst the stakeholders themselves during the projects is also essential." To ensure understanding, "it is very important for the team at some point to have a sort of kick-off and determine what we want to use the BIM model for during our process" (#16). Interviewees 11 and 15 suggested a need for collaboration between NZGBC and the software development company to develop an add-on for BIM that can link the data tightly.

Executing BIM correctly was identified as a significant solution. Because the integration process will require extensive information, "we need to get to a point where the model has so much detail" (#4). However, the level of BIM development in New Zealand is still low. This, therefore, requires considerable efforts amongst stakeholders to have BIM in New Zealand developed with higher LOD and BIM maturity level.

Providing education, training, and showcasing BIM-Green Star benchmark projects were also suggested to mitigate the problem. Interviewee 7 shared that stakeholders need to be "educated and understand what they (BIM & Green Star) are, and how they come together." Besides, "we could prove it to somebody that it works a certain way … a higher profile project might get a lot more attention" (#14).

Making BIM mandatory was interestingly raised as a quick and effective solution. Interviewee 11 believed "mandating is probably going to be the fastest way to get the nation as a whole to have some experience of new things and therefore build up that story that supports its use." This was followed by the interviewee 4's opinion that "if BIM is mandated, and it is a common standard, then you could see it and somehow manage to work with Green Star, there would be a benefit."

Table 3.6 provides a summary of solutions for the integration of BIM and Green Star in New Zealand. Similar to the barriers/challenges to the integration, those who have been working in large companies provided wider solutions to the integration. Integrating the processes of BIM and Green Star was perceived as the most effective solution, followed by executing BIM correctly.

Table 3.6. Solutions for the integration of BIM and Green Star summary

| Green Star & BIM Solutions | No of Response | Construction Type | | | | Company Size | | Experience (Years) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Design | Contractor | Consultancy | Others | Large | SMEs | ≥15 | <15 |
| Integrating the Processes | 09/21 | 3/8 | 1/3 | 4/6 | 1/4 | 08/17 | 1/4 | 4/8 | 05/13 |
| Excecuting BIM correctly | 07/21 | 3/8 | 1/3 | 3/6 | 0/4 | 07/17 | 0/4 | 4/8 | 03/13 |
| Collaborating between Construction Practitioners | 06/21 | 3/8 | 1/3 | 1/6 | 1/4 | 06/17 | 0/4 | 0/8 | 06/13 |
| Providing Education | 05/21 | 4/8 | 0/3 | 0/6 | 1/4 | 03/17 | 2/4 | 3/8 | 02/13 |
| Changing Green Star Submission Requirements | 03/21 | 2/8 | 0/3 | 1/6 | 0/4 | 02/17 | 1/4 | 1/8 | 02/13 |
| Providing Green Star Material Database | 03/21 | 1/8 | 1/3 | 0/6 | 1/4 | 03/17 | 0/4 | 1/8 | 02/13 |
| Providing Benchmark Projects | 03/21 | 1/8 | 1/3 | 1/6 | 0/4 | 02/17 | 1/4 | 1/8 | 02/13 |
| Mandating BIM | 02/21 | 1/8 | 0/3 | 1/6 | 0/4 | 01/17 | 1/4 | 2/8 | 00/13 |

### 3.4.7 Future studies

The research suggests that the focus on Green Star itself and its relationship with BIM are still not fully understood by construction professionals and academia in New Zealand. Possibly, due to geographical isolation and its unique characteristics, it is a challenge to adopt green building practices. For example, although insulated glazing is widespread globally, interviewee 8 mentioned the realistic of the New Zealand buildings that "they (New Zealand) have just discovered double glazing." Therefore, using multiple sources from outside of New Zealand to confirm the validation and reliability of the current practice of Green Star in New Zealand is still inadequate. Furthermore, the data collection in this research was carried out mainly in Auckland which may not be entirely appropriate to reflect the situation in New Zealand. Further research will use the quantitative approach to collect the data from the experienced construction professionals, Green Star practitioners, assessors, and GSAP specifically, in the whole of New Zealand to validate the results of these interviews.

Based on the perspectives of the interviewees regarding the benefits of using BIM to enhance the Green Star certification uptake, understanding the BIM practices and assessing the success of the BIM projects in New Zealand are crucial to the development of BIM and Green Star. Further research will focus on building a framework for BIM assessment providing all the essential criteria and their inter-relationships impacting the implementation of BIM.

## 3.5 Conclusion

This research examined the perspectives of construction professionals in New Zealand towards the Green Star situation and its relationship with BIM adoption. 21 interviews with 25 interviewees were conducted with construction experts for either BIM or Green Star projects. The respondents perceived that the most significant benefits of

Green Star are to the environment and the occupants. Four additional benefits were outlined as benefits to the developers, the owners, raising social conscience to green building, and being a beneficial benchmarking system, see Figure 3.3.

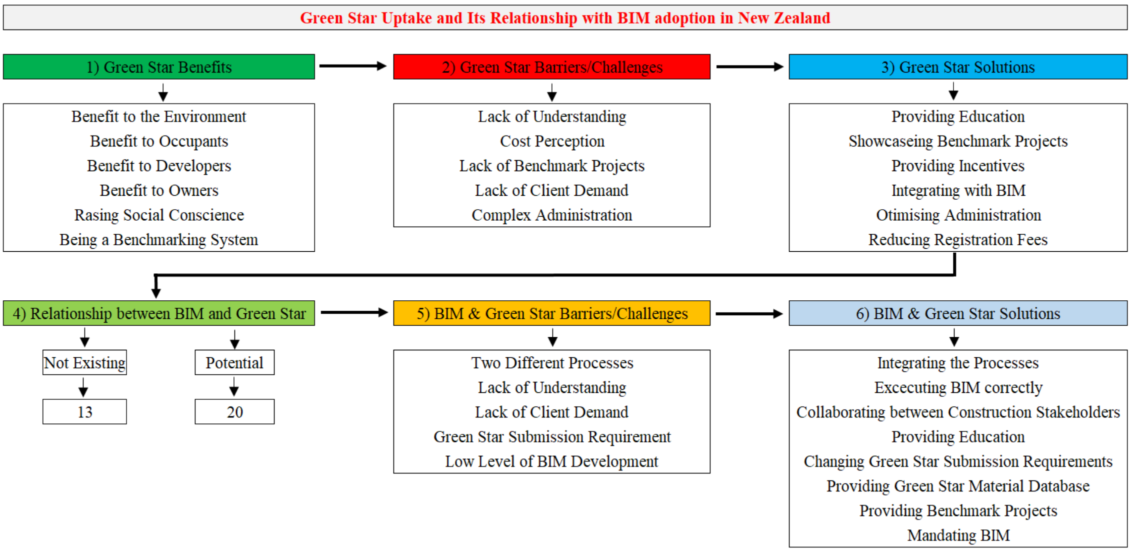



Figure 3.3. Results of Green Star uptake and its relationship with BIM

The significant barriers/challenges to the Green Star certification uptake were identified as lack of understanding, cost perception, lack of benchmark projects, lack of client demand, and complex administration. To mitigate these, six solutions were suggested by the interviewees, providing education was seen as paramount for further Green Star development.

The results indicated that a relationship between BIM and Green Star does not exist currently. However, there is potential for integration when BIM and Green Star are executed appropriately and linked to each other. It is believed that the Green Star process could be more straightforward for all of the relevant project stakeholders combined with an increase to the BIM adoption rate. However, five main barriers/challenges were suggested for the lack of current integration. These were the nature of the separate processes, lack of client demand, inappropriate Green Star submission requirements, low level of BIM development, and lack of both BIM and

Green Star understanding. Integrating BIM process with Green Star process was suggested as the most effective solution for this, followed by executing BIM correctly to achieve higher BIM level and LOD.

In summary, this research has contributed to the existing body of knowledge in two key ways. It is the first research providing valuable insights into the use of Green Star in the context of New Zealand. Also, the potential of taking advantage of using BIM to enhance the uptake of Green Star uptake and vice versa. The results are useful for construction practitioners and academics to understand the current relationship between BIM and Green Star in New Zealand to generate further practices and further studies. Additionally, similar to hundreds of green rating systems established globally, Green Star New Zealand is still in its early stages compared to the development of BREEAM and LEED. Research and results on Green Star New Zealand could offer learning lessons and guidelines for the other green rating systems, which generally fail to attract attention from academia.

# Chapter 4 An Empirical Examination of Green Star Certification Uptake and Its Relationship with BIM Adoption in New Zealand

## 4.1 Prelude

This chapter aims to examine and evaluate the benefits, barriers/challenges, and solutions for Green Star uptake and its relationship with BIM adoption in New Zealand identified in Chapter 3 . Responses collected from construction practitioners in New Zealand using the questionnaire survey were analysed through descriptive and statistical tests. Amongst the seven benefits of Green Star, providing a healthy place for end-users were perceived as the most significant. Whereas, the perception of the cost of investing in the Green Star certification was determined as the topmost barrier beside the other four barriers/challenges. Six solutions were provided to mitigate the barriers/challenges in which all of them were proved as effective ones. Showcasing the benchmark Green Star projects widely was highlighted as the best solution for the current problems. Furthermore, the research confirmed the potential relationship between BIM and Green Star. However, collaborating between construction practitioners to optimise Green Star process should be focused to have BIM and Green Star integrated properly. This chapter provided insights into the current Green Star and BIM practices in which the factors affecting Green Star and BIM and Green Star integration were revealed based on their significance levels. The New Zealand Green Building Council (NZGBC), the government/local authorities, and construction practitioners could use the results as a guideline to have effective strategies towards the sustainable development of New Zealand.

## 4.2 Introduction

The construction industry has been criticised due to its negative impacts causing environmental degradation, carbon emissions, and global warming (Doan et al., 2017; Suzer, 2015). Green building has emerged as a key topic recently in the construction field to mitigate the current problem of the building sector (Doan et al., 2017). Also, hundreds of green rating systems have been developed to reduce the negative impacts of construction projects on the environment (Vierra, 2016). Green Star New Zealand, established by the New Zealand Green Building Council (NZGBC), is one of the internationally-recognised rating systems to promote the sustainability of construction projects (NZGBC, 2019a). However, only over 254 construction projects were certified as Green Star projects during 2007 and 2019, a modest number of Green Star certified projects (NZGBC, 2019c).

One of the reasons explaining the low uptake of Green Star in New Zealand could be a lack of understanding (Doan et al., 2019d). Also, Green Star has not been an attractive topic to the researchers in New Zealand, with very few publications. Amongst three journal articles focusing on Green Star conducted by other researchers, two of them examined the Indoor Environment Quality (IEQ) (Byrd & Rasheed, 2016; Rasheed et al., 2017), a significant category amongst nine categories required for the assessment by NZGBC. Whereas, whether the cost of green buildings is higher than conventional buildings was investigated by Rehm and Ade (2013).

However, there is no research exploring the current practice of Green Star in New Zealand except for Doan et al. (2019d) research. Although benefits, barriers/challenges, and solutions for Green Star uptake were provided by Doan et al. (2019d), a further validation stage is necessary to confirm the results. This is because the snowball sampling method used in Doan et al. (2019d) research could be susceptible to selection bias (Kalton & Graham, 1983; Wheeler, Shanine, Leon, & Whitman, 2014). Furthermore, literature from other green rating systems was used to validate the results from Doan et al. (2019d) research. This could lack slightly accurate context since Green Star could be not completely similar to other green rating systems.

It is noticed that green BIM has caught researchers' attention recently. The integration of BIM and LEED (Leadership in Energy and Environmental Design) is expected to support the designers during the design stage to be more productive (Jalaei & Jrade, 2015). Also, BREEAM (Building Research Establishment Assessment Method)-BIM was researched to produce an automatic sustainability assessment (Ilhan & Yaman, 2016). Therefore, whether BIM can support Green Star uptake in New Zealand was explored by Doan et al. (2019d) and these results need to be validated.

This research aims to validate the results of the Green Star uptake and its relationship with BIM adoption in New Zealand, revealed by Doan et al. (2019d). By examining the perspectives of the construction practitioners in New Zealand, the research could provide insights into Green Star uptake. Findings of the research could be used as a guideline for NZGBC and construction companies in New Zealand to have effective strategies to achieve the potential benefits of Green Star uptake.

## 4.3 Research Methodology

A questionnaire was adopted as the main data collection instrument. Its purpose is to generalise and to promote the confidence of the findings in Doan et al. (2019d) research. In Doan et al. (2019d) research, the qualitative approach, using 21 semi-structured interviews, was adopted to examine the perspectives of construction professionals towards Green Star uptake and its relationship with BIM in New Zealand. Although the qualitative method provides "deep, rich observational data", "the virtues of hard, generalizable survey data" could be generally offered by the quantitative one (Onwuegbuzie & Leech, 2005; Sieber, 1973). In other words, the quantitative method is considered appropriate in this research to add rigour to the qualitative approach used in Doan et al. (2019d) research (Amaratunga et al., 2002; Johnson & Onwuegbuzie, 2004). Construction professionals' perspectives towards Green Star uptake and its relationship with BIM in New Zealand were found out using sequential explanatory design. This mixed-method has "the potential to provide new insights into, and enhanced understanding of phenomena being investigated … providing rich data, lead to new lines of thinking, and by intentionally engaging multiple perspectives and presenting a greater diversity of views" (Krivokapic-Skoko & O'neill, 2011).

### 4.3.1 Questionnaire design

The questionnaire comprised three main sections including demographics, Green Star uptake and BIM and Green Star integration. There are three themes investigated for Green Star uptake. These are the benefits of Green Star certification uptake, the barriers/challenges to Green Star certification uptake, and solutions for Green Star certification uptake. The themes chosen for BIM and Green Star integration were the benefits of Green Star and BIM integration, the barriers/challenges to Green Star and BIM integration, and the solutions for Green Star and BIM integration.

Demographic data collected included the respondents' positions in their companies, their companies' sizes, and their types of companies. It went on to establish their experience in the New Zealand construction industry. It examined the number of

Green Star and BIM projects they have been involved in, and the highest BIM maturity levels and LODs (level of development) in their BIM projects.

Table 4.1 summarises the results in Doan et al. (2019d) research regarding the benefits, barriers/challenges and solutions for Green Star uptake in New Zealand. Six benefits of Green Star are the benefits to the environment, occupants, owners, developers along with raising social conscience to green buildings, and being a great benchmarking system (Doan et al., 2019d). The benefits of Green Star to the developers were divided into two parts in terms of selling price and trademark. Therefore, seven statements were prepared for the questionnaire concerning the benefits of Green Star certification uptake. Also, five barriers/challenges to Green Star certification uptake including the cost perception, understanding, benchmark projects, client demand, and complex administrative process were found out in Doan et al. (2019d) research. As a result, five statements towards the barriers/challenges to Green Star certification uptake were prepared. Regarding the solutions for Green Star certification uptake, six statements towards the education, benchmark projects, incentives, Green Star process, integration between Green Star and BIM, and registration fees, based on the findings of Doan et al. (2019d), were prepared.

Table 4.1. Benefits, barriers/challenges, and solutions for Green Star uptake

| Benefits of Green Star certification uptake | Code |
|---|---|
| The Green Star certified project reduces the environmental impact of the construction industry. | BE1 |
| The Green Star certified project provides a healthy place for end-users. | BE2 |
| The Green Star certified project saves operation costs for end-users. | BE3 |
| The Green Star certified project is generally sold for a higher price compared to the non-certified project. | BE4 |
| The Green Star certification is a marketing tool to attract end-users. | BE5 |
| The Green Star certification raises the social conscience of sustainable construction. | BE6 |
| The Green Star certification is a benchmarking system for the design for better building performance modellings (e.g., energy, lighting). | BE7 |
| **Barriers/challenges to Green Star certification uptake** | **Code** |
| Perception of the cost of investing in the Green Star certification. | BA1 |
| Lack of understanding of the Green Star benefits. | BA2 |
| Lack of benchmark projects which can showcase the benefits of the Green Star certification. | BA3 |
| Lack of client demand for the Green Star certification uptake. | BA4 |
| The complex administration process of the Green Star certification uptake. | BA5 |
| **Solutions for Green Star certification uptake** | **Code** |
| Clients should be educated about the benefits of Green Star certification. | SO1 |
| Benchmark Green Star projects should be showcased widely. | SO2 |
| Incentives (e.g., tax reduction) should be provided for Green Star certified projects. | SO3 |
| The Green Star process should be optimised to simplify the administration of getting Green Star certification. | SO4 |
| Green Star should be integrated with BIM. | SO5 |
| Green Star registration fees should be reduced from the current level. | SO6 |

The benefits, barriers/challenges, and solution for the integration of BIM and Green Star were provided in Table 4.2. Five benefits were revealed in Doan et al. (2019d) research. Any information used to assess the sustainability of the building for Green Star certification uptake could be held within the BIM workflow (Doan et al., 2019d). Also, automatic Green Star assessment and reducing Green Star assessment time were stated as the benefits for the integration. Besides exploring the impacts of BIM on Green Star, Doan et al. (2019d) found out that increasing the Green Star certification uptake can potentially increase the BIM adoption rate.

Table 4.2. Benefits, barriers/challenges, and solutions for Green Star and BIM integration

| Benefits of Green Star and BIM integration | Code |
|---|---|
| Building performance modellings (e.g., energy, lighting) used for Green Star assessment can be implemented using BIM. | BEI1 |
| Building models can incorporate all the information (e.g., Building Users' Guide, Commissioning report) for Green Star assessment of the project. | BEI2 |
| Green Star credits can be integrated with BIM for automatic Green Star assessment. | BEI3 |
| Using BIM for Green Star certification uptake can potentially reduce the assessment time. | BEI4 |
| Green Star certification uptake requires the building performance modellings and related information, which are the aspects of the BIM process. Therefore, increasing the Green Star certification uptake can potentially increase the BIM adoption rate. | BEI5 |
| **Barriers/challenges to Green Star and BIM integration** | **Code** |
| BIM implementation and Green Star certification have two completely separate processes. | BAI1 |
| Lack of client demand for projects that required both BIM and Green Star. | BAI2 |
| The New Zealand Green Building Council requires only 2D documents for the assessment process rather than a full BIM model. | BAI3 |
| BIM maturity level in New Zealand is currently low. | BAI4 |
| LOD in New Zealand is currently low. | BAI5 |
| Lack of understanding on the positive potentials of integrating BIM with Green Star. | BAI6 |
| **Solutions for Green Star and BIM integration** | **Code** |
| Clients and stakeholders should be educated on both BIM implementation and Green Star certification processes. | SOI1 |
| The Green Star certification and BIM implementation processes should be integrated. | SOI2 |
| The New Zealand Green Building Council should change their document requirements to reflect BIM adoption. | SOI3 |
| BIM should be executed properly first (the BIM maturity level and LOD have to be high enough) before the integration with Green Star. | SOI4 |
| Green Building Council should work with construction stakeholders to optimise the Green Star certification process. | SOI5 |
| A Green Star material database should be created for BIM integration. | SOI6 |
| Benchmark projects based on BIM-Green Star integration should be showcased widely. | SOI7 |
| BIM implementation should be mandated in New Zealand for certain types of projects (e.g., public projects). | SOI8 |

Although the five mentioned benefits could be achieved by integrating BIM with Green Star, barriers/challenges to the integration should be considered and addressed. Six main barriers/challenges were revealed including the separate processes, lack of client demand, requirements for Green Star assessment, low BIM maturity level, low LOD, and lack of understanding (Doan et al., 2019d).

After examining the barriers/challenges to the integration of Green Star and BIM, eight potential solutions were provided to mitigate the mentioned barriers/challenges (Doan et al., 2019d). These are regarding the education, implementation processes, documents requirements, BIM execution, collaborations, material database, benchmark projects, and mandating (Doan et al., 2019d).

Except the demographics part, a five-point Likert scale was used in the questionnaire, where 1 = Strongly Disagree; 2 = Slightly Disgaree; 3 = Neutral; 4 = Slightly Agree; 5 = Strongly Agree.

### 4.3.2 Sampling

The criteria used to select the appropriate respondents was based on their experience in the New Zealand construction industry and their experience in either Green Star or BIM projects. The questionnaire was distributed to construction professionals having at least three years' experience in the New Zealand construction industry. Also, participating in at least one Green Star or one BIM project was essential.

Because Green Star and BIM are still in their early stages in New Zealand (Doan et al., 2019d), there may be a limit number of respondents satisfying the mentioned criteria. Therefore, a mixed sampling technique was adopted to increase the number of participants, which is a common technique in quantitative studies (Teddlie & Yu, 2007). Both random sampling and purposive sampling were adopted in this research. The random sampling ensures that "each individual in the population has an equal probability of being selected" (Creswell & Creswell, 2017), which "provides the ability to generalise to a population" (Creswell & Creswell, 2017). Whereas, the purposive sampling ensures the correctness of the data owing to the expertise of the participants (Teddlie & Yu, 2007).

The questionnaire was developed on Qualtrics which was then self-administered via Green Star and BIM groups on LinkedIn. Also, potential respondents were invited to participate in the research using contacts obtained from the NZGBC and the Architectural Designers New Zealand (ADNZ) database.

Before distributing the questionnaire, the pilot testing was conducted by inviting 21 construction professionals to check the research instrument. The purpose of this step is to avoid the misinterpretation of the questions and to check the time taken to complete the questionnaire, wording, layout, and ordering of the questions (Grimm, 2010). The final questionnaire was revised based on their suggestions.

After two months of distributing the questionnaire, 166 construction professionals accessed to the questionnaire link amongst 403 invitations. However, only 85 participants completed the Green Star part in which the statements regarding the benefits, barriers/challenges, and solution for Green Star uptake in New Zealand were answered. Whereas, 77 responses were received for the BIM and Green Star integration part. The response rate for Green Star uptake and Green Star and BIM integration is 21% and 19.1% respectively, considered as a usual rate for the questionnaire (Akintoye, 2000; Oke & Aghimien, 2018).

### 4.3.3 Analysis

The questionnaire data was analysed using both descriptive and statistical tests with the aid of the Statistical Package for the Social Sciences (SPSS) version 24. The one-sample *t*-test was adopted to determine the significance of the statements. Specifically, the test aims to reject the null hypothesis that the means of the benefits, barriers/challenges, and solutions for Green Star and BIM and Green Star integration are not significantly different from the test value with $p$-value < 0.05. With the five-point Likert scale, the test value of 3.0 is considered appropriate for the one-sample *t*-test (B.-G. Hwang, Zhao, & Toh, 2014; Kavishe, Jefferson, & Chileshe, 2018). Whereas, Owusu-Manu et al. (2018) and Manu et al. (2018) suggested testing the mean score with the test value of 3.5 in the five-point Likert scale. Consequently, the one-sample *t*-test was conducted in 2 rounds, with the test values of 3.5 and 3.0.

Although no minimum sample size is required for the one-sample *t*-test (Kavishe et al., 2018), a comparison with other studies regarding the sample size was also carried out. The sample sizes in this research are appropriate compared to 45 of Robert, Dansoh, and Ofori–Kuragu (2014), 34 of Cheung, Chan, Lam, Chan, and Ke (2012), and 28 of Kavishe et al. (2018) research.

To ensure the correctness of the results, the normal distribution of the data was checked before going through the one-sample *t*-test (Ross & Willson, 2018). According to Field (2013), the normality of the data could be spotted by calculating the values of skewness and kurtosis. All the statements have the values of skewness within the range ±2 and ±3 for the values of kurtosis proving the normality of the data (Griffin & Steinbrecher, 2013; Schneider & Wheeler-Kingshott, 2014).

## 4.4 Results and Discussions

Before conducting further analysis, Cronbach's Alpha test was carried out to evaluate the reliability and internal consistency of the collected data. 0.7 was considered as the cut off point for the test by most of the studies (Kavishe et al., 2018; Owusu-Manu et al., 2018). The results for the test in this research are 0.771 for Green Star uptake and 0.84 for BIM and Green Star integration respectively, implying that the data is reliable for further analysis.

### 4.4.1 Demographic information

The criteria for selecting the respondents were checked to eliminate inappropriate cases. Firstly, the number of Green Star and the number of BIM projects were examined to remove the cases in which the construction professionals have not been involved in any BIM and Green Star projects. Eight cases were removed for Green Star part which is the same for BIM and Green Star integration part. Secondly, less than three year's experience in the New Zealand construction industry was checked to ensure that the respondents have perceived certain knowledge in the industry. One case was removed when the respondent only has one year's experience for both Green Star part and BIM and Green Star integration part. It is noticed that four cases in Green Star part have two years' experience, but they were accepted for the analysis. This is because they proved their experience in this topic with the number of Green Star projects they have been involved in.

Table 4.3 shows the characteristics of the respondents participating in this research. Three is the average number of Green Star projects those respondents involved in while thirteen is the average number of BIM projects. Green Star Accredited Professionals (GSAP) account for the significant percentage of the respondents with around 26%, followed by architects and mechanical, electrical, and plumbing (MEP) engineers with 15% and 14% respectively. It is noted that a respondent can hold multiple positions at the same time. For example, one respondent is an MEP engineer, a Green Star assessor, and a GSAP while another respondent is a BIM manager, an architect, and a GSAP. Furthermore, Table 4.3 shows the number of respondents working in small and medium-sized enterprises (SMEs) and large companies. SMEs are those who have less than 20 employees, defined by the New Zealand Ministries (MBIE, 2017; MED, 2011).

Table 4.3. Respondents' demographics in Green Star uptake section

| Respondent Role | Frequency (%) |
|---|---|
| GSAP | 31 (26.05%) |
| Green Star Assessor | 02 (01.68%) |
| Architect | 18 (15.13%) |
| MEP Engineer | 17 (14.29%) |
| Contractor | 08 (06.72%) |
| BIM Manager | 07 (05.88%) |
| Quantity Surveyor | 07 (05.88%) |
| Project Manager | 05 (04.20%) |
| Structural Engineer | 04 (03.36%) |
| Client | 03 (02.52%) |
| Others | 17 (14.29%) |
| Company Size | Frequency (%) |
| SME | 21 (27.63%) |
| Large company | 55 (72.37%) |
| Experience | 02-13-46* |
| No of Green Star projects | 00-03-35*(50**) |
| No of BIM projects | 00-13-100*(68**) |

*Min-Average-Max
**Number of respondents involving in Green Star/BIM projects

The average experience of the respondents for BIM and Green Star integration section is fourteen years, see Table 4.4. Three and thirteen are the average numbers of Green Star and BIM projects they have been involved in respectively. Almost all of the respondents have been involved in BIM projects while over three-quarters of the respondents have practical experience in Green Star. For those who have been involved in BIM projects, BIM level 2 and LOD 300 are considered as the average BIM maturity level and LOD in New Zealand, with almost a third of the respondents.

Table 4.4. Respondents' demographics in BIM and Green Star integration section

| Respondent Role | Frequency (%) |
|---|---|
| GSAP | 29 (26.85%) |
| Green Star Assessor | 02 (01.85%) |
| Architect | 17 (15.74%) |
| MEP Engineer | 16 (14.81%) |
| BIM Manager | 07 (06.48%) |
| Quantity Surveyor | 06 (05.56%) |
| Contractor | 05 (04.63%) |
| Project Manager | 05 (04.63%) |
| Structural Engineer | 04 (03.70%) |
| Client | 03 (02.78%) |
| Others | 14 (12.96%) |
| Company Size | Frequency (%) |
| SME | 18 (26.47%) |
| Large company | 50 (73.53%) |
| Experience | 03-14-50* |
| No of Green Star projects | 00-03-35*(52**) |
| No of BIM projects | 00-13-100*(65**) |
| BIM maturity levels | Frequency (%) |
| Level 1 | 05 (07.69%) |
| Level 2 | 20 (30.77%) |
| Level 3 | 07 (10.77%) |
| Unsure | 33 (50.77%) |
| LODs | Frequency (%) |
| 200 | 03 (04.62%) |
| 300 | 19 (29.23%) |
| 350 | 15 (23.08%) |
| 400 | 05 (07.69%) |
| 500 | 04 (06.15%) |
| Unsure | 19 (29.23%) |

*Min-Average-Max
**Number of respondents involving in Green Star/BIM projects

Over a quarter of the respondents are GSAP while two Green Star assessors also participated in the survey. Architects and MEP engineers have similar figures regarding the percentage of the respondents, around 15%. Whereas, the figures for BIM managers, quantity surveyors, contractors, project managers, structural engineers, and clients are not much different from each other ranging from 2.78% to 6.48%.

Almost three-quarters of the respondents are working in large companies, but there are still a higher number of respondents working in SMEs, with 18 cases. From the demographic information shown in Table 4.3 and Table 4.4, it is reasonable to conclude that the respondents' knowledge is suitable for enhancing the reliability and validity of the research results.

### 4.4.2 Green Star uptake

#### Benefits of Green Star certification uptake

The data of seven statements towards the benefits of Green Star certification uptake were analysed using the one-sample *t*-test. It is clear from Table 4.5 that BE2 was perceived as the most important benefit of Green Star, followed by BE1. They have the highest mean scores compared to the rest, which was then used to rank the benefits of Green Star. BE7 and BE5 have similar scores, which were ranked 3rd and 4th. While 5th and 6th places belong to BE3 and BE6 respectively with almost identical scores. BE4 is the only benefit receiving the mean score close to 4, 3.96.

Table 4.5. One-sample *t*-test results of the benefits of Green Star certification uptake

| | | | | | One-sample *t*-test (test value =3.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% confidence interval of the difference | |
| Benefit | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BE1 | 4.26 | 0.839 | 0.096 | 2 | 7.934 | 75 | 0.000 | 0.763 | 0.57 | 0.95 |
| BE2 | 4.38 | 0.711 | 0.082 | 1 | 10.806 | 75 | 0.000 | 0.882 | 0.72 | 1.04 |
| BE3 | 4.09 | 0.897 | 0.103 | 5 | 5.754 | 75 | 0.000 | 0.592 | 0.39 | 0.8 |
| BE4 | 3.96 | 0.871 | 0.100 | 7 | 4.610 | 75 | 0.000 | 0.461 | 0.26 | 0.66 |
| BE5 | 4.13 | 0.806 | 0.092 | 4 | 6.834 | 75 | 0.000 | 0.632 | 0.45 | 0.82 |
| BE6 | 4.08 | 0.744 | 0.744 | 6 | 6.783 | 75 | 0.000 | 0.579 | 0.41 | 0.75 |
| BE7 | 4.16 | 0.880 | 0.101 | 3 | 6.516 | 75 | 0.000 | 0.658 | 0.46 | 0.86 |

All of the standard deviation (SD) values of seven statements are less than 1 indicating a high consistency in agreement amongst respondents' perspectives. Furthermore, all values of the standard error (SE) mean close to 0 enhancing the reliability and validity of the results. In other words, the mean of the sample is sufficiently precise to the true mean of the population. Also, all the *t*-values are positive, and *p*-values are significant indicating that the means of seven statements are significantly higher than the test value of 3.5. In other words, seven benefits of Green Star certification uptake are all important.

The findings align with existing literature. A. King (2017) stated that green-certified buildings could provide sustainable and a healthy place for building occupants. Furthermore, green rating systems have been used as benchmarking systems for the design. Specifically, LEED has been used in the US to "provide a benchmarking system to assess levels of sustainability achieved by a building" (Krishnamurti, Biswas, & Wang, 2010). Whereas, Green Star (Australia) has been adopted as a benchmarking system to measure the energy efficiency of a project (Ng, Chen, & Wong, 2013).

The benefit of green rating systems as a marketing tool to attract end-users was also mentioned in the literature. Fuerst and McAllister (2011) revealed that one of the benefits of LEED is a marketing benefit. Whereas, Byrd and Leardini (2011) highlighted the benefit of LEED is "for commercial marketing and promotion rather than for significant environmental concerns." This was also confirmed by Morris, Zuo, Wang, and Wang (2018) that the potential of using Green Star (Australia) as a marketing tool was the most perceived benefit by construction professionals. Furthermore, saving operation costs were found out by Kansal and Kadambari (2010). Zuo and Zhao (2014) and Ying Liu, Pheng Low, and He (2012) also implied the low operating cost of green buildings.

Regarding the 6$^{th}$ ranking benefit of Green Star, it was confirmed by Kato, Too, and Rask (2009). Kato et al. (2009) revealed that Green Star (Australia) certified buildings encourage tenants to participate in sustainable events, inspire them to monitor energy and water use, and inspire the staff to be "green people." Higher selling price of Green Star certified projects compared to the non-certified projects is the only benefit having the mean score less than 4. Whether a green building has a higher selling price compared to a conventional building is an interesting topic which has been studied by many researchers. Zhang, Wu, and Liu (2018) summarised 18 studies towards the green price premium. Although the results of some studies indicated that the green price premium is positive, others concluded that it is not statistically significant. Consequently, the green price premium is still a controversial topic. This is consistent with the results of BE4 having the lowest rank compared to the rest.

### Barriers/challenges to Green Star certification uptake

Table 4.6 shows the one-sample *t*-test results of the barriers/challenges to Green Star certification uptake. BA1 and BA4 are the two most significant barriers/challenges to Green Star certification uptake, with the mean scores of 4.36 and 4.29 respectively. The results for BA2 and BA5 are similar with 3.97 and 3.91 mean scores. BA3 is the only barrier having the mean score less than 3.5.

Table 4.6. One-sample *t*-test results of the barriers/challenges to Green Star certification uptake

| First Round | | | | | One-sample *t*-test (test value =3.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% confidence interval of the difference | |
| Barrier | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BA1 | 4.36 | 0.605 | 0.069 | 1 | 12.334 | 75 | 0.000 | 0.855 | 0.72 | 0.99 |
| BA2 | 3.97 | 0.952 | 0.109 | 3 | 4.339 | 75 | 0.000 | 0.474 | 0.26 | 0.69 |
| BA3 | 3.37 | 1.220 | 0.140 | 5 | -0.940 | 75 | 0.350 | -0.132 | -0.41 | 0.15 |
| BA4 | 4.29 | 0.861 | 0.099 | 2 | 7.991 | 75 | 0.000 | 0.789 | 0.59 | 0.99 |
| BA5 | 3.91 | 1.022 | 0.117 | 4 | 3.479 | 75 | 0.001 | 0.408 | 0.17 | 0.64 |
| Second Round | | | | | One-sample *t*-test (test value =3.0) | | | | | |
| | | | | | | | | | 95% confidence interval of the difference | |
| Barrier | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BA3 | 3.37 | 1.220 | 0.140 | 1 | 2.632 | 75 | 0.010 | 0.368 | 0.09 | 0.65 |

Although the SD values of the barriers/challenges are higher than those of the benefits, the values are less than 2 indicating that the perspectives of the participants are consistent with each other (LabCE, 2019). Whereas, the SE mean values close to 0 promoting the reliability and validity of the data. Except for BA3, all the *t*-values of barriers/challenges to Green Star certification uptake are positive with significant *p*-values to the test value of 3.5. This proves that those barriers/challenges are significant towards Green Star certification uptake. BA3 was then checked with the test value of 3.0 in the second round as B.-G. Hwang et al. (2014), and Kavishe et al. (2018) stated that 3.0 is still the appropriate test value to examine the significance of the barrier. The results in the second round show that BA3 is still a significant barrier/challenge to Green Star certification uptake with positive *t*-value and significant *p*-value to the test value of 3.0.

The results are consistent with the existing literature. Cost is the most significant barrier to Green Star (Australia) (Morris et al., 2018), and to green buildings in the US (Ahn, Pearce, Wang, & Wang, 2013), and in China (P. T. Lam, Chan, Chau, Poon, & Chun, 2009). Regarding lack of client demand, it was determined as one of the most significant barriers to green buildings in Singapore (B. G. Hwang & Tan, 2012) and Malaysia (Samari, Ghodrati, Esmaeilifar, Olfat, & Shafiei, 2013).

Lack of understanding was ranked first and a foremost barrier to green buildings in Kuwait (AlSanad, 2015) and second in the US (Darko, Chan, Ameyaw, He, & Olanipekun, 2017). It is also a common barrier to green buildings in various countries such as in England (Williams & Dair, 2007), Malaysia (Samari et al., 2013), and Singapore (B. G. Hwang & Tan, 2012). Besides, the complexity of the process was considered as one of the three most significant barriers to Green Star (Australia) (Morris et al., 2018). It was also determined as a barrier by Darko et al. (2017). Furthermore, lack of benchmark projects was identified as a barrier to green buildings by Ayarkwa, Acheampong, Wiafe, and Boateng (2017) and Samari et al. (2013). It, however, was ranked in a lower group of the barriers/challenges to green buildings, which is similar to the results of this research

### Solutions for Green Star certification uptake

Table 4.7 shows the results of the one-sample *t*-test for the solutions for Green Star certification uptake. Interestingly, SO2 was perceived as the most effective solution even though it has the lowest rank in the barriers/challenges to Green Star certification uptake in the previous section. SO1 and SO3 have the same mean score, 4.34. However, the SD value of SO1 less than the one of SO3; they were ranked 2$^{nd}$ and

3rd respectively. The 4th place belongs to SO4. SO6 and SO5 are two solutions having the mean scores less than 4.

Table 4.7. One-sample *t*-test results of the solutions for Green Star certification uptake

| First Round | | | | | | | One-sample *t*-test (test value =3.5) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% confidence interval of the difference | |
| Solution | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| SO1 | 4.34 | 0.644 | 0.074 | 2 | 11.400 | 75 | 0.000 | 0.842 | 0.69 | 0.99 |
| SO2 | 4.47 | 0.642 | 0.074 | 1 | 13.214 | 75 | 0.000 | 0.974 | 0.83 | 1.12 |
| SO3 | 4.34 | 0.946 | 0.109 | 3 | 7.761 | 75 | 0.000 | 0.842 | 0.63 | 1.06 |
| SO4 | 4.21 | 0.957 | 0.110 | 4 | 6.475 | 75 | 0.000 | 0.711 | 0.49 | 0.93 |
| SO5 | 3.45 | 1.063 | 0.122 | 6 | -0.432 | 75 | 0.667 | -0.053 | -0.30 | 0.19 |
| SO6 | 3.53 | 1.013 | 0.116 | 5 | 0.226 | 75 | 0.821 | 0.026 | -0.21 | 0.26 |
| Second Round | | | | | | | One-sample *t*-test (test value =3.0) | | | |
| | | | | | | | | | 95% confidence interval of the difference | |
| Solution | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| SO5 | 3.45 | 1.063 | 0.122 | 2 | 3.668 | 75 | 0.000 | 0.447 | 0.20 | 0.69 |
| SO6 | 3.53 | 1.013 | 0.116 | 1 | 4.530 | 75 | 0.000 | 0.526 | 0.29 | 0.76 |

All the SD values close to 1 and the SE mean values close to 0 implying the reliability and validity of the data. SO5 is the only solution having a negative *t*-value while the *p*-value of SO6 is not significant. They were then analysed in the second round with the test value of 3.0 to consider their significance as the solutions for Green Star development. In other words, the other four solutions are considered effective and should be followed to improve the number of Green Star certified projects. The results of SO5 and SO6 in the second round shows that they have positives *t*-values with significant *p*-values suggesting the positive impacts of these two solutions on Green Star certification uptake.

SO1, SO2, SO3 were not only considered as the most effective solutions for Green Star development in New Zealand, but also they were found out to have significant impacts on sustainable construction in the US (Darko et al., 2017), Singapore (B. G. Hwang &

Tan, 2012), and Ghana (Ayarkwa et al., 2017). SO4 was also mentioned in Singapore (B. G. Hwang & Tan, 2012) and Ghana contexts (Ayarkwa et al., 2017).

SO5 and SO6 were seen as the two less effective solutions compared to the rest in this research, with 6th and 5th ranks. This is reasonable because SO6 was only mentioned in Ayarkwa et al. (2017), one of three recent studies suggesting solutions for green rating systems, including Ayarkwa et al. (2017), Darko et al. (2017), and B. G. Hwang and Tan (2012), while SO6 was not mentioned at all in those three studies. However, Y. Lu, Wu, Chang, and Li (2017) summarised the results of 10 studies in green BIM topic proving the potential of using BIM to support green building assessments.

The management efficiency and success rate of applications could be increased while the cost for green building registration could be reduced with the implementation of BIM (Y. Lu et al., 2017). Y. Lu et al. (2017) stated that 75% of elective credits in LEED-NC 2009 could be assessed using BIM. GhaffarianHoseini, Tien Doan, et al. (2017) also found out the relationship between BIM and Green Star and indicated the potential of integrating Green Star with BIM for their further development. Why integrating Green Star with BIM was not a common solution was mentioned by Y. Lu et al. (2017) after reviewing 400 studies on this topic. “Low industrial acceptance of green BIM applications despite a large number of BIM studies have been conducted” was considered as a gap by Y. Lu et al. (2017). This aligns with Doan et al. (2019d) results. Although integrating Green Star with BIM could accelerate the Green Star uptake and BIM adoption rate, the relationship between them does not exist in the current practices in New Zealand (Doan et al., 2019d). In other words, integrating Green Star with BIM should be examined carefully by both construction professionals and NZGBC staff to have effective strategies for Green Star development.

### 4.4.3 BIM and Green Star integration uptake

#### Benefits of BIM and Green Star integration

The results of the one-sample *t*-test for the benefits of Green Star and BIM integration are shown in Table 4.8. BEI1 and BEI2 are two benefits having the highest mean scores, 3.93 and 3.79 respectively, which were ranked 1st and 2nd. BEI4 has the mean score just over 3.5, holding the 3rd place, while both BEI3 and BEI5 have the mean scores below

3.5, ranked 4th and 5th. All the values of SD of five benefits are less than 1 while the values of SE mean close to 0 indicating the reliability and validity of the data collected.

Table 4.8. One-sample *t*-test results of the benefits of Green Star and BIM integration

| First Round | | | | | One-sample *t*-test (test value =3.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% confidence interval of the difference | |
| Benefit | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BEI1 | 3.93 | 0.982 | 0.119 | 1 | 3.581 | 67 | 0.001 | 0.426 | 0.19 | 0.66 |
| BEI2 | 3.79 | 0.986 | 0.120 | 2 | 2.460 | 67 | 0.015 | 0.294 | 0.06 | 0.53 |
| BEI3 | 3.46 | 0.921 | 0.112 | 4 | -0.395 | 67 | 0.694 | -0.044 | -0.27 | 0.18 |
| BEI4 | 3.54 | 0.984 | 0.119 | 3 | 0.370 | 67 | 0.713 | 0.044 | -0.19 | 0.28 |
| BEI5 | 3.34 | 0.956 | 0.116 | 5 | -1.395 | 67 | 0.167 | -0.162 | -0.39 | 0.07 |
| Second Round | | | | | One-sample *t*-test (test value =3.0) | | | | | |
| | | | | | | | | | 95% confidence interval of the difference | |
| Benefit | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BEI3 | 3.46 | 0.921 | 0.112 | 2 | 4.080 | 67 | 0.000 | 0.456 | 0.23 | 0.68 |
| BEI4 | 3.54 | 0.984 | 0.119 | 1 | 4.560 | 67 | 0.000 | 0.544 | 0.31 | 0.78 |
| BEI5 | 3.34 | 0.956 | 0.116 | 3 | 2.918 | 67 | 0.005 | 0.338 | 0.11 | 0.57 |

It is clear from Table 4.8 that BEI1 and BEI2 are the two most perceived benefits from the respondents, with positive *t*-values and *p*-values < 0.05. Although BEI4 has the *t*-value > 0, its *p*-value = 0.713 > 0.05. Because the mean values of BEI3 and BEI5 are less than 3.5, they have negative *t*-values when the one-sample *t*-test was conducted with the test value equal to 3.5. As a result, BEI3-5 were analysed in the second round with the test value 3.0 to consider the importance of these three benefits.

The results in the second round indicate the importance of BEI3-5 to the test value of 3.0 with positive *t*-values and all *p*-values > 0.05. In conclusion, all the five mentioned benefits in Doan et al. (2019d) research were well-perceived from the respondents. It is noted that the benefits of using BIM for Green Star certification uptake were more recognised compared to the opposite way. BEI5, the benefit of using Green Star for increasing BIM adoption rate, has the lowest rank compared to the benefits of using BIM for Green Star certification uptake including BEI 1-4.

The implementation of BIM for green rating systems certification uptake were mentioned in previous studies. Motawa and Carter (2013) suggested the use of BIM for energy analysis for passing the performance criteria of LEED or BREEAM. Half of the Energy and Atmosphere credits in LEED could be utilised with the BIM application (W. Wu & Issa, 2014). Azhar, Brown, and Farooqui (2009) mentioned the BIM application on LEED Daylight credit. Azhar and Brown (2009) revealed that LEED documentation was prepared as part of the BIM-based performance analyses by half of the construction professionals working in the US. According to Gandhi and Jupp (2014), 88% of Green Star (Australia) points could be achieved by implementing BIM. Whereas, GhaffarianHoseini, Tien Doan, et al. (2017) stated that BIM utilisation could assist to obtain 75% of the Green Star criteria. This is consistent with the results of this research where BEI1 and BEI2 were ranked as the highest benefits regarding the integration of Green Star and BIM.

Credits of green rating systems could be integrated with BIM for automatic assessment, which was mentioned in the current literature. A method which can partially automate the process of LEED and BIM was suggested by Jalaei and Jrade (2014). LEED was also focused by T. Nguyen, Toroghi, and Jacobs (2015) with the assistance of BIM to produce an automatical LEED score report. Whereas, Y. Chen and Hsieh (2013) developed a BIM-assisted rule-based approach to examine the green building design automatically. As a result, Green Star credits are potentially integrated with BIM for automatic Green Star assessment, leading to the reduction on the assessment time. Park, Park, Kim, and Kim (2012) stated that BIM implementation could increase the speed and accuracy of the energy assessment.

Regarding BEI5, it is the new finding of the research focusing on the opposite way in which the Green Star certification uptake could affect the BIM adoption rate. Two-thirds of 21 interviewees in Doan et al. (2019d) research pointed out the impact of Green Star on BIM, which was then proved as a significant benefit of the integration by the respondents participating in the questionnaire in this research.

### Barriers/challenges to BIM and Green Star integration

The results of the one-sample *t*-test of the barriers/challenges to Green Star and BIM integration are shown in Table 4.9. Interestingly, BAI1 and BAI4 have the same mean score, 4.06. However, the SD value of BAI1 is less than the one of BAI4; BAI1 was then ranked 1$^{st}$ as the most significant barrier/challenge to Green Star and BIM integration. BAI6 holds the 3$^{rd}$ place with a similar mean score, 4.04. The 4$^{th}$ place belongs to BAI2 with the mean score of 3.87 while BAI3 and BAI5 share the lowest ranks with the mean scores of 3.72 and 3.63 respectively. All the SD values close to 1 along with the SE means close to 0 prove the reliability and validity of the collected data.

Table 4.9. One-sample *t*-test results of the barriers/challenges to Green Star and BIM integration

| First Round | | | | | One-sample *t*-test (test value =3.5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% confidence interval of the difference | |
| Barrier | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BAI1 | 4.06 | 0.808 | 0.098 | 1 | 5.702 | 67 | 0.000 | 0.559 | 0.36 | 0.75 |
| BAI2 | 3.87 | 1.006 | 0.122 | 4 | 3.014 | 67 | 0.004 | 0.368 | 0.12 | 0.61 |
| BAI3 | 3.72 | 0.975 | 0.118 | 5 | 1.866 | 67 | 0.066 | 0.221 | -0.02 | 0.46 |
| BAI4 | 4.06 | 0.976 | 0.118 | 2 | 4.724 | 67 | 0.000 | 0.559 | 0.32 | 0.79 |
| BAI5 | 3.63 | 1.091 | 0.132 | 6 | 1.000 | 67 | 0.321 | 0.132 | -0.13 | 0.40 |
| BAI6 | 4.04 | 0.836 | 0.101 | 3 | 5.365 | 67 | 0.000 | 0.544 | 0.34 | 0.75 |
| Second Round | | | | | One-sample *t*-test (test value =3.0) | | | | | |
| | | | | | | | | | 95% confidence interval of the difference | |
| Barrier | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| BAI3 | 3.72 | 0.975 | 0.118 | 1 | 6.095 | 67 | 0.000 | 0.721 | 0.48 | 0.96 |
| BAI5 | 3.63 | 1.091 | 0.132 | 2 | 4.778 | 67 | 0.000 | 0.632 | 0.37 | 0.90 |

All the *t*-values for six barriers are positive, but the *p*-values for BAI3 and BAI5 are not statistically significant, *p*-values > 0.05. Therefore, BAI3 and BAI5 were analysed with the test value of 3.0 in the second round to check their significance. The results indicate the significance of the BAI3 and BAI5 with positive *t*-values and *p*-values < 0.05. In conclusion, Green Star and BIM have completely separate processes, BAI1, is the most significant barrier. Whereas, low LOD in BIM adoption, BAI5, has the lowest rank regarding the barriers/challenges to Green Star and BIM integration compared to five other barriers/challenges.

It is understandable when BAI1 is considered as the most significant barrier. Several studies have been conducted to examine the feasibility of the integration of green rating systems and BIM. Siddiqui et al. (2009) provided insights into the integration of sustainable design solutions and BIM for better sustainable project delivery processes. Whereas, J. K.-W. Wong and Kuan (2014) tried offering a solution to streamline the BEAM Plus process to have it integrated with BIM. However, Azhar et al. (2011) concluded that “no one-to-one relationship exists between LEED certification process and BIM-based sustainability analyses” currently even though the potential of the integration was demonstrated. Therefore, combining Green Star and BIM processes should be researched to mitigate the existing problem.

According to the BIM maturity levels suggested by Bew and Richards (2008) and adapted by Doan et al. (2019c), BIM can only be linked to sustainability once it reaches level 3 or 6D BIM. In other words, high BIM maturity level and high LOD are the prerequisite requirements for the integration. However, the UK, one of BIM pioneers in the world, just mandated BIM level 2 in 2016 (CO, 2011). Therefore, it is appropriate when low BIM maturity level and LOD were perceived by the respondents in New Zealand. It is also clear from Table 4.4 that the majority of the construction practitioners in New Zealand are still in BIM level 2 and LOD 300 as the highest BIM maturity level and LOD they achieved.

Lack of BIM understanding was pointed out as a significant barrier to BIM adoption in New Zealand (Doan et al., 2019c) while lack of Green Star understanding was determined as a considerable barrier to Green Star uptake in New Zealand (Doan et al., 2019d). Therefore, the barrier of lack of understanding of the positive potentials of integrating BIM with Green Star is understandable. In the same vein, lack of client demand for either BIM projects or Green Star projects were identified by Doan et al.

(2019c) and Doan et al. (2019d). As a result, the lack of client demand for projects that required both BIM and Green Star is reasonable.

Regarding the BAI3, all the requirements for the Green Star assessment could be found out using Green Star Technical Manual v3.1 (NZGBC, 2016). According to the manual, most of the credits could be assessed using short reports and drawings instead of modellings (NZGBC, 2016). Therefore, the Green Star certification seekers are not encouraged to use BIM to bring benefits for both NZGBC and themselves.

### Solutions for BIM and Green Star integration

Table 4.10 shows the results of the one-sample *t*-test for the solutions for Green Star and BIM integration in New Zealand. SO5 is considered as the best solution with the highest mean score, 4.28, followed by SO7 with the mean score of 4.26. SO6 and SO7 are the two solutions left with the mean scores higher than 4.0, 4.16 and 4.10 respectively. SO4 and SO8 share similar mean scores, 3.79 and 3.78. The 7$^{th}$ place belongs to SO3 with 3.40 mean score while SO2 holds the lowest rank with 3.35 mean score. The values for SD and SE mean of all eight solutions close to 1 and 0 respectively implying the reliability and validity of the collected data.

Table 4.10. One-sample *t*-test results of the solutions for Green Star and BIM integration

| First Round | | | | | | | | One-sample *t*-test (test value =3.5) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% confidence interval of the difference | |
| Solution | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| SOI1 | 4.10 | 0.794 | 0.096 | 4 | 6.259 | 67 | 0.000 | 0.603 | 0.41 | 0.80 |
| SOI2 | 3.35 | 1.062 | 0.129 | 8 | -1.142 | 67 | 0.257 | -0.147 | -0.40 | 0.11 |
| SOI3 | 3.40 | 1.174 | 0.142 | 7 | -0.712 | 67 | 0.472 | -0.103 | -0.69 | 0.18 |
| SOI4 | 3.79 | 1.001 | 0.121 | 5 | 2.423 | 67 | 0.018 | 0.294 | 0.05 | 0.54 |
| SOI5 | 4.28 | 0.688 | 0.083 | 1 | 9.345 | 67 | 0.000 | 0.779 | 0.61 | 0.95 |
| SOI6 | 4.16 | 0.745 | 0.090 | 3 | 7.322 | 67 | 0.000 | 0.662 | 0.48 | 0.84 |
| SOI7 | 4.26 | 0.785 | 0.095 | 2 | 8.038 | 67 | 0.000 | 0.765 | 0.57 | 0.95 |
| SOI8 | 3.78 | 1.091 | 0.132 | 6 | 2.113 | 67 | 0.038 | 0.279 | 0.02 | 0.54 |
| Second Round | | | | | | | | One-sample *t*-test (test value =3.0) | | |
| | | | | | | | | | 95% confidence interval of the difference | |
| Solution | Mean | SD | SE Mean | Rank | *t* | *df* | Sig. (2-tailed) | Mean diff. | Lower | Upper |
| SOI2 | 3.35 | 1.062 | 0.129 | 2 | 2.741 | 67 | 0.008 | 0.353 | 0.10 | 0.61 |
| SOI3 | 3.40 | 1.174 | 0.142 | 1 | 2.790 | 67 | 0.007 | 0.397 | 0.11 | 0.68 |

Except for SO2 and SO3, all the solutions have positive *t*-values and *p*-values < 0.05 indicating the effectiveness of the mentioned solutions. After analysing SO2 and SO3 with the test value of 3.0 in the second round of the one-sample *t*-test, the results indicate the significance of the solutions SO2 and SO3 with *t*-values > 2 and *p*-values < 0.05.

Optimising the Green Star process with the help from construction stakeholders in the industry, SOI5, was perceived as the most optimal solution for Green Star and BIM integration. This is appropriate due to the current complex administration process of Green Star pointed out in Doan et al. (2019d) research, which may suffer the integration. Besides, the requirements for Green Star assessment should be adjusted to have them linked to BIM adoption, SOI3, and integrating Green Star and BIM processes, SOI2, can provide positive impacts on the integration. Although the majority of credits of green rating systems could be achieved potentially with the assist of BIM, the results of the integration shown in previous research are still limited. Only 26 BEAM plus credits amongst a total of 80 credits could be achieved with BIM implementation in J. K.-W. Wong and Kuan (2014) research while only 5 LEED credits were examined with the use of BIM in Azhar et al. (2011) research. J. K.-W. Wong and Kuan (2014) indicated the need for a standardised process of the integration of green rating systems and BIM.

Creating a Green Star material database was found out as one of the best solutions for the integration which was also suggested by Seghier, Ahmad, Wah, and Samuel (2018) when green BIM papers, focusing mainly on LEED and BREEAM, were reviewed. Providing education, SOI1, and showcasing benchmark projects, SOI7, were suggested as solutions for BIM adoption (Doan et al., 2019c) and Green Star certification uptake in New Zealand (Doan et al., 2019d). There is no exception for suggested solutions for Green Star and BIM integration; SOI7 is considered as the second most effective solution while the score for SOI1 is not far behind.

As found out in the barriers/challenges to Green Star and BIM integration section that the BIM maturity level and LOD of BIM adoption in New Zealand still need to be higher for better Green Star and BIM integration, suggested by Bew and Richards (2008) and Doan et al. (2019c). Therefore, executing BIM properly first is one of the prerequisite factors that should be focused, SOI4. Mandating BIM, SOI8, was revealed as an effective solution for the integration, which was also mentioned by W. Wu and Issa (2014) and Dummenahally and Glema (2016).

## 4.5 Conclusion and Recommendations

This research evaluated the significance of the results revealed by Doan et al. (2019d) regarding Green Star uptake and its relationship with BIM adoption in New Zealand. Specifically, seven benefits, five barriers/challenges, and six solutions for Green Star uptake along with five benefits, six barriers/challenges, and eight solutions for BIM and Green Star integration were examined. The results indicate that all the findings revealed by Doan et al. (2019d) are correct in which all the statements are significant to the test value 3.0 through the one-sample *t*-test.

Figure 4.1 summarises the results of this research. All the benefits, barriers/challenges, and solution were ranked based on their significance. Regarding Green Star uptake, providing a healthy place for end-users, reducing the environmental impact of the construction industry, and being a benchmarking system are the three most benefits perceived by the respondents. Amongst highly ranked barriers/challenges to Green Star certification uptake, perception to cost, lack of client demand, and lack of understanding were the topmost barriers. While the top-ranked solutions belong to showcasing the benchmark Green Star projects, educating clients on Green Star benefits, and providing incentives for Green Star certified projects.

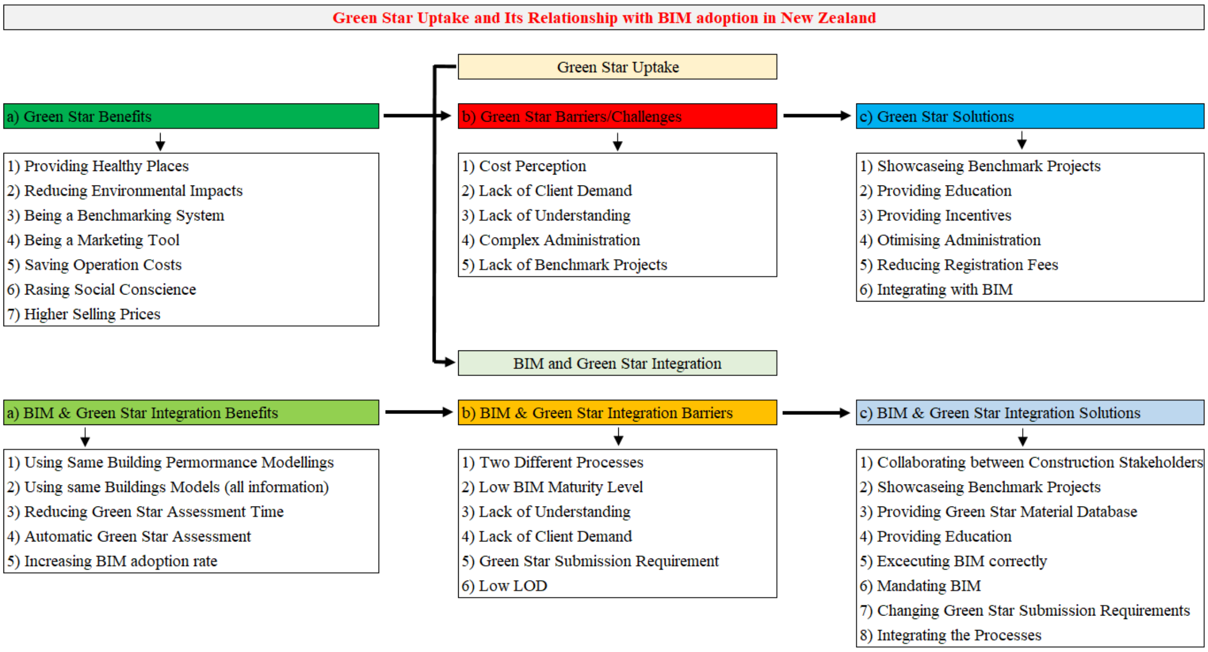



Figure 4.1. Research results summary

Towards BIM and Green Star integration, building performance modellings (e.g., energy, lighting) used for Green Star assessment can be implemented using BIM was revealed as the most significant benefit amongst the examined benefits. This was followed by the benefit that building models can incorporate all the information (e.g., Building Users' Guide, Commissioning report) for Green Star assessment of the project and the benefit of reducing Green Star assessment time. Regarding the barriers/challenges, having two separate processes is the most considerable one to Green Star and BIM integration. Low BIM maturity level and the lack of understanding are the next two barriers/challenges should be mostly focused. To mitigate the existing problems, collaborating between construction stakeholders to optimise the Green Star certification process was implied as the best solution. While showcasing BIM-Green Star benchmark projects and providing Green Star material database were highlighted as the second and third most effective solutions.

Based on the results of the research, it is recommended that NZGBC should be more active in involving construction stakeholders in registering for Green Star projects. Amongst the five identified barriers for Green Star uptake, understanding is one of the essential factors to the development of Green Star. While the complex administrative process of Green Star and lack of benchmark Green Star projects prevents people from seeking their projects certified. The government/local authorities should also encourage the Green Star practice owing to the determined benefits by providing incentives for Green Star certified projects. For example, 50% remission of levies to 5 Star or higher Green Star certified projects has been offered by Wellington City Council promoting the development of both Green Star and society towards sustainable development of the country (Doan et al., 2019d).

Clients and current practitioners are the key factors affecting the development of Green Star. They should keep updating with green buildings practices to enhance their knowledge to perceive the benefits of Green Star leading to the involvement in Green Star practices. Although integrating Green Star with BIM was not considered as the topmost solution to Green Star development by respondents, many studies proved its effectiveness. Therefore, it is suggested that both NZGBC and construction practitioners examine the possibility of the integration owing to the explored benefits in many studies.

According to the research results of BIM and Green Star integration, it requires the effort from not only NZGBC but also both the government and construction practitioners to achieve the potential benefits of Green Star and BIM integration. The NZGBC could work with construction practitioners to streamline the Green Star process, revising the requirements for Green Star assessment, providing Green Star material database, and showcasing the BIM-Green Star benchmark projects. Whereas, the government could mandate BIM to certain types of construction projects to support the integration leading to the benefits to the construction industry and the society.

This research contributes to the current knowledge in two key ways. Firstly, this research provided insights into Green Star uptake and its relationship with BIM adoption in New Zealand. Secondly, the characteristics of Green Star were determined and evaluated which then can be used as guidelines for NZGBC, the government/local authorities, and construction practitioners to have effective strategies towards sustainable development.

Because executing BIM correctly was pointed out as an effective solution for the integration, further research will focus on evaluating BIM adoption in New Zealand to consider their readiness for the integration.

# Chapter 5 Developing a Framework for Building Information Modelling (BIM) Adoption in New Zealand

## 5.1 Prelude

Chapter 3 and Chapter 4 highlighted the impacts of BIM adoption on Green Star uptake. However, they also indicated that BIM adoption in New Zealand is still in its early stages. A lack of BIM understanding and a lack of guidelines were revealed as significant challenges to adoption BIM, mentioned in Chapter 2 . Therefore, it is necessary to improve the construction practitioners' understanding and provide them with BIM guidelines. This chapter aims to develop a BIM adoption framework to determine the key factors affecting the success of a BIM project. What are the critical categories affecting BIM adoption? and What are the relationships amongst those critical categories affecting BIM adoption? are answered in this chapter.

Both primary and secondary data was used; 21 qualitative interviews and industry guidelines from the 3 most well-known global Business Excellence Models (BEMs) were simultaneously analysed. The results indicate that the BIM adoption framework has 7 main categories with 39 indicators. By taking advantage of using the developed framework, construction companies could assess their BIM performance or their BIM maturity level. Also, they can evaluate their strengths and weaknesses towards BIM adoption for the future. Based on the perspectives of the interviewees, Leadership is considered the most significant category having a significant impact on all of the remaining categories. Besides, the success of Strategic Planning is affected by Leadership and Clients & Other Stakeholders. It is implied that Leadership and Resources have significant impacts on People while Leadership, Clients & Other Stakeholders, and People influence Process. Results strongly depends on Leadership, Strategic Planning, and Process. This research contributed to the existing body of knowledge by providing the categories with specific factors assisting BIM practitioners in assessing their BIM performance for further BIM improvement.

## 5.2 Introduction

The potential benefits of Building Information Modelling (BIM) adoption have been highlighted recently due to their possibility to revolutionise the construction industry. Newton and Chileshe (2012) determined 9 main benefits of BIM adoption in South Australia. While 18 BIM drivers were highlighted by Eadie, Odeyinka, et al. (2013) in the UK. Also, Ghaffarianhoseini, Tookey, et al. (2017) categorised BIM benefits systematically into 9 different types owing to its wide range of benefits.

New Zealand is considered to be in its early stages towards widespread BIM adoption. Construction stakeholders could potentially gain 14 benefits by implementing BIM (Doan et al., 2019c). However, barriers to BIM adoption exist and should be eliminated for better implementation (Doan et al. (2019c).

This research is the next stage in the process after examining the BIM perspectives in New Zealand (Doan et al., 2019c). It aims to develop a framework for BIM adoption to address the identified BIM barriers. Specifically, the framework will include critical factors affecting BIM adoption in New Zealand to enhance the BIM understanding and to provide the guidelines for effective BIM implementation. Besides, it could help construction professionals to evaluate the success and the maturity level of BIM adoption by themselves.

Green Star certification could take advantage of the framework for further considering integrating BIM with Green Star to accelerate the BIM adoption rate and the number of Green Star certified buildings. As it is suggested that achieving high BIM maturity level plays a crucial role in the integration between BIM and Green Star (Doan et al., 2019d).

## 5.3 Research Methodology

To develop a framework, either primary data such as data from interviews, focus groups, etc. or secondary data from existing literature could be used. For example, Donato and Shee (2015) developed a framework to increase collaboration amongst stakeholders in the construction supply chain through a literature review. While Valdes-Vasquez and Klotz (2012) established a framework for social sustainability considerations using an expert-based approach. To promote the reliability of the framework, various methods using both primary and secondary data could be adopted. A risk management framework was developed by S. Q. Wang, Dulaimi, and Aguria (2004) using literature review, interviews, and survey. Whereas, literature review, focus group, expert interview, and case study were adopted in Meng (2010) research to develop an assessment framework for construction supply chain relationships.

In this study, both primary and secondary data were used to develop the BIM adoption framework. The research methods and stages proposed by Weisheng Lu and Yuan (2011) and Ngacho and Das (2015) were adapted in this research. Figure 5.1 indicates the research stages in which brainstorming section was completed through the initial analysis of the interviews data and literature review. After completing the initial analysis, two phases including the development of main categories and detailed analysis of both primary and secondary data to determine the indicators within the main categories were conducted. Then, all the characteristics of the BIM adoption framework are finalised.

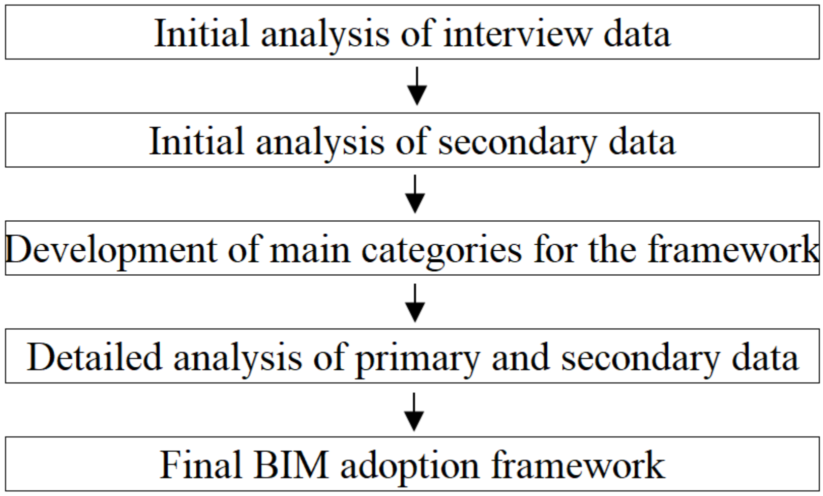



Figure 5.1. The process of developing the BIM adoption framework

This study adopted 21 semi-structured transcribed interviews conducted in Doan et al. (2019c) research, see Table 5.1. Interviewees are those who are construction experts in New Zealand having at least 8 years' relevant industry experience. Those interview transcripts were analysed focusing on the significant factors affecting BIM adoption in this research.

Table 5.1. Demographics of the interviewees

(Doan et al., 2019c)

| Interviewee | Construction Position | Experience (years) | Construction Type | Company Size | BIM Projects |
|---|---|---|---|---|---|
| #1 | Senior QS | 10 | Contractor | Large | 1 |
| #2 | BIM Manager & GSAP[1] | 14 | Design | Large | >50 |
| #3 | Director, Building Scientist,<br>Green Star Assessor, & GSAP | 12 | Consultancy | Large | >50 |
| #4 | Senior Architect, GSAP, & Green Star Assessor | 15 | Design | Large | 30 |
| #5 | Technical Services Manager, Design Manager, GSAP, &<br>Green Star Assessor | 22 | Contractor | Large | 6 |
| #6 | 1) Director & Building Surveyor[2]<br>2) Building Surveyor | 14<br>4 | Consultancy | SME | 15 |
| #7 | Principal & Designer | 30 | Design | SME | 4 |
| #8 | Senior Cost Manager | 20 | Consultancy | Large | 1 |
| #9 | Building Services Technical Leader | 8 | Consultancy | Large | 7 |
| #10 | Director & Building Performance Expert | 19 | Consultancy | SME | 1 |
| #11 | 1) BIM Manager[2]<br>2) Building Scientist | 22<br>3 | Design | Large | >50 |
| #12 | 1) Associate & Structural Engineer[2]<br>2) Drawing Office Manager | 10<br>19 | Design | Large | >50 |
| #13 | Structural Technician | 8 | Design | Large | 1 |
| #14 | Sustainability Leader, Green Star Assessor, & GSAP | 13 | Design | Large | >50 |
| #15 | BIM Construction Manager | 11 | Contractor | Large | 40 |

| | | | | | |
|---|---|---|---|---|---|
| #16 | Technical Lead & Senior QS | 12 | Multidiscipline | Large | >50 |
| #17 | BIM Consultant, Application Engineer, & Business Analyst | 17 | Information Technology | SME | >50 |
| #18 | Associate Senior Architect | 11 | Design | Large | >50 |
| #19 | 1) BIM Development Engineer[2]<br>2) Senior Structural and Sustainable Engineer, & GSAP | 20<br>8 | Consultancy | Large | 50 |
| #20 | Principal QS | 8 | Multidiscipline | Large | 2 |
| #21 | GSAP & Green Star Assessor | 10 | Non-profit | Large | 0 |

[1]Green Star Accredited Professional
[2]Corresponding interviewee

## 5.4 Results

### 5.4.1 Initial analysis of interview data

After conducting the initial analysis of interview data, there are five main possible categories affecting BIM adoption in New Zealand. Firstly, the role of BIM managers is considered as the priority factor needs to be evaluated; interviewee 7 stated that “you cannot start off doing a BIM project unless you employ the right person in the beginning. The architecture firm has a BIM manager; the construction company has a BIM manager.” Therefore, factors related to the BIM manager will be examined and potentially grouped into one category.

The next category could be related to the role of clients. Every project starts with a demand from a client; however, “the clients are sort of lacking behind on saying they want a BIM project” in New Zealand, stated by interviewee 15. The strategic planning category should also be considered in the framework because it would include BIM standards, policies, etc., which was highlighted by interviewee 4 that “there is probably no New Zealand standard” for BIM adoption.

One of the indispensable themes having a significant impact on BIM adoption is the BIM skills of the construction practitioners. It was pointed out by interviewee 19 that “we are desperately short of good expertise.” Finally, the available resources for BIM adoption such as software or hardware should also be considered. Interviewee 17 outlined “the investment in hardware and software … a significant capital investment cost” for BIM adoption.

### 5.4.2 Initial analysis of secondary data

To justify the main categories discovered from the qualitative interviews in the previous step, “building a framework in construction” was used as a keyword in the

Google Scholar database to look for any developed frameworks which may have similar patterns. “Building a conceptual framework for measuring business performance in construction: an empirical evaluation,” written by Bassioni, Price, and Hassan (2005), is one of the first papers in the results that provided a framework containing similar identified categories. The idea of Bassioni et al. (2005)’s framework originated from the Business Excellence Models (BEMs). Therefore, the well-known BEMs were searched to compare with the five main categories identified.

Until now, around 100 BEMs have been developed and adopted in over 80 countries and territories (Mohammad, Mann, Grigg, & Wagner, 2011); however, Baldrige Excellence Framework (BEF) and European Foundation for Quality Management Excellence Model (EFQMEM) are most widely being used worldwide (Gómez-López, López-Fernández, & Serrano-Bedia, 2017; Mohammad et al., 2011; Tickle, Mann, & Adebanjo, 2016). It is noted that the New Zealand Business Excellence Foundation also adopts the BEF to assess the performance of organisations in New Zealand (NZBEF, 2019). BEF and EFQMEM are, therefore, analysed for further BIM adoption framework development.

The Australian Business Excellence Framework (ABEF) will also be included in the analysis because New Zealand and Australia have many things in common which are worth making a comparison. According to Scheer (2017), “Australia, New Zealand, and the UK have a similar basis of law. They have a common democratic system, and they have the same types of legislation and regulations around investment and trade.” ABEF is also considered as a globally known quality framework because it is reviewed and updated annually (Talwar, 2011).

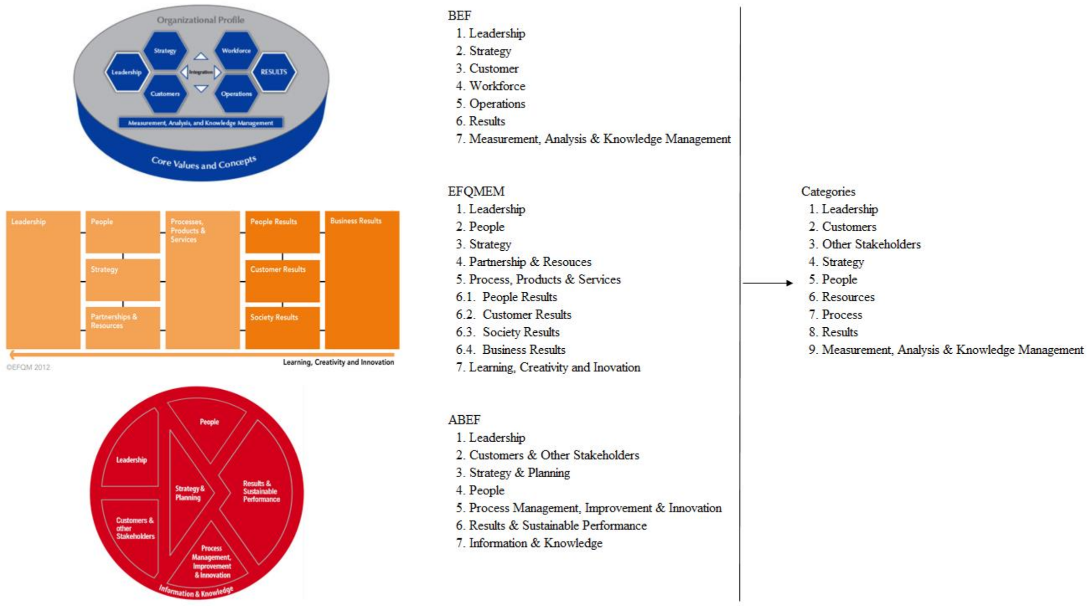



Figure 5.2. Criteria of BEF, EFQMEM, and ABEF

(adapted from National Institute of Standards and Technology (NIST) (2019), EFQM (2018), and SAI-Global (2019))

All of the main categories of 3 frameworks are summarised in Figure 5.2. It is clear that all of them have 7 main categories. Interestingly, the last category for each framework is not an independent and separated category compared to the others, but their purpose is to measure and analyse the rest of the categories to improve them continuously. Besides, the Customers category is a part of BEF and ABEF while EFQMEM and ABEF include the Partnership/Other Stakeholders category in their frameworks. However, only the Resources category is accounted for by EFQMEM.

After analysing the BEMs, a total of 9 categories exist. These are: 1) Leadership; 2) Customers; 3) Other Stakeholders; 4) Strategy; 5) People; 6) Resources; 7) Process; 8) Results; 9) Measurement, Analysis & Knowledge Management.

### 5.4.3 Development of main categories of the framework

After completing the initial analysis of the interview findings and literature review, the primary identified categories were examined to consider their fitness for inclusion into the BIM adoption framework. Interestingly, all five identified categories in the interview results are also the categories appearing in the BEMs' frameworks, see Figure 5.3.

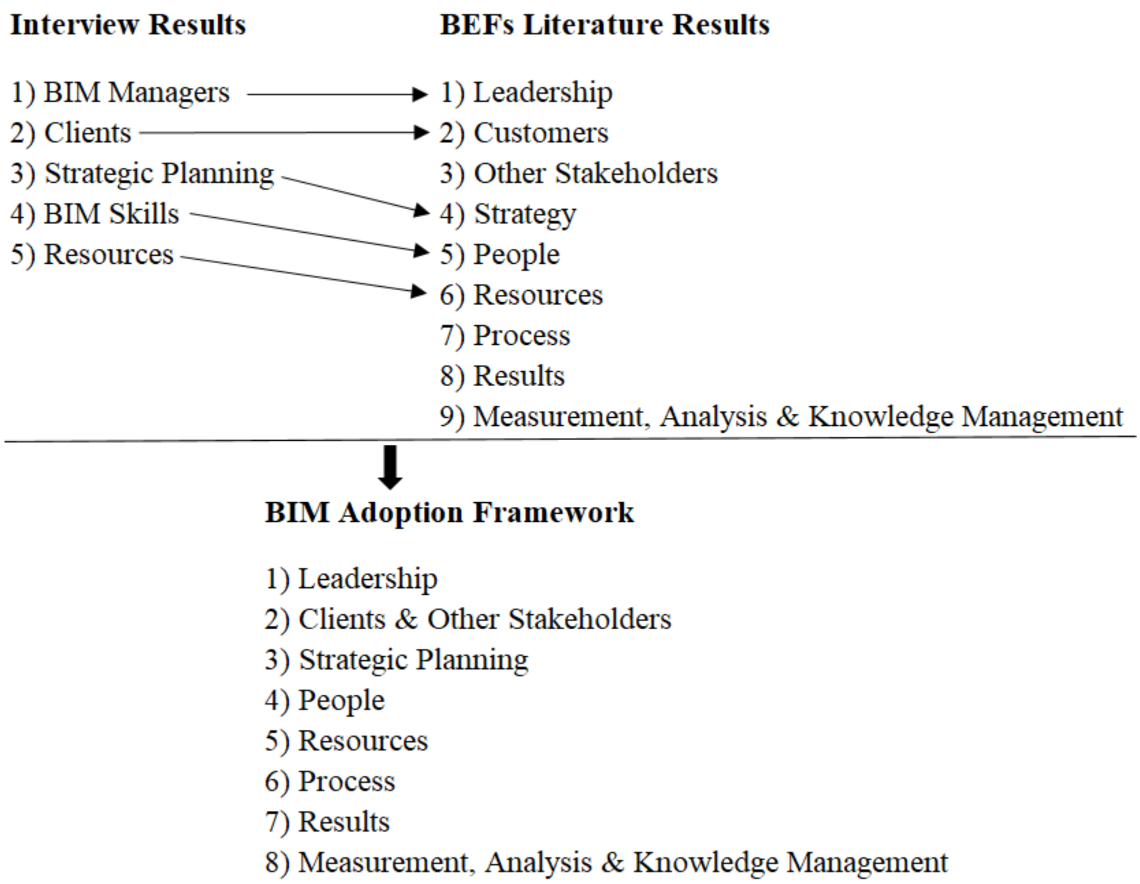



Figure 5.3. Main categories of the BIM adoption framework

According to NIST (2019), EFQM (2018), and SAI-Global (2011), the Leadership category considers the effectiveness of the leaders' roles by providing guidance and inspiring their employees leading to the success of their organisations. The purpose of this category is the same as the BIM managers. Interviewee 13 stated, "having a BIM manager in the beginning is very important to make sure everybody is on the same page."

The identified Clients category in the interview results is related to the lack of clients requirement. To solve this problem, interviewee 2 suggested that the organisation needs to "understand who the client is, and what they really want" which is also the definition of the Customers category, exploring how the organisation engages and understands their clients to satisfy their requirements (NIST, 2019; SAI-Global, 2011).

ABEF considers Customers & the Other Stakeholders as one category that should also be the case for the BIM adoption framework. According to interviewee 3, "the contractors are not taking the BIM model, and using it necessarily to coordinate throughout the construction;" and Chan (2015) and Bosch-Sijtsema et al. (2017) remarked that "BIM does not help if our counterparties are not using BIM." Therefore, understanding the stakeholders' needs and collaborating with them are necessary as to the clients.

Regarding the Strategy category, it requires the organisation to develop strategic objectives, policies, and plans for the projects (EFQM, 2018; NIST, 2019; SAI-Global, 2011). It was also mentioned by interviewee 20 that "it is about engaging a professional in BIM and then help them create a BIM strategy" to have a successful BIM project. While interviewee 12 highlighted the need for a strategic plan by asking a rhetoric question that "how you run your BIM project if you do not have a strategic plan?"

In terms of the BIM skills category, "the barrier to BIM adoption is a lack of skilled professionals in the industry, and also the lack of education," highlighted by interviewee 20. In other words, how to upskill and train the employees is essential towards BIM adoption. This was rigorously mentioned as the People category in BEFs to create a high-performance workplace to develop their skills and engage them in contributing to organisational success (EFQM, 2018; NIST, 2019; SAI-Global, 2011). Therefore, the BIM skills category will be changed to the People category as a better indicator of the BIM adoption framework.

The Resources category is also relevant based on an initial analysis of the interviews. According to the interviewees, BIM implementation requires high economic investment. Interviewee 3 highlighted that "it is a high investment if you have to hire a BIM manager or hire a brand new staff member to build the team to do BIM because those people tend to ask quite high salaries because they are in demand." While interviewee 17 pointed out "the investment in IT, investment in hardware and software." It was also considered an essential category by EFQM (2018) to secure and manage the finances, equipment, and technology to support the operation of the organisation.

The Process, Results, and Measurement, Analysis & Knowledge Management categories were only determined after analysing the BEMs. They were then considered as the themes for further analysing the interview results before confirming the necessary categories for the BIM adoption framework. NIST (2019), EFQM (2018), and SAI-Global (2011) defined Process as a category to design, manage, and improve processes to improve the quality of the outputs and achieve organisational success. After reanalysing the interview results with the Process theme, it is also considered as a reliable indicator for the framework. Interviewee 17 stated that "you need to have a BIM process for a nice good implementation" while "the BIM Execution Plan (BEP) is the blueprint of the whole process," highlighted by interviewee 9. As a result, Process was added into the framework.

Results are always considered as an indispensable category to evaluate the success of a project or an organisation. To examine it thoroughly, all the results of the mentioned categories including Leadership, Customers & Other Stakeholders, Strategy, People, Resources, and Process need to be evaluated to determine whether the organisation meets or exceeds those expectations (EFQM, 2018; NIST, 2019; SAI-Global, 2011). Also, financial results need to be checked. This was stated as an essential factor in the development of the BIM adoption framework. Interviewee 1 wondered "will they get the return on their investment?" while interviewee 5 pointed out a current major challenge towards BIM implementation that "people do not see the return on the investment, they just see the outgoing costs." Therefore, the Results category is needed for the BIM adoption framework.

Regarding the Measurement, Analysis & Knowledge Management category, it is not considered as a separate category but attached inside all other ones to measure, analyse, review, and improve the organisation performance (NIST, 2019). There is no exception to BIM adoption. Interviewee 9 shared his perspective towards BIM skills improvement that "BIM understanding comes with time hopefully and also proper training. So, people need to go through the process again and again." While interviewee 19 expressed that "the more you learn, the better you become; the more you do, the more skills you have, the more adaptable you become … you can never write an execution plan on day one." Consequently, they will be considered as an attached category for the framework.

In conclusion, 8 categories including 1) Leadership; 2) Clients & Other Stakeholders; 3) Strategic Planning; 4) People; 5) Resources; 6) Process; 7) Results; and 8) Measurement, Analysis & Knowledge Management are considered as the main categories for the BIM adoption framework.

### 5.4.4 Detailed analysis of both primary and secondary data

In this section, both interviews transcripts and BEMs' criteria will be detailed analysed at the same time to compare the compatibility of the results.

#### Leadership

The interview transcripts were analysed focusing on the Leadership or BIM managers theme while the criteria of the Leadership category of the BEMs were compared to establish if they supported the results from the interviews.

As stated above by interviewee 13 that having a BIM manager is important to have a success BIM project. However, "BIM managers, BIM coordinators, they are all like hen's teeth. They are rare, and it is hard to find those people" (#5). Also, for the BIM manager currently, "they are sitting here and wearing two hats, as a project manager or as an engineer or an architect, but also trying to manage the BIM process" (#9). Interviewee 1 asked a rhetorical question that "do you have a BIM Manager who is not the architect, who is not one of the engineers in building, an actual person who coordinates the entire process ?" Based on EFQM (2018)'s criteria for Leadership, excellent organisations have leaders who act as role models and be able to react in a timely manner. Therefore, the organisation needs to have a BIM manager with a clear BIM leadership role, which is considered as the first and foremost criterion for the Leadership category.

According to NIST (2019), EFQM (2018), and SAI-Global (2011), the purposes, visions, and values should be developed by the leaders to direct the employees towards the organisational success. Interviewee 7 suggested a solution to have a successful BIM adoption that “employ the BIM manager very carefully, then, you solve everything as long as they listen to him. If he is employed correctly and he is the right sort of person, then, it is ok because he tells the rest of the team.” This also justifies the needs for promoting communication between the leaders and employees in the BEF, EFQMEM, and ABEF (EFQM, 2018; NIST, 2019; SAI-Global, 2011). In other words, the BIM leadership team should play a strategic role (with goals and objectives) that will guide the organisation towards BIM adoption, and communicate openly with and engages employees for BIM adoption.

Lack of expertise was highlighted by interviewee 6 that “we have to have enough expertise in the industry, but we are not ready for it yet.” To minimise this problem, the leadership team needs to commit to continuous improvement in their BIM skills, and also their employees’ BIM skills. Interviewee 7 mentioned that “if you are a leader of this process and the rest of the consulting team do not understand it very well, you have to help educate them, and so they understand what has to be delivered on time, and the models and everything have to be done exactly.” Increasing the leaders’ skills and the employees’ skills were also mentioned in the Leadership category by NIST (2019), EFQM (2018), and SAI-Global (2011).

As a result, there are five criteria for the Leadership category for the BIM adoption framework. These include a clear BIM leadership role, developing a strategic role for BIM adoption, open communication amongst the leadership team and their employees, the leadership team's commitment to their BIM skills improvement, and the leadership team's commitment to their employees' BIM skills improvement.

### Clients & Other Stakeholders

When the role of the clients was mentioned to the success of a BIM project, interviewee 19 pointed out that:

> *"The client does not understand what they want to do with the facilities … trying to understand their needs and our ways of doing things and educating them, getting them to change their entrenched behaviour, getting them to get the FM people on board early so that they know what they want, they tell us what they want rather than us telling them how to use it."*

In other words, the clients' expectations for the project should be determined for better BIM planning. Also, interviewee 14 suggested that "when you get invited onto a project, you should always educate your client like this (BIM) is available, would you like this option?" Interviewee 2 detailed that:

> *"If they only want a building, let's say a building like that … the whole thing about BIM is, 'hey, we can give you a good design, that is fully coordinated,' and if the client says 'yes, I do want that,' sweet. As an architect, I can say 'hey, what about if you combine the design and the construction together, you can have more efficiency in the whole process?' If they understand what the value is, they might say yes."*

Therefore, educating clients on BIM is necessary for the success of a BIM project. Understanding and building a relationship with a customer is one of the significant criteria of the Customer category of the BEF and ABEF (NIST, 2019; SAI-Global, 2011).

The role of the stakeholders was also mentioned. "Everyone needs to work in a collaborative environment. They will talk in the same language; getting cost managers, architects, designers, engineers, mechanical, electrical engineers, fire engineers, and clients all talking the same language" (# 8). It means that all the stakeholders also need to understand each other's expectations to deliver quality results for a BIM project.

This was included in the Partnership & Resources category of the EFQMEM (EFQM, 2018) and the Customers and other Stakeholders category of the ABEF (SAI-Global, 2011). Furthermore, every stakeholder should be not reluctant to share information concerning BIM adoption with each other. Interviewee 17 revealed that:

> *"A digital prototype would be beneficial and efficient if 100% of people would think 'we share models,' but people still share papers and pdfs. Why? Because the thing is electric property, because the one owns something, but it is wrong. BIM is rooted in sharing and caring; otherwise, you do not have the prototype; just imagine I go to my contractor, and I deliver ductwork, I bring the ductwork onsite, but I am not building this into the spotlight because it is my intellectual property. Does this work? Absolutely not."*

One of the solutions to that problem is to have a BIM contract. Interviewee 7 shared that "with 3D BIM and no legal contract, no way to enforce compliance" while interviewee 10 indicated that "if BIM is mandated or it is in the contract … it makes people engage and provide things in a timely fashion."

In conclusion, five criteria are covered in the Clients & Other Stakeholders category. These are understanding the clients' expectations, understanding other stakeholders' expectations, educating clients on BIM, being willing to share information concerning BIM adoption amongst stakeholders, and employing a standard form of contract for the procurement of BIM.

### Strategic Planning

According to interviewee 1, "one of the big problems is that BIM is difficult for SMEs (small and medium enterprises)" in which they account for 97% of the companies in New Zealand (MBIE, 2017). Interviewee 20 recommended "engaging a professional in BIM which then helps them to create a BIM strategy." Besides having a BIM manager with a clear BIM leadership role and playing a strategic role, having a BIM strategy is also the key step towards BIM adoption. All the BEF, EFQMEM, and ABEF included

Strategy as the fundamental category in their frameworks (EFQM, 2018; NIST, 2019; SAI-Global, 2011).

Interviewee 19 suggested the need for the whole collaboration amongst stakeholders in the beginning, “you cannot hope to achieve benefits for everyone if you do not define what it is, what you are trying to do at the start and get people to move in the same direction.” In other words, it is necessary to have “the will from all the different stakeholders to engage with it” (#10).

Therefore, all stakeholders should be involved in developing the BIM strategic plan. Both EFQMEM and ABEF mentioned the criterion of engagement of the stakeholders to promote the confidence of the strategic plan in the frameworks (EFQM, 2018; SAI-Global, 2011). Furthermore, the strategic plan for BIM adoption should be translated into specific requirements for each stakeholder. Interviewee 11 highlighted the need for “getting it translated and handed out across to the consulting team” while interviewee 13 pointed out the challenge to BIM adoption that “a lot of information was not translated amongst stakeholders.”

For BIM adoption, the company “has got massive overhead expense” (#7); they need to “have resources to design a collaborative model” (#2). However, “a lot of places are under-resourced” (#13). Thus, the company should allocate the resources effectively to ensure the success of BIM adoption. Without exception, analysing the resources required for the success of the company were all included in the BEF, EFQMEM, and ABEF (EFQM, 2018; NIST, 2019; SAI-Global, 2011).

As a result, the Strategic Planning category contains four criteria. These are developing a BIM strategic plan, involving all stakeholders in developing the BIM strategic plan, allocating resources effectively, and translating the BIM strategic plan into specific requirements for each stakeholder.

### People

Lack of expertise is one of the significant challenges to BIM adoption pointed out by most of the interviewees. Interviewee 19 shared:

> *"if we had done it badly and had a bad experience, we will say bad things and that comes down to their existence, their lack of skills, their lack of investment, and you are not going to get far if you do not upskill, if you do not embrace, if you do not change your mindset."*

Therefore, it is necessary to provide training to the employees before implementing BIM. Interviewee 17 indicated that "in many companies, they do not put half an hour aside each day for training for the software. It is easy, just half an hour, but we are confused, we keep ourselves busy."

Entrenched behaviour was also highlighted as a significant barrier by half of the interviewees. Interviewee 19 suggested that "people need to realise to change the way they do things, they just simply need to accept that there are better ways and they need to adopt." Thus, the employees should be flexible and commit to the BIM strategies of their companies. Providing training and assuring employees to follow the company's strategies are considered as the necessary criteria in the People/Workforce category of the BEF, EFQMEM, and ABEF (EFQM, 2018; NIST, 2019; SAI-Global, 2011).

The current capacity of the industry was also seen as a challenge to BIM adoption. "The capacity of the industry, that is capacity in terms of having the capacity to change … They do not have the time or capacity to change" (#1). Interviewee 3 stated that "the construction industry is already running at 110%, just trying to build whatever we got to build." Therefore, creating an environment conducive allowing the employees to improve their BIM skills is imperative besides providing the training.

According to interviewee 8, "everyone is always trying to find the best way to do it, and they all have their own ideas, they will want to put those ideas forward, some will fail, some will win, and all of a sudden you will get to a place where that is the convention." This means that collecting and analysing the employees' ideas are important and the company should encourage them to share their ideas to improve BIM adoption. Creating a cooperative work environment encouraging creativity and innovation is mentioned in the BEF, EFQMEM, and ABEF (EFQM, 2018; NIST, 2019; SAI-Global, 2011).

In summary, four criteria were identified for the People category. These are providing the necessary training for BIM adoption, committing to BIM strategies by the employees, creating an environment conducive for the employees, and encouraging the employees to share their ideas to improve BIM adoption.

### Resources

From the three frameworks mentioned above, only EFQMEM considered three main factors for the Resources category including finances, equipment, and technology (EFQM, 2018). This also reflects the results collected from the interviewees. Interviewee 15 stated that "obviously if you want to start using BIM, you have to make some initial investment … you have to invest additionally in buying software or hardware and training people." While interviewee 3 believed "it is a high investment if you have to hire a BIM manager or hire a brand new staff member to build the team to do BIM. Those people tend to ask for quite high salaries because they are in demand. The BIM software itself is quite expensive, and a lot of other things."

As a result, the Resources category for the BIM adoption framework will examine four criteria. These are available software for BIM adoption, available hardware for BIM adoption, available skilled employees for BIM adoption, and available financial resources for further BIM investment.

### Process

Interviewee 16 revealed, “the biggest barrier would be the process because people cannot work out how to do it, cause no one really knows how to do it.” To solve this problem, interviewee 9 suggested:

> *“having a proper BEP (BIM Execution Plan), and making sure that it covers all aspects of the project … when you issued that project for tender, you would also issue BEP because they also say exactly what was expected of the contractor, how the model will be shared with them, what they can do with it, what information they need to put back into the model and everything like that.”*

As mentioned by interviewee 19 above that “you can never write an execution plan on day one,” a process of continuously developing the BEP to have a final comprehensive BEP is essential towards the success of the BIM project. The work process design was highlighted in all the BEF, EFQMEM, and ABEF to prove its crucial role in the Processes/Operations category (EFQM, 2018; NIST, 2019; SAI-Global, 2011).

Ensuring the competence of the employees and the process of learning were also mentioned in the EFQMEM and ABEF (SAI-Global, 2011). According to interviewee 9, “BIM understanding comes with time hopefully and also proper training. So, people need to go through the process again and again.” In other words, adequate training to improve the employees’ BIM skills should be provided before and during the BIM implementation process.

According to interviewee 8, “BIM is about the process and how people communicate throughout the various phases of design and construction and to enable them to work in a single environment.” However, interviewee 13 pointed out that:

> *“There is a disconnection already between the architect and their drafting team. They were trying to relay information to them, then they were trying to relay information back to me, and there was stuff gets lost. Something might be told from the architect, might tell their drafting this needs to happen, and then I will get a message from the drafting team that says you need to know this change, and sometimes you get all the information, sometimes you do not, sometimes there is not much of it.”*

Therefore, it is necessary to communicate changes in the BIM implementation process to all employees involved, which was also mentioned by the BEF towards the requirements of the collaborators (NIST, 2019).

For the Process category, three criteria are used including developing a comprehensive BEP; providing adequate training during the BIM implementation process; and communicating changes to all employees involved in the process.

### Results

Regarding the results of the BIM project, two main factors were pointed out by the interviewees. Firstly, the project implemented using BIM should generally satisfy the clients’ expectations. Interviewee 9 indicated “it depends on our clients. They think that it can profit or not. What I mean by profit is that it will cost them less and reduce their risk by using BIM on their projects.” Secondly, the return on investment (ROI) was mentioned. Interviewee 1 asked a rhetoric question that “I think it has to come down to the industry. We talk about the ROI. Will they get a return on their investment?” While interviewee 5 wondered about the ROI, “I do not see the ROI. I just see the outgoing costs.”

Satisfying the clients' expectations and earning profit were identified as two key factors for the Results category of the BEF, EFQMEM, and ABEF (EFQM, 2018; NIST, 2019; SAI-Global, 2011). The BEF, EFQMEM, and ABEF also took into account another four factors, including the effective leadership team, effective strategy, effective process and competent employees (EFQM, 2018; NIST, 2019; SAI-Global, 2011). While satisfying stakeholders' expectations were included in the EFQMEM, and ABEF (EFQM, 2018; SAI-Global, 2011). Consequently, seven factors were included in the BIM adoption framework.

#### Measurement, Analysis & Knowledge Management

Regarding the Measurement, Analysis & Knowledge Management category, only the BEF and ABEF (as Information & Knowledge for the ABEF) detailed it in the guidelines (NIST, 2019; SAI-Global, 2011). The purpose of this category is to establish effective systems and processes for data collection to continuously analyse and improve the organisation's performance. Agreeing with the sharing from interviewees 9 and 19 above, interviewee 8 stated that "you have to get to the point where they go, learn the lessons, and then try again on another project." Although the interviewees indicated the need for going through the process continuously to gain the experience, no one detailed any specific information for this category. Therefore, the purpose and information provided in the BEF and ABEF were adopted.

The purpose of the Leadership category is to have a leader to develop a strategic plan to improve the organisation's performance (NIST, 2019; SAI-Global, 2011). To have an effective strategic plan, it is necessary for the BIM leadership team to monitor and review the strategic plan regularly for BIM adoption. The BEF mentioned this in the Measurement, Analysis, & Improvement of Organisational Performance factor (NIST, 2019). Collecting the data from customers and stakeholders is imperative for the organisation’s performance analysis and improvement, which was pointed out by both BEF and ABEF (NIST, 2019; SAI-Global, 2011). Based on NIST (2019), it is necessary to analyse and review the developed strategic objectives. In other words, a formal process to track the effectiveness of our BIM strategic plan should be used. Then, the BIM strategic plan will be reviewed and updated. Assessing how the organisation executes the strategy was also included in the BEF (NIST, 2019). It means a formal process to track the effectiveness of implementing BIM should be conducted to review the BIM implementation process regularly.

In contrast to the previous categories, Measurement, Analysis & Knowledge Management was not stood independently as a category. Therefore, the factors mentioned above will be distributed to the appropriate categories. As a result, there are only seven separated categories. The following section will summarise all the categories and factors for the BIM adoption framework.

### 5.4.5 Final BIM adoption framework

After conducting detailed analysis using both primary and secondary data, 7 main categories with 39 factors were established, see Table 5.2.

Table 5.2. BIM adoption framework

| |
|---|
| Leadership |
| 1. The organisation has a clear BIM leadership role. |
| 2. The BIM leadership team plays a strategic role (with goals and objectives) that will guide the organisation towards BIM adoption. |
| 3. The BIM leadership team monitors and reviews the strategic plan regularly for BIM adoption. |
| 4. The BIM leadership team communicates openly with and engages employees for BIM adoption. |
| 5. The BIM leadership team is committed to continuous improvement in their own BIM skills. |
| 6. The BIM leadership team is committed to continuous improvement in employees' own BIM skills. |
| Clients & Other Stakeholders (e.g., architects, contractors, MEP, QS, suppliers) |
| 1. The organisation determines clients' expectations for planning the BIM adoption. |
| 2. The organisation determines stakeholders' expectations for BIM adoption. |
| 3. The organisation has a clear approach to collect clients' feedback after completing BIM projects. |
| 4. The organisation has a clear approach to collect stakeholders' feedback after completing BIM projects. |
| 5. The organisation educates clients on BIM. |
| 6. The organisation employs a standard form of contract for the procurement of BIM. |
| 7. The organisation is not reluctant to share information concerning BIM adoption with other stakeholders. |
| Strategic Planning |
| 1. The organisation has a BIM strategic plan (e.g., BIM standards, BIM specifications, policies). |
| 2. The organisation involves all stakeholders in developing the BIM strategic plan. |
| 3. The organisation allocates the resources effectively to ensure the success of BIM adoption. |
| 4. The organisation translates the strategic plan for BIM adoption into specific requirements for each stakeholder. |
| 5. The organisation uses a formal process to track the effectiveness of the BIM strategic plan. |
| 6. The organisation has its BIM strategic plan reviewed and updated regularly. |
| People |
| 1. The organisation provides the necessary training for BIM adoption (before implementing BIM). |
| 2. The organisation creates an environment conducive for the employees to improve their BIM skills. |
| 3. The organisation encourages employees to share their ideas to improve BIM adoption. |
| 4. The employees are committed to the strategies for BIM adoption within the organisation. |
| Resources |
| 1. The organisation has available software for BIM adoption. |

| |
|---|
| 2. The organisation has available hardware for BIM adoption. |
| 3. The employees have the required skills needed for BIM adoption. |
| 4. The organisation has the financial resources for further BIM investment. |
| Process |
| 1. The organisation provides adequate training to improve employees' BIM skills (during the BIM implementation process). |
| 2. The organisation develops a comprehensive BIM Execution Plan for each BIM project. |
| 3. The organisation uses a formal process to track the effectiveness of implementing BIM. |
| 4. The organisation reviews the BIM implementation process regularly. |
| 5. The organisation communicates changes in BIM implementation process to all employees involved in the process. |
| Results |
| 1. In the organisation, projects implemented using BIM generally satisfy the clients' expectations. |
| 2. In the organisation, projects implemented using BIM generally satisfy the stakeholders' expectations. |
| 3. The BIM leadership team is effective in BIM adoption. |
| 4. The organisation developed an effective BM plan for BIM adoption. |
| 5. The organisation developed an effective BIM implementation process for BIM adoption. |
| 6. The employees became capable of implementing BIM. |
| 7. The organisation has a positive return on investment for BIM adoption. |

The developed framework raises a number of questions for further exploration. For example, how do the categories relate to and affect each other and which is the most critical factor affecting BIM adoption in New Zealand? Interviewee 7 stated that:

> *"You cannot start off doing a BIM project unless you employ the right person in the beginning. The architecture firm has a BIM manager; the construction company has a BIM manager … employ that person very carefully, the BIM manager, then you solve everything as long as they listen to him. If he is employed correctly and he is the right sort of person, then it is ok because he tells the rest of the team."*

Therefore, the first hypothesis is that Leadership is the most important factor to the BIM adoption affecting the rest of the categories in the framework. Strategic Planning would be affected by Leadership and Clients & Other Stakeholders is the second hypothesis. This is because BIM adoption requires "getting everybody to the table as early as possible, everybody needs to understand that the more time they put upfront, the better the results are. You have to try to convince them that it is everybody's best interest to be on-board" (#13). Therefore, Leadership and Clients & Other Stakeholders play a pivotal role in Strategic Planning.

Lack of expertise is considered as a significant barrier to BIM adoption acknowledged by most of the interviewees. Interviewee 7 indicated that "if you are a leader of this process and the rest of the consulting team do not understand it very well, you have to help educate them." Besides, "if you want to start using BIM … you have to invest additionally in buying software or hardware and training people" (#15). As a result, People is hypothesised to be affected by Leadership and Resources. Whereas, Leadership, Clients & Other Stakeholders, and People are having impacts on Process is the fourth hypothesis. As mentioned above by interviewees 8 and 9 that BIM requires the effort from everyone in the project in which each of the BIM managers, clients, stakeholders, and employees plays an essential role towards the success of a BIM project.

The final hypothesis is the impact of Leadership, Strategic Planning, and Process on Results. Interviewee 9 revealed the significant factor affecting to the BIM adoption that "the BEP is like the framework on how your all the information would get shared" while interviewee 12 believed "BEP is a roadmap of what BIM uses you want to use … BEP is a key player."

To use the framework effectively, the BEF and EFQMEM have used the points ranging 0-1000 to assess the organisation performance. Figure 5.4 shows the scores for each category of the frameworks.

| BEF | |
|---|---|
| 1. Leadership | 120 |
| 2. Strategy | 85 |
| 3. Customer | 85 |
| 4. Workforce | 85 |
| 5. Operations | 85 |
| 6. Results | 450 |
| 7. Measurement, Analysis & Knowledge | 90 |
| Total | 1000 |

| EFQMEM | |
|---|---|
| 1. Leadership | 100 |
| 2. People | 100 |
| 3. Strategy | 100 |
| 4. Partnership & Resouces | 100 |
| 5. Process, Products & Services | 100 |
| 6. Results | 500 |
| 7. Learning, Creativity and Inovation | 0 |
| Total | 1000 |

→

| BIM Adoption Framework | Point |
|---|---|
| 1. Leadership | 110 |
| 2. Clients & Other | 83 |
| 3. Strategic Planning | 83 |
| 4. People | 83 |
| 5. Resources | 83 |
| 6. Process | 83 |
| 7. Results | 475 |
| Total | 1000 |

Figure 5.4. Frameworks' points

(adapted from EFQM (2018) and NIST (2015))

It is clear from Figure 5.4 that the point for each category is similar except Leadership of the BEF and Results of both BEF and EFQMEM. Therefore, the point systems of these two frameworks will be adapted for the BIM adoption framework by taking the average of the points of Leadership and Results while the rest points were divided equally amongst the rest categories. Consequently, the point of Leadership is 110 and of Results is 475 while 83 is the point for each category left of the BIM adoption framework.

In both BEF and EFQMEM, there are four levels of awards including Commitment Award, Proficiency Award, Mastery Award, and Excellence Award for the BEF (Veenstra & Furst-Bowe, 2017); Committed to Excellence Validation, Committed to Excellence Assessment, Recognised for Excellence, and EFQM Global Excellence Award for EFQMEM (EFQM, 2019). Interestingly, there are also 4 levels of BIM maturity (Doan et al., 2019c). Therefore, the BIM maturity level of a construction company could be assessed using the indicators of the frameworks along with the points for each category. 1000 points could be divided equally for each level where over 250 points indicate for BIM maturity level 1, over 500 points for BIM maturity level 2, and over 750 for BIM maturity level 3.

## 5.5 Conclusion

This research aims to develop a BIM adoption framework to provide significant indicators to the success of a BIM project. After a detailed analysis of 21 interview transcripts and guidelines of the most well-known BEMs including BEF, EFQMEM, and ABEF, 7 categories with 39 factors were identified. The 7 categories are Leadership, Clients & Other Stakeholders, Strategic Planning, People, Resources, Process, and Results.

BIM understanding would be improved by the use of the developed framework, in which essential factors were identified within each category to provide the guidelines for BIM adopters. Based on the identified factors, construction companies could evaluate the status and maturity level of their companies towards BIM adoption. Then, their weaknesses could be addressed. Furthermore, assessing the BIM maturity level of their practice could assist them to forecast the time when BIM and Green Star could be integrated to have an efficient process for BIM and Green Star uptake.

Five hypotheses were developed. Firstly, Leadership is the most important factor to the BIM adoption affecting the rest of the categories in the framework. Also, Leadership and Clients & Other Stakeholders play a key role to Strategic Planning. Thirdly, People is affected by Leadership and Resources. Next, Leadership, Clients & Other Stakeholders, and People have an influence on Process. Finally, Leadership, Strategic Planning, and Process have impacts on Results. Future studies will examine the interrelationship amongst seven categories to determine the important role of each category to the success of a BIM project besides validating five hypotheses mentioned above.

# Chapter 6 Structural Equation Modelling of Building Information Modelling (BIM) Adoption Framework in New Zealand

## 6.1 Prelude

This chapter aims to validate the framework developed in Chapter 5 . Also, the critical indicators of each category affecting BIM adoption and the relationships between categories are examined. Specifically, 3 research questions, including: What are critical categories affecting BIM adoption?; What are critical indicators of each category affecting BIM adoption?; and What are the relationships amongst those critical categories affecting BIM adoption?, are answered in this chapter.

The developed framework in Chapter 5 was validated with the use of PLS-SEM. The results indicate that Leadership, Client & Other Stakeholders, Strategic Planning, Resources, People, Process, and Results are essential categories affecting BIM adoption. Having a clear BIM leadership, educating clients on BIM, reviewing and updating the BIM strategic plan, investing in BIM software, encouraging employees to share their ideas to improve BIM adoption, providing adequate training were determined as the most important indicators that BIM adopters should be considered. It is also noticed that the results of BIM adoption strongly depend on the effectiveness of the BIM leadership team.

The results confirmed the hypotheses proposed in Chapter 5 . Leadership is the most essential category affecting all other categories. Leadership and Clients & Other Stakeholders have impacts on Strategic Planning. People is influenced by Leadership and Resources. Whereas, People along with Leadership and Clients & Other Stakeholders affect Process. Leadership, Strategic Planning, and Process have direct impacts on Results.

The developed framework could support construction organisations to evaluate their BIM practice. Weaknesses could be found out and eliminated based on the identified categories and indicators. Also, the level of impacts of each category and indicators was determined. The organisations could use the results as guidelines to plan for their BIM adoption.

## 6.2 Introduction

BIM has a wide range of potential benefits that can transform the construction industry (Crotty, 2013). Therefore, it has been focused on recently by researchers to drive widespread BIM adoption in the industry. Realising the benefits of the BIM adoption, several countries such as Finland, Norway, Denmark, Netherlands, and the UK have mandated BIM to certain BIM maturity level for all public sector buildings or government projects (Smith, 2014b).

New Zealand has started paying attention to BIM adoption. BIM mandate has been a discussed theme in recent years because of its potential benefits to the New Zealand construction industry (EBOSS, 2018). According to Doan et al. (2019c) research, only a third of the construction professionals believed that BIM would be mandated in New Zealand.

BIM adoption in New Zealand is still in its early stages, stated by Doan et al. (2019c), in which ten barriers/challenges to BIM adoption in New Zealand were revealed. The lack of BIM understanding and guidelines are the critical challenges to BIM adoption in New Zealand currently (Doan et al., 2019c). Therefore, a BIM framework was developed to demonstrate the essential factors affecting BIM adoption in New Zealand to enhance BIM understanding in New Zealand (Doan et al., 2019a). According to Doan et al. (2019a), there are 7 main categories with 39 factors affecting BIM adoption. 5 hypotheses were developed to demonstrate the relationship between those 7 categories (Doan et al., 2019a).

This research, the next stage after developing the BIM adoption framework in New Zealand, aims to validate the framework as well as confirming the 5 hypotheses proposed by Doan et al. (2019a). The relationships between factors and categories in the BIM adoption framework will be demonstrated to provide insights into the framework with the use of structural equation modelling (SEM).

## 6.3 Research Methodology

SEM was adopted to confirm the developed BIM adoption framework. SEM is a popular technique for research using multiple observed variables allowing "complex phenomena to be statistically modelled and tested" (Lomax & Schumacker, 2004). Also, it can provide "the validity and reliability of observed scores from measurement instruments" (Lomax & Schumacker, 2004). According to Seo, Little, Shogren, and Lang (2016), it is a powerful and flexible analytic tool for lantern constructs and statistical assumptions. Ali, Kim, Li, and Cobanoglu (2018) highlighted the benefits of SEM towards testing the relationships. This research aims to examine and validation the variables and their relationships affecting BIM adoption. Therefore, SEM is considered appropriate for this research in which the relationship between 39 factors and 7 categories will be analysed.

The research stages are shown in Figure 6.1. Firstly, the survey was distributed to constructional professionals in New Zealand to collect the data for conducting SEM. The data was then screened to remove the inappropriate cases and to check the normal distribution of the data collected. Next, SEM was conducted with two rounds in which the measurement model and the structural model were assessed respectively. Finally, the findings and discussion were drawn from SEM.

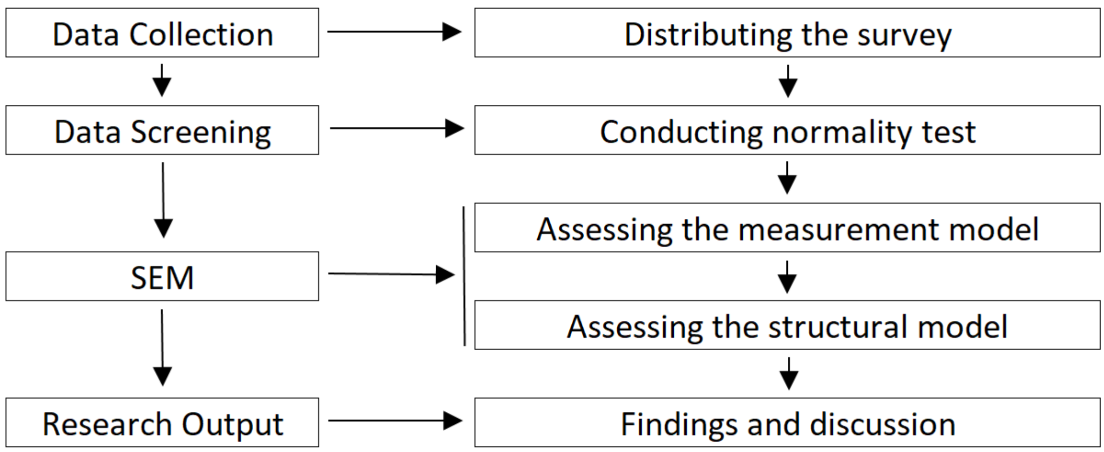



Figure 6.1. Research stages

## 6.4 Data Collection

A questionnaire survey was developed based on the categories and factors revealed in Doan et al. (2019a) research. It comprises two parts, demographics and BIM adoption framework. In the demographics part, how many BIM projects that respondents have been involved in is the main question to consider the experience of the respondents to BIM adoption. It aims to remove cases where the respondents have not been involved in any BIM project. Thirty-nine statements, see Table 6.1, were prepared for the BIM adoption framework part using a 5-point Likert scale where 1 = Strongly Disagree; 2 = Slightly Disagree; 3 = Neutral; 4 = Slightly Agree; 5 = Strongly Agree.

Table 6.1. BIM adoption framework statements

(adapted from Doan et al. (2019a))

| |
|---|
| Leadership (LEA) |
| LEA1. Our organisation has a clear BIM leadership role.<br>LEA2. Our BIM leadership team plays a strategic role (with goals and objectives) that will guide our organisation towards BIM adoption.<br>LEA3. Our BIM leadership team monitors and reviews the strategic plan regularly for BIM adoption.<br>LEA4. Our BIM leadership team communicates openly with and engages employees for BIM adoption.<br>LEA5. Our BIM leadership team is committed to continuous improvement in their own BIM skills.<br>LEA6. Our BIM leadership team is committed to continuous improvement in employees' own BIM skills. |
| Clients & Other Stakeholders (e.g., architects, contractors, MEP, QS, suppliers) (CLI) |
| CLI1. Our organisation determines clients' expectations for planning the BIM adoption.<br>CLI2. Our organisation determines stakeholders' expectations for BIM adoption.<br>CLI3. Our organisation has a clear approach to collect clients' feedback after completing BIM projects.<br>CLI4. Our organisation has a clear approach to collect stakeholders' feedback after completing BIM projects.<br>CLI5. Our organisation educates clients on BIM.<br>CLI6. Our organisation employs a standard form of contract for the procurement of BIM.<br>CLI7. Our organisation is not reluctant to share information concerning BIM adoption with other stakeholders. |
| Strategic Planning (STR) |
| STR1. Our organisation has a BIM strategic plan (e.g., BIM standards, BIM specifications, policies).<br>STR2. Our organisation involves all stakeholders in developing the BIM strategic plan.<br>STR3. Our organisation allocates the resources effectively to ensure the success of BIM adoption.<br>STR4. Our organisation translates the strategic plan for BIM adoption into specific requirements for each stakeholder.<br>STR5. Our organisation uses a formal process to track the effectiveness of the BIM strategic plan.<br>STR6. Our organisation has its BIM strategic plan reviewed and updated regularly. |
| Resources (RES) |
| RES1. Our organisation has available software for BIM adoption.<br>RES2. Our organisation has available hardware for BIM adoption.<br>RES3. Our employees have the required skills needed for BIM adoption. |

| |
|---|
| RES4. Our organisation has the financial resources for further BIM investment. |
| People (PEO) |
| PEO1. Our organisation provides the necessary training for BIM adoption (before implementing BIM).<br>PEO2. Our organisation creates an environment conducive for the employees to improve their BIM skills.<br>PEO3. Our organisation encourages employees to share their ideas to improve BIM adoption.<br>PEO4. Our employees are committed to the strategies for BIM adoption within our organisation. |
| Process (PRO) |
| PRO1. Our organisation provides adequate training to improve our employees' BIM skills (during the BIM implementation process).<br>PRO2. Our organisation develops a comprehensive BIM Execution Plan for each BIM project.<br>PRO3. Our organisation uses a formal process to track the effectiveness of implementing BIM.<br>PRO4. Our organisation reviews the BIM implementation process regularly.<br>PRO5. Our organisation communicates changes in our BIM implementation process to all employees involved in the process. |
| Results (RE) |
| RE1. In our organisation, projects implemented using BIM generally satisfy the clients' expectations.<br>RE2. In our organisation, projects implemented using BIM generally satisfy the stakeholders' expectations.<br>RE3. Our BIM leadership team is effective in BIM adoption.<br>RE4. Our organisation developed an effective BM plan for BIM adoption.<br>RE5. Our organisation developed an effective BIM implementation process for BIM adoption.<br>RE6. Our employees became capable of implementing BIM.<br>RE7. Our organisation has a positive return on investment for BIM adoption. |

This research adopted mixed method sampling techniques which are not uncommon in quantitative research (Asante, Opoku-Asare, & Wemegah, 2015; Dhillon, MZain, Singh, Kaur, & Nordin, 2016; Teddlie & Yu, 2007). The questionnaire was developed using Qualtrics and distributed on LinkedIn groups. Qualtrics assists the survey developers to send the survey to a large number of targeted participants in a short time (Erhardt, 2018). Also, the data collected from Qualtrics could be exported to Statistical Package for the Social Sciences (SPSS) directly (Erhardt, 2018; Lamberts et al., 2019). Whereas, LinkedIn has been known as a powerful professional networking tool (Schneiderman, 2016). As stated by Doan et al. (2019a) that BIM adoption in New Zealand is still in its early stages, there might be a limited number of construction professionals responding to the survey. Emails were simultaneously sent to potential respondents based on their information on LinkedIn and Architectural Designers New Zealand (ADNZ). As a result, 66 responses were received after two months when the survey was distributed.

## 6.5 Data Screening

The demographics of the responses collected were checked to ensure that the respondents either have been involved in at least one BIM project. All the respondents satisfied that criterion. The normal distribution of data was then assessed, as suggested by Ali, Rasoolimanesh, Sarstedt, Ringle, and Ryu (2018), to avoid reducing the statistical power. According to Griffin and Steinbrecher (2013) and Schneider and Wheeler-Kingshott (2014), data is normal distribution when the values of skewness and kurtosis within the range ±2 and ±3 respectively. None of the values of the collected data is outside the mentioned range proving that data is appropriate for SEM.

## 6.6 SEM

Based on the characteristics of the 39 factors affecting BIM adoption along with the number of responses received, partial least squares (PLS) SEM is considered as the most appropriate technique. Firstly, the formative measurement model was developed from 39 factors of the BIM adoption framework rather than the reflective measurement model. If the factors are not mutually interchangeable and the factors represent causes of the categories, the formative measurement model should be selected (Joseph F Hair Jr, Hult, Ringle, & Sarstedt, 2016). PLS-SEM is the most appropriate technique for the formative measurement model (Alpert, Kamins, Sakano, Onzo, & Graham, 2001). Secondly, "PLS is a more rigorous approach … avoids small sample size problem" (Henseler, Ringle, & Sinkovics, 2009; Mintu-Wimsatt & Graham, 2004), with 66 collected responses in this research. Therefore, SmartPLS was selected for the analysis.

Although the sample size and normally distributed data are not required by the PLS-SEM technique (Joe F Hair Jr, Matthews, Matthews, & Sarstedt, 2017; Julien & Ramangalahy, 2003), they were tested in this research to ensure the validity and reliability of the collected data. The normal distribution of the data was checked with the values of skewness and kurtosis above while the 10-times rule method, the most widely adopted (Kock & Hadaya, 2018), was used to check whether the sample size is appropriate for PLS-SEM. There are 7 categories in the BIM adoption framework meaning that there is a potential of having a category impacted by six other ones. In other words, the sample size required for the PLS-SEM technique should be greater than 60. Therefore, 66 collected responses are appropriate for further data analysis.

The PLS-SEM was developed based on the BIM adoption framework, see Table 6.1. It is clear from Figure 6.2 that CLI and RE have the most observed variables, with seven for each. Six measurement factors are used for LEA which is the same for STR. The least observed variables belong to RES and PEO while five factors are used to measure PRO. According to Doan et al. (2019a), LEA is the most important category to BIM adoption having impacts on all other categories including CLI, STR, RES, PEO, PRO, and RE. STR is affected by both LEA and CLI while PEO depends on LEA and RES (Doan et al., 2019a). PRO is influenced by LEA, CLI, and PEO (Doan et al., 2019a). LEA, STR, and PRO have significant impacts on RE (Doan et al., 2019a).

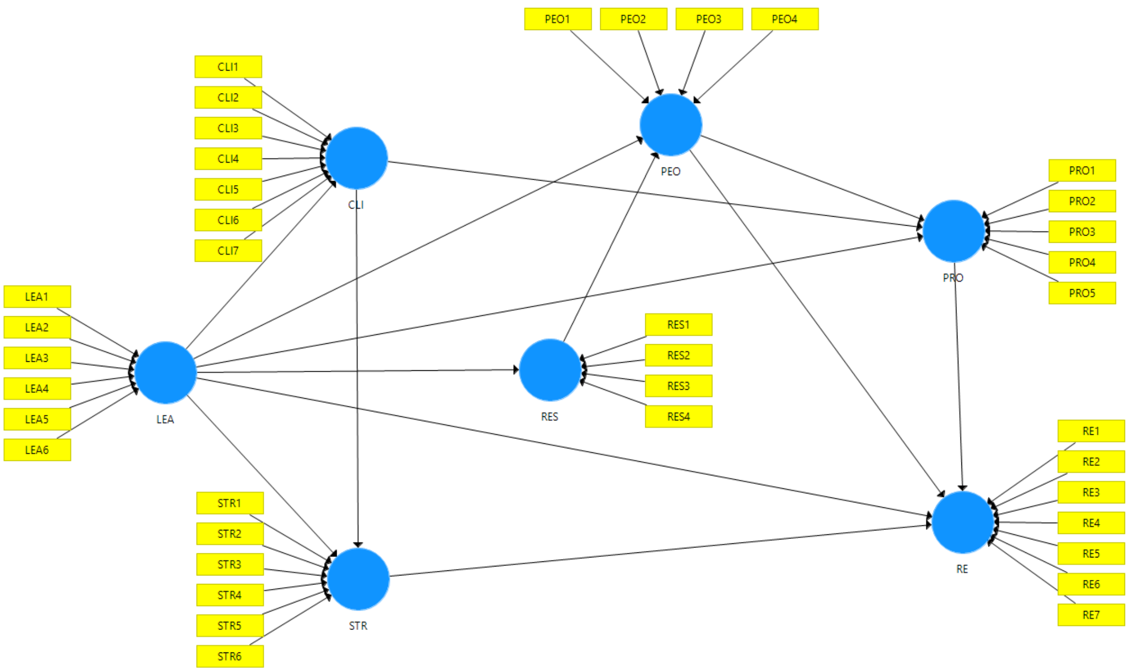



Figure 6.2. The BIM adoption PLS-SEM model

To assess the BIM adoption PLS-SEM, a two-step approach should be conducted including assessing the measurement model and the structural model (Ali, Rasoolimanesh, et al., 2018), which is described in the next sections.

### 6.6.1 Assessing the measurement model

According to Lowry and Gaskin (2014), “no single technique is universally accepted for validating formative measures.” Therefore, this research adopted the most popular approach for testing the construct validity of formative indicators, which was used in 29 studies during 2001-2015, revealed by Ali, Rasoolimanesh, et al. (2018). A 3-step approach, which was also suggested by Lowry and Gaskin (2014), includes testing the variance inflation factors (VIFs), checking the indicator weights, and checking the significance of the indicator weights. According to Joseph F Hair Jr et al. (2016), non-significant indicator weights should be retained if their outer loadings are above 0.5. Therefore, checking the significance of the indicator weights was replaced by checking the outer loadings.

Andreev, Heart, Maoz, and Pliskin (2009) stated that the VIF values for the observed variables should be less than 10 to avoid multicollinearity while Joseph F Hair Jr et al. (2016) suggested using 5.0 as the cut-off point for VIF values in the context of PLS-SEM. The results of the BIM adoption PLS-SEM indicate that the VIF values for LEA1, LEA2 and LEA6; CL3 and CLI4; STR5 and STR6; RE1 and RE2; RE4 and RE5 are greater than 5.0. Because “multicollinearity causes redundant information” (Yoo et al., 2014), those observed factors were checked to consider whether they should be removed from the model.

LEA1 and LEA2 may have a similar meaning to the respondents when they mention the leadership role. Doan et al. (2019a) highlighted the need to have clear BIM leadership role in BIM adoption framework; LEA2, therefore, was removed from the model. Towards CLI, clients could be understood as part of stakeholders. Because Doan et al. (2019a) indicated the lack of BIM understanding and lack of BIM requirements from clients, CLI4 was discarded to focus on understanding clients, CLI3. STR6 was kept by eliminating STR5 to focus on reviewing and updating the BIM strategic plan. Similar to CLI3 and CLI4, RE2 was removed to highlight clients’ expectations to BIM adoption. Regarding RE4 and RE5, RE5 was kept as it mentions about the BIM implementation process in PRO having a direct impact on RE.

After removing LEA2, CLI4, STR5, RE2, and RE4, the model was rerun to detect the multicollinearity. All the VIF values are now less than 5.0 satisfying the first condition of the construct validity of formative indicators, see Table 6.2.

Table 6.2. Results of VIFs, outer weights, outer loadings and *p*-values of the measurement model

| | VIFs | Outer weights | Outer loadings | *P*-values |
|---|---|---|---|---|
| LEA1 -> LEA | 2.867 | 0.427 | 0.913 | 0.000 |
| LEA3 -> LEA | 3.301 | 0.151 | 0.853 | 0.000 |
| LEA4 -> LEA | 4.283 | 0.053 | 0.859 | 0.000 |
| LEA5 -> LEA | 3.942 | 0.279 | 0.890 | 0.000 |
| LEA6 -> LEA | 4.998 | 0.214 | 0.877 | 0.000 |
| CLI1 -> CLI | 1.930 | 0.038 | 0.709 | 0.000 |
| CLI3 -> CLI | 1.901 | 0.286 | 0.795 | 0.000 |
| CLI5 -> CLI | 2.489 | 0.466 | 0.906 | 0.000 |
| CLI6 -> CLI | 1.724 | 0.284 | 0.779 | 0.000 |
| CLI7 -> CLI | 1.461 | 0.167 | 0.615 | 0.000 |
| STR1 -> STR | 3.626 | 0.367 | 0.910 | 0.000 |
| STR2 -> STR | 3.668 | 0.124 | 0.847 | 0.000 |
| STR3 -> STR | 2.634 | 0.232 | 0.809 | 0.000 |
| STR6 -> STR | 2.892 | 0.408 | 0.921 | 0.000 |
| RES1 -> RES | 4.848 | 0.459 | 0.936 | 0.000 |
| RES2 -> RES | 4.699 | 0.235 | 0.904 | 0.000 |
| RES3 -> RES | 1.768 | 0.415 | 0.861 | 0.000 |
| PEO1 -> PEO | 1.860 | 0.475 | 0.846 | 0.000 |
| PEO2 -> PEO | 3.521 | 0.050 | 0.855 | 0.000 |
| PEO3 -> PEO | 3.874 | 0.530 | 0.901 | 0.000 |
| PEO4 -> PEO | 3.480 | 0.093 | 0.838 | 0.000 |
| PRO1 -> PRO | 2.449 | 0.419 | 0.912 | 0.000 |
| PRO2 -> PRO | 2.689 | 0.259 | 0.836 | 0.000 |
| PRO3 -> PRO | 3.406 | 0.048 | 0.826 | 0.000 |
| PRO4 -> PRO | 4.315 | 0.195 | 0.894 | 0.000 |
| PRO5 -> PRO | 2.752 | 0.224 | 0.833 | 0.000 |
| RE1 -> RE | 1.620 | 0.019 | 0.504 | 0.000 |
| RE3 -> RE | 3.589 | 0.596 | 0.966 | 0.000 |
| RE5 -> RE | 2.846 | 0.342 | 0.901 | 0.000 |
| RE6 -> RE | 3.357 | 0.086 | 0.798 | 0.000 |
| RE7 -> RE | 2.063 | 0.060 | 0.637 | 0.000 |

After running the model to check the outer weight for each factor, the values of CL2, STR4, and RES4 are negative. They, therefore, were removed because of their poor relative contribution to the model, suggested by Ringle and Sarstedt (2016). Finally, the outer loadings along with their significance were determined with a bootstrapping procedure with 10000 subsamples; 10000 subsamples are considered appropriate to ensure the stability of the results (Romero, 2017, 2018). Table 6.2 shows that all outer loadings are greater than 0.5 and they are significant with *p*-values equal 0.000.

The reliability and validity of the construct measures of the BIM adoption PLS-SEM model with 31 factors were ensured after testing the VIFs, outer weights, and outer loadings.

### 6.6.2 Assessing the structural model

After confirming the reliability and validity of the construct measures of the model, the predictive capabilities and the relationships amongst the constructs were examined in this section. A 5-step approach was revealed as a common approach suggested by many researchers to assess the structural model (Ali, Rasoolimanesh, et al., 2018; Joseph F Hair Jr et al., 2016; Henseler et al., 2009). The approach consists of assessing the coefficient of determination ($R^2$), the path coefficient, the $f^2$ effect size, the predictive relevance ($Q^2$), and the $q^2$ effect size.

Figure 6.3 shows the $R^2$ values and the path coefficients of the model. The $R^2$ values of all the categories are greater than 0.33 indicating the substantial level of predictive accuracy (Henseler et al., 2009). To determine whether the path coefficients are appropriate, the model was run with a bootstrapping procedure with 10000 subsamples. It is clear from Table 6.3 that all the values for the path coefficients are significant with *p*-values $< 0.05$.

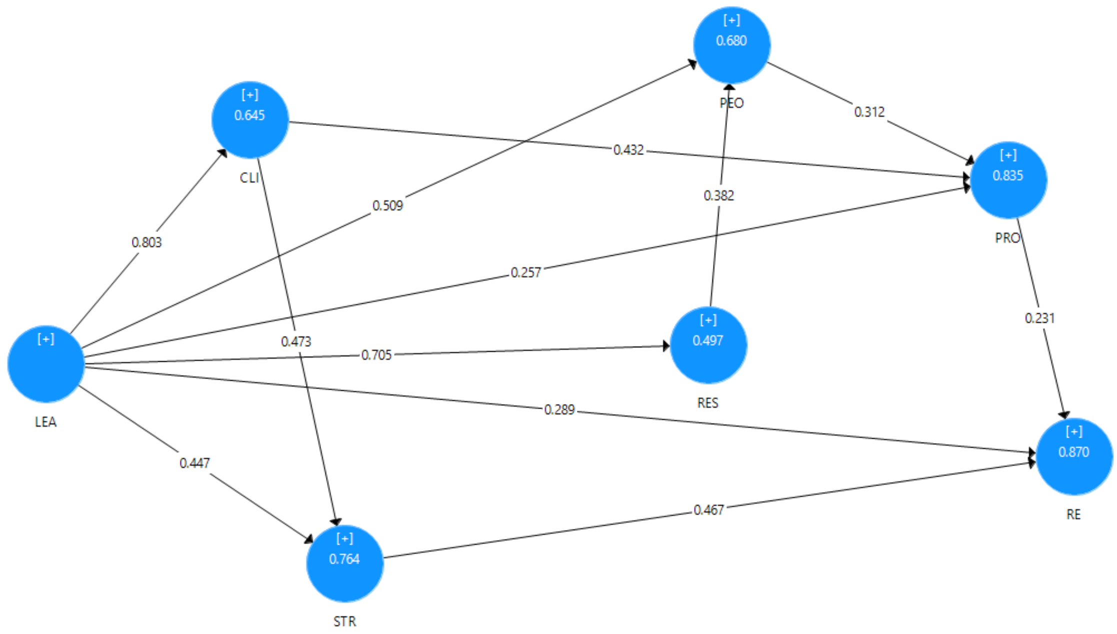



Figure 6.3. Results of the BIM adoption PLS-SEM model

Table 6.3. Significance testing results of the path coefficients

| | Original Sample | Sample Mean | Standard Deviation | *T*-statistics | *P*-values |
|---|---|---|---|---|---|
| LEA -> CLI | 0.803 | 0.813 | 0.048 | 16.668 | 0.000 |
| LEA -> STR | 0.447 | 0.448 | 0.100 | 4.455 | 0.000 |
| LEA -> RES | 0.705 | 0.723 | 0.061 | 11.615 | 0.000 |
| LEA -> PEO | 0.509 | 0.525 | 0.102 | 4.970 | 0.000 |
| LEA -> PRO | 0.257 | 0.250 | 0.100 | 2.578 | 0.010 |
| LEA -> RE | 0.289 | 0.299 | 0.097 | 2.975 | 0.003 |
| CLI -> STR | 0.473 | 0.479 | 0.095 | 4.966 | 0.000 |
| CLI -> PRO | 0.432 | 0.441 | 0.094 | 4.581 | 0.000 |
| STR -> RE | 0.467 | 0.448 | 0.089 | 5.261 | 0.000 |
| RES -> PEO | 0.382 | 0.373 | 0.108 | 3.548 | 0.000 |
| PEO -> PRO | 0.312 | 0.311 | 0.081 | 3.859 | 0.000 |
| PRO -> RE | 0.231 | 0.241 | 0.101 | 2.283 | 0.022 |

Table 6.4 shows the results of the $f^2$ effect sizes. According to Joseph F Hair Jr et al. (2016), 0.35, 0.15, and 0.02 represent for the sizes of the effect which are large, medium, and small of the exogenous latent factor. Except for the effect sizes of LEA on

PRO and RE together with the effect size of PRO on RE are small, the other effect sizes are either large or medium.

Table 6.4. Results of the $f^2$ effect sizes, the predictive relevance $Q^2$, and the $q^2$ effect sizes

| | CLI | | STR | | RES | | PEO | | PRO | | RE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $f^2$ | $q^2$ | $f^2$ | $q^2$ | $f^2$ | $q^2$ | $f^2$ | $q^2$ | $f^2$ | $q^2$ | $f^2$ | $q^2$ | $Q^2$ |
| LEA | 1.817 | 0.137 | 0.301 | 0.042 | 0.988 | 0.156 | 0.408 | 0.187 | 0.102 | 0.024 | 0.150 | 0.025 | |
| CLI | | | 0.337 | 0.197 | | | | | 0.394 | 0.158 | | | 0.348 |
| STR | | | | | | | | | | | 0.431 | 0.044 | 0.522 |
| RES | | | | | | | 0.230 | 0.083 | | | | | 0.367 |
| PEO | | | | | | | | | 0.228 | 0.043 | | | 0.449 |
| PRO | | | | | | | | | | | 0.095 | 0.023 | 0.577 |
| RE | | | | | | | | | | | | | 0.479 |

After evaluating the $f^2$ effect sizes, the predictive relevance $Q^2$ was examined with blindfolding procedure. Table 6.4 shows that all the $Q^2$ values are greater than 0 indicating the good reconstruction of the observed values (Joseph F Hair Jr et al., 2016; Henseler et al., 2009). In other words, the model has predictive relevance.

Because the $q^2$ effect size is not provided by SmartPLS, it was computed manually based on the equation below (Joseph F Hair Jr et al., 2016; Henseler et al., 2009).

$$q^2 = \frac{Q^2_{included} - Q^2_{excluded}}{1 - Q^2_{included}}$$

The results shown in Table 6.4 indicate that the $q^2$ effect sizes of the relationships amongst the categories are either small or medium, which are higher than 0.02 and 0.15 respectively (Joseph F Hair Jr et al., 2016; Henseler et al., 2009).

## 6.7 Discussion

It is clear from Table 6.2 that LEA1 has the highest and important outer weight, 0.427, and outer loading, 0.913, in the LEA category. Therefore, having a clear BIM leadership role is the most critical aspect of the LEA category. It aligns with the suggestions from Deutsch (2018) that leadership is one of the most essential criteria of BIM adoption, and the leadership role should be clarified to have a successful BIM project. Educating clients on BIM plays an essential role in the CLI category, with the significant outer weight of 0.466 and the significant outer loading of 0.906. In other words, focusing on the clients understanding should be prioritised to improve the CLI category for better BIM implementation. Rodgers et al. (2015) also mentioned the necessity of educating clients on the values of BIM projects.

Regarding the STR category, the significant factor with the highest outer weighting and outer loading belongs to STR6, with 0.408 and 0.921 respectively. It highlights the need for reviewing and updating the BIM strategic plan regularly which was also revealed as one of the responsibilities of the BIM champion in Chunduri, Kreider, and Messner (2013) research. Based on Olatunji (2011), 55% of the BIM implementation costs is for the software. This is consistent with the research results in which the BIM software is the essential factor in the RES category with the significant outer weight of 0.459 and the significant outer loading of 0.936.

Towards the PEO category, encouraging employees to share their ideas to improve BIM adoption is a significant factor with 0.530 and 0.091 as the outer weight and the outer loading respectively. Ho, Tserng, and Jan (2013) indicated the necessity of sharing of knowledge and feedback within the companies to prevent mistakes in future projects. Farnsworth, Beveridge, Miller, and Christofferson (2015) revealed that a few companies had used intranet pages for sharing BIM practices and lessons learned. Providing adequate training to improve employees BIM skills during the BIM implementation process is highlighted in the PRO category with the highest outer weight, 0.419, and outer loading, 0.912. This reflects the Zhao et al. (2016) results in which the lack of BIM expertise is one of the serious risks to BIM adoption. Interestingly, the results of BIM adoption mainly depend on the effectiveness of the BIM leadership team, with the highest outer weight, 0.596, and outer loading, 0.966.

The BIM adoption framework and five hypotheses suggested in Doan et al. (2019a) research are considered appropriate with significant path coefficients and high $R^2$ values, see Figure 6.3. LEA is the most important category to BIM adoption and impacts all other categories. LEA and CLI affect STR while PEO depends on LEA and RES. LEA, CLI, and PEO influence PRO while RE is impacted by LEA, STR, and PRO.

The $R^2$ value of RE is 0.870 meaning that 87% variations in RE are explained by LEA, CLI, STR, RES, PEO, and PRO. It is noticed that the $R^2$ value of RES is lowest compared to the rest categories, 0.497. It is understandable because the available resources for BIM adoption do not entirely depend on leadership. Based on the results of the measurement model, RE depends mainly on the BIM software with significant and highest outer weight. However, the available BIM software is still needed to be improved for specialised tasks for BIM adoption (Ignatova, Zotkin, & Zotkina, 2018). Also, the need for the strong power of computers for BIM adoption was also mentioned by Tulenheimo (2015). These explained why RE has the lowest $R^2$ values.

The reliability and validity of the BIM adoption PLS-SEM model were confirmed after examining the $f^2$ effect sizes, the predictive relevance $Q^2$, the $q^2$ effect sizes. The results show that all the categories have at least small effect sizes to the others while the value of $Q^2$ is positive indicating that the observed values are well-reconstructed and predictive relevance is achieved. To sum up, the results of the model confirmed the BIM adoption framework developed by Doan et al. (2019a).

It is clear from Table 6.5 that LEA is the most important category to BIM adoption when it affects all other categories in the BIM adoption framework. This is consistent with the internationally recognised frameworks such as the Baldrige Excellence Framework (BEF), European Foundation for Quality Management Excellence Model (EFQMEM), and Australian Business Excellent Framework (ABEF) when LEA is the first and foremost factor for all of them (EFQM, 2018; NIST, 2015; SAI-Global, 2011). It is noticed that STR also plays a pivotal role to RE besides LEA. Therefore, the factors in STR should also be focused to improve the quality of a BIM project.

Table 6.5. The effects amongst categories of the BIM adoption framework

| | Original Sample | Sample Mean | Standard Deviation | *T*-statistics | *P*-values |
|---|---|---|---|---|---|
| LEA -> CLI | 0.802 | 0.813 | 0.048 | 16.690 | 0.000 |
| LEA -> STR | 0.829 | 0.843 | 0.040 | 20.589 | 0.000 |
| LEA -> RES | 0.704 | 0.731 | 0.058 | 12.146 | 0.000 |
| LEA -> PEO | 0.779 | 0.795 | 0.055 | 14.288 | 0.000 |
| LEA -> PRO | 0.847 | 0.856 | 0.036 | 23.395 | 0.000 |
| LEA -> RE | 0.872 | 0.882 | 0.031 | 28.412 | 0.000 |
| CLI -> STR | 0.462 | 0.469 | 0.098 | 4.724 | 0.000 |
| CLI -> PRO | 0.430 | 0.443 | 0.095 | 4.528 | 0.000 |
| CLI -> RE | 0.324 | 0.323 | 0.073 | 4.457 | 0.000 |
| STR -> RE | 0.481 | 0.460 | 0.092 | 5.254 | 0.000 |
| RES -> PEO | 0.392 | 0.379 | 0.110 | 3.573 | 0.000 |
| RES -> PRO | 0.123 | 0.118 | 0.046 | 2.647 | 0.008 |
| PEO -> PRO | 0.313 | 0.311 | 0.081 | 3.877 | 0.000 |
| PEO -> RE | 0.075 | 0.077 | 0.038 | 1.971 | 0.049 |
| PRO -> RE | 0.238 | 0.246 | 0.099 | 2.414 | 0.016 |
| RES -> RE | 0.029 | 0.030 | 0.018 | 1.639 | 0.101 |

## 6.8 Conclusion

This research aims to examine the relationships amongst factors affecting BIM adoption in New Zealand. Specifically, a BIM adoption framework, with 7 main categories along with 39 factors, and five hypotheses developed by Doan et al. (2019a) were examined. The framework was assessed by checking the measurement model, with evaluating the VIFs, outer weights, outer loadings, and *p*-values, along with checking structural model, with evaluating $R^2$, $f^2$, $Q^2$, and $q^2$. The results indicate that 31 factors amongst 39 are reliable and valid to evaluate a BIM project, see Table 6.6.

Table 6.6. Final BIM adoption framework

| Leadership |
|---|
| 1. The organisation has a clear BIM leadership role.<br>2. The BIM leadership team monitors and reviews the strategic plan regularly for BIM adoption.<br>3. The BIM leadership team communicates openly with and engages employees for BIM adoption.<br>4. The BIM leadership team is committed to continuous improvement in their own BIM skills.<br>5. The BIM leadership team is committed to continuous improvement in employees' own BIM skills. |
| Clients & Other Stakeholders (e.g., architects, contractors, MEP, QS, suppliers) |
| 1. The organisation determines clients' expectations for planning the BIM adoption.<br>2. The organisation has a clear approach to collect clients' feedback after completing BIM projects.<br>3. The organisation educates clients on BIM.<br>4. The organisation employs a standard form of contract for the procurement of BIM.<br>5. The organisation is not reluctant to share information concerning BIM adoption with other stakeholders. |
| Strategic Planning |
| 1. The organisation has a BIM strategic plan (e.g., BIM standards, BIM specifications, policies).<br>2. The organisation involves all stakeholders in developing the BIM strategic plan.<br>3. The organisation allocates the resources effectively to ensure the success of BIM adoption.<br>4. The organisation has its BIM strategic plan reviewed and updated regularly. |
| Resources |
| 1. The organisation has available software for BIM adoption.<br>2. The organisation has available hardware for BIM adoption.<br>3. The employees have the required skills needed for BIM adoption. |
| People |
| 1. The organisation provides the necessary training for BIM adoption (before implementing |

| |
|---|
| BIM). |
| 2. The organisation creates an environment conducive for the employees to improve their BIM skills. |
| 3. The organisation encourages employees to share their ideas to improve BIM adoption. |
| 4. The employees are committed to the strategies for BIM adoption within the organisation. |
| Process |
| 1. The organisation provides adequate training to improve their employees' BIM skills (during the BIM implementation process). |
| 2. The organisation develops a comprehensive BIM Execution Plan for each BIM project. |
| 3. The organisation uses a formal process to track the effectiveness of implementing BIM. |
| 4. The organisation reviews the BIM implementation process regularly. |
| 5. The organisation communicates changes in the BIM implementation process to all employees involved in the process. |
| Results |
| 1. In the organisation, projects implemented using BIM generally satisfy the clients' expectations. |
| 2. The BIM leadership team is effective in BIM adoption. |
| 3. The organisation developed an effective BIM implementation process for BIM adoption. |
| 4. The employees became capable of implementing BIM. |
| 5. The organisation has a positive return on investment for BIM adoption. |

It was found out that Leadership is the most important category to BIM adoption with significant impacts on the rest categories. A clear BIM leadership role is the most crucial factor in Leadership. It, therefore, is recommended that BIM adopters should pay attention to the leadership especially with having a clear BIM leadership. Also, BIM adopters are suggested to review and update the BIM strategic plan regularly for better BIM implementation. This is because Strategic Planning has the second most impact on the results of BIM adoption, and it was most affected by reviewing and updating the BIM strategic plan.

The research contributes to the construction industry by providing insights into categories and factors affecting BIM adoption. How the categories affecting each other was revealed besides highlighting the most important factors within the categories.

BIM adopters, therefore, could use the research results as a guideline to plan for their BIM projects to improve the results of the BIM projects.

The BIM adoption framework was developed for the New Zealand context. It should be adjusted to use for other countries. Also, the suggested BIM categories and factors in the BIM adoption framework may not cover all the aspects of BIM adoption. For example, the currently limited technology for BIM adoption was not included leading to the low $R^2$ value for the resources.

The relationship of BIM and Green Star in New Zealand was found out in Doan et al. (2019d) research which was then confirmed in Doan et al. (2019b) research. These studies revealed that BIM adoption could have a substantial impact on Green Star certification uptake if BIM adopters could achieve BIM level 3. Base on Doan et al. (2019a), the developed factors in the BIM framework could be used to predict the BIM maturity level. Further studies, therefore, will develop a BIM-Green Star system dynamics modelling based on the BIM adoption framework to forecast the BIM development and when it could have impacts on Green Star certification uptake in New Zealand.

# Chapter 7 System Dynamics Modelling of Building Information Modelling (BIM) and Its Relationship with Green Star

## 7.1 Prelude

Chapter 5 and Chapter 6 developed and validated a BIM adoption framework while Chapter 2 , Chapter 3 , and Chapter 4 highlighted the impacts of BIM on Green Star uptake. Based on the results of the previous chapter, this chapter develops a BIM-Green Star system dynamics model. It aims to provide insights into BIM and Green Star development over time. What are the critical categories affecting BIM and Green Star uptake?; How do those categories affect BIM and Green Star uptake?; and What is the most important category affecting BIM and Green Star uptake? are answered in this chapter.

After running the developed SD model, the results indicate that a construction organisation in New Zealand could achieve BIM level 2 in 5 years. The effort has to be made by the organisation in an additional 3 years to reach BIM level 3. At the end of year 9 is the appropriate time to have BIM integrated with Green Star. Clients & Other Stakeholders, Process, and Results are the categories having direct impacts on the relationship between BIM and Green Star. Different strategies for BIM and Green Star development were tested using the developed SD model to identify the most appropriate ones. Leadership should be primarily focused owing to its significant impact on BIM and Green Star adoption, followed by Clients & Other Stakeholders, and Strategic Planning.

The developed SD model could display the behaviour of each category over time. Construction organisations could use the SD model to improve their understanding towards BIM and Green Star adoption. Furthermore, the model could be adapted with the inputs provided by those organisations.

## 7.2 Introduction

Owing to the potential benefits of Building Information Modelling (BIM) that could transform the construction industry, BIM has been mandated for certain types of projects in many countries (Edirisinghe & London, 2015; McAuley, Hore, & West, 2017). Newton and Chileshe (2012) revealed 9 benefits of adopting BIM to the South

Australia construction industry. While 18 BIM drivers were identified by Eadie, Odeyinka, et al. (2013) in the UK context. Recognising the vital role of BIM adoption to the construction industry, the Cabinet Office (CO) in the UK planned to mandate BIM level 2 by 2016 (CO, 2011). Whereas, the French government decided to adopt BIM for 500,000 houses developed in 2017 (Bhatti et al., 2018). Incentives were provided for early BIM adopters in Singapore to increase the BIM adoption rate. Specifically, $6 million was funded for BIM investment to cover the training, consultancy, software, and hardware cost in Singapore (McAuley et al., 2017). Also, Construction Productivity and Capability Fund was established to provide $250 million for BIM activities in Singapore (McAuley et al., 2017). As a result, BIM has been an attractive topic to researchers globally.

In contrast with the current intense focus of the other countries, BIM has still in its early stages in New Zealand with little effort from the government, construction organisations, and researchers (Doan et al., 2019c). The BIM Acceleration Committee (BAC) and BIM Tertiary Education were established in 2014 to encourage BIM development in New Zealand (BAC, 2019a, 2019b). However, only a few guidelines and resources were provided by these organisations (BAC, 2019c).

Regarding the effort from the BIM publications in New Zealand, only three journal papers were found in the Scopus database with the keywords (“BIM” + “New Zealand”). However, BIM as a critical topic focusing on the New Zealand context was only researched by one of them. Harrison and Thurnell (2015) revealed the potential benefits and barriers of adopting 5D BIM by quantity surveyors to the New Zealand construction industry.

A research project has been conducted to provide insights into BIM adoption in New Zealand. Firstly, potential benefits, barriers/challenges, and solutions for BIM adoption in the New Zealand construction industry were revealed by Doan et al. (2019c). Doan et al. (2019c) highlighted improving BIM understanding and the need for more guidelines to support BIM adopters. Doan et al. (2019a), therefore, developed a BIM framework with essential categories and factors affecting BIM adoption in New Zealand. This is to provide insights into BIM understanding, and it also can be used to evaluate the BIM practice of the BIM adopters. The BIM adoption framework was then validated and confirmed by Doan et al. (2019e). Besides, Doan et al. (2019c) stated that adopting BIM could improve the sustainability of construction projects. The relationship between BIM and Green Star was then examined. Doan et al. (2019b) and Doan et al. (2019d) revealed the potential benefits, barriers/challenges, and solutions of the integration of BIM and Green Star.

This research, a next stage of the research project, aims to develop a system dynamics (SD) model to examine the BIM implementation over time and determine the appropriate time for BIM and Green Star integration. How the key categories in the BIM adoption framework behave over the years is examined. Also, the development of the BIM maturity level could be forecasted. Furthermore, different strategies to improve the BIM maturity level are tested to determine the best strategy for BIM adoption.

## 7.3 Research Methodology

SD modelling was adopted to examine the BIM development and its relationship with Green Star in this research. SD modelling is a modelling technique used to "analyse large-scale complex management problems and evaluate long-term behaviour of real-world systems" (Doan & Chinda, 2016; Li Hao, Hill, & Yin Shen, 2008). SD modelling is employed to enhance knowledge and understanding of the system, and to discover strategies that improve system behaviour (Albin et al., 2001; Doan & Chinda, 2016; Ogunlana et al., 2003; Richardson & Pugh III, 1981). Also, it is "best suited to handle complex dynamic systems involving nonlinear relationships and both 'hard' and 'soft' data" (Tang, Ng, & Skitmore, 2019). Furthermore, it is stated as a useful method to modellers which could provide insights quickly with low cost (Pienaar et al., 2015).

SD modelling has been used frequently in recent research in the construction area. Jokar and Mokhtar (2018), for example, developed a cement SD model to measure the $CO_2$ released in the cement industry. Whereas, a construction waste SD model was built by Ding, Zhu, Tam, Yi, and Tran (2018) to assess the impacts of waste reduction on environmental benefits. Nasir and Hadikusumo (2018) investigated the relationship between owners and contractors towards contract management functions with the use of SD modelling. Abotaleb and El-adaway (2018) provided insights into out-of-sequence work in construction projects through SD modelling. As a result, SD modelling is considered as a suitable method for this research.

Amongst popular software programs used for SD modelling such as Vensim, Dynamo, and AnyLogic, iThink is selected for this research. This is because “it is a powerful tool for communicating interdependencies between processes and problems” (J. L. J. Hao et al., 2010; Yao & Hao, 2014). Also, it provides an intuitive icon-based interface that could simplify the modelling stages (J. L. J. Hao et al., 2010; Hongping Yuan, 2012).

## 7.4 Development of a Dynamic Model of BIM and Its Relationship with Green Star

### 7.4.1 BIM element

According to Doan et al. (2019a) and Doan et al. (2019e), there are seven categories affecting BIM adoption in New Zealand. They are Leadership (LEA), Client & Other Stakeholders (CLI), Strategic Planning (STR), Resources (RES), People (PEO), Process (PRO), and Results (RE). Structural equation modelling (SEM) was adopted to determine the relationships between categories affecting BIM adoption in Doan et al. (2019e) research. The numbers shown in Figure 7.1 are the path coefficients representing the impacts between categories. For example, 0.705 represents for the impact of LEA on RES; it means that when LEA goes up by 1 standard deviation, RES goes up by 0.705.

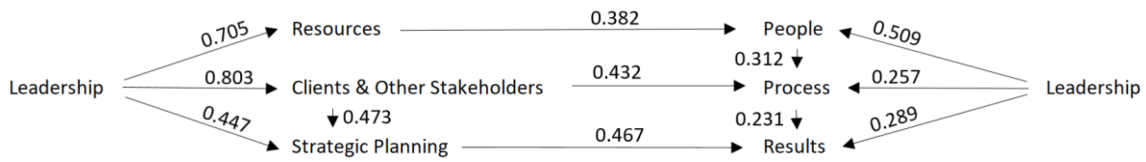
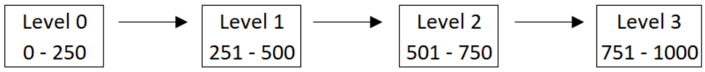



Figure 7.1. BIM element sectors

(adapted from Doan et al. (2019e))

Based on Doan et al. (2019a), the BIM maturity level could be predicted by measuring the development of LEA, CLI, STR, RES, PRO, PRO, and RE. How to assess the BIM maturity level is indicated in Figure 7.2. To achieve BIM level 3, for example, the total score for 7 categories mentioned above should be higher or equal to 751.

**BIM Maturity Level**




| **Sector** | **Maximum Score** |
|---|---:|
| LEA | 110 |
| CLI | 83 |
| STR | 83 |
| RES | 83 |
| PEO | 83 |
| PRO | 83 |
| RE | 475 |
| Total | 1000 |

Figure 7.2. BIM maturity level assessment

From the findings of Doan et al. (2019a) and Doan et al. (2019e), the BIM element of the SD model was developed, see Figure 7.3.

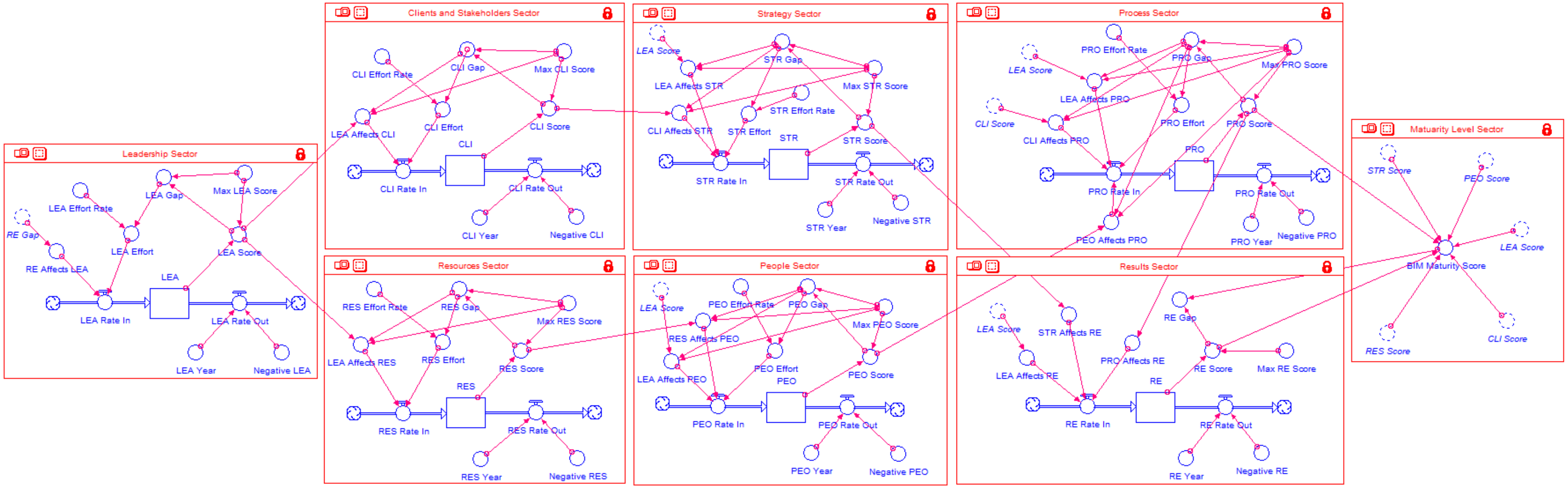



Figure 7.3. BIM element of the SD model

The BIM SD model consists of 8 sectors. 7 sectors represent 7 categories affecting BIM adoption while the relationships between sectors were displayed using arrows. For example, the arrow from the *LEA Score* to *LEA Affects RES* indicates the impact of LEA on RES. Whereas, the last sector assessing the BIM maturity level by calculating the total score of those 7 sectors as below:

*BIM Maturity Score = LEA Score + PEO Score + PRO Score + RES Score + RE Score + CLI Score + STR Score*.

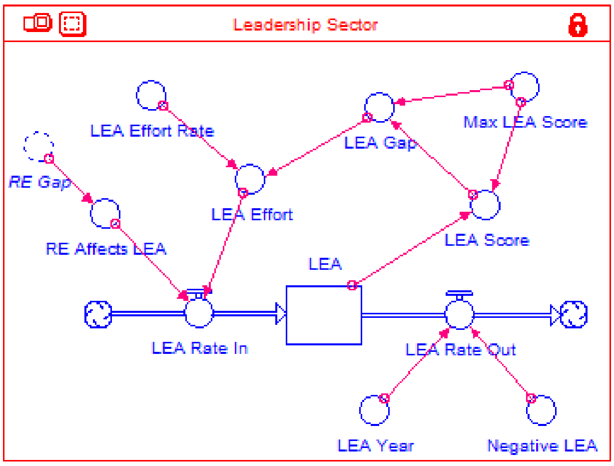



Figure 7.4. LEA sector

Figure 7.4 provides a simple presentation of the LEA sector. *LEA Score* is based on the LEA stock, flows, and limited by *Max LEA Score*. *LEA Rate In* depends on *RE Affects LEA* and *LEA Effort*.

Figure 7.4 can be explained as follows: When the value of *BIM Maturity Score* is low, or *RE Score* is low (*RE Score* account for 47.5% of *BIM Maturity Score*), the value of *RE Gap* is high. This forces the organisation to focus on improving LEA because LEA is the most crucial category affecting BIM adoption (Doan et al., 2019a; Doan et al., 2019e). In other words, *RE Gap* affects *RE Affects LEA*. Also, the organisation may consider making a continuing effort with *LEA Effort* when the value of *LEA Score* is low leading to the high value of *LEA Gap*. As a result, the value of *LEA Score* increases with an increased value of *LEA Rate In* depended on the values of *RE Affects LEA* and *LEA Effort*. It is noticed that the values of *LEA Score* and *LEA Gap* are limited by 110 while it is 475 for *RE Gap*. Furthermore, the value of *LEA Score* could be deducted if there are problems with the LEA category causing *LEA Rate Out*. For example, a BIM leader may leave the organisation which leaves the organisation with an unclear BIM leadership role. The value of *LEA Score*, therefore, decreases.

LEA has impacts on the rest of the sectors displayed by arrows from LEA sector to the rest of the sectors. How LEA impacts the rest sector were indicated in Figure 7.1. Once the value of *LEA Score* is determined, the values of *CLI Score*, *STR Score*, *RES Score*, *PEO Score*, *PRO Score*, *and RE Score* are determined. Then, the *BIM Maturity Score* is measured.

### 7.4.2 BIM and Green Star element

Doan et al. (2019d) and Doan et al. (2019b) revealed that BIM adoption could potentially enhance Green Star certification uptake. However, barriers/challenges to the integration of BIM and Green should be solved first. Amongst solutions provided by Doan et al. (2019d) and Doan et al. (2019b), improving BIM adoption plays a vital role. Educating clients and stakeholders on BIM implementation was identified as the first solution to the integration (Doan et al., 2019b; Doan et al., 2019d), which is also the factor affecting the CLI category (Doan et al., 2019a; Doan et al., 2019e). Also, the BIM process, related to the PRO category, was suggested to integrate with the Green Star process (Doan et al., 2019a; Doan et al., 2019b; Doan et al., 2019d; Doan et al., 2019e).

Furthermore, showcasing the benchmark projects is necessary to encourage people to adopt BIM and Green Star (Doan et al., 2019b; Doan et al., 2019d). In other words, the results of the BIM project should be beneficial to BIM adopters, which is related to RE category. Finally, BIM level 3 should be achieved before integrating it with Green Star (Doan et al., 2019b; Doan et al., 2019d). The value of *BIM Maturity Score* is expected to be over 750 to be adequately integrated with Green Star.

As a result, the BIM and Green Star element of the SD model was developed, see Figure 7.5. As mention above that BIM and Green Star integration depends on four factors of BIM adoption, *BIM and Green Star Integration* depends on *CLI Level*, *PRO Level*, *RE Level*, and *BIM Maturity Level*. The levels of CLI, PRO, RE, and BIM maturity are calculated based on the scores provided in Figure 7.2.

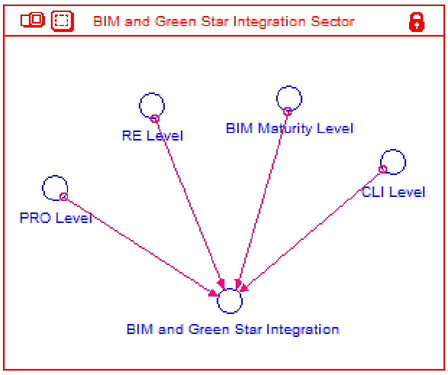



Figure 7.5. BIM and Green Star element of the SD model

The final SD model of BIM and its relationship with Green Star is provided in Figure 7.6. It consists of 2 elements, BIM element and BIM and Green Star element, with a total of 9 sectors.

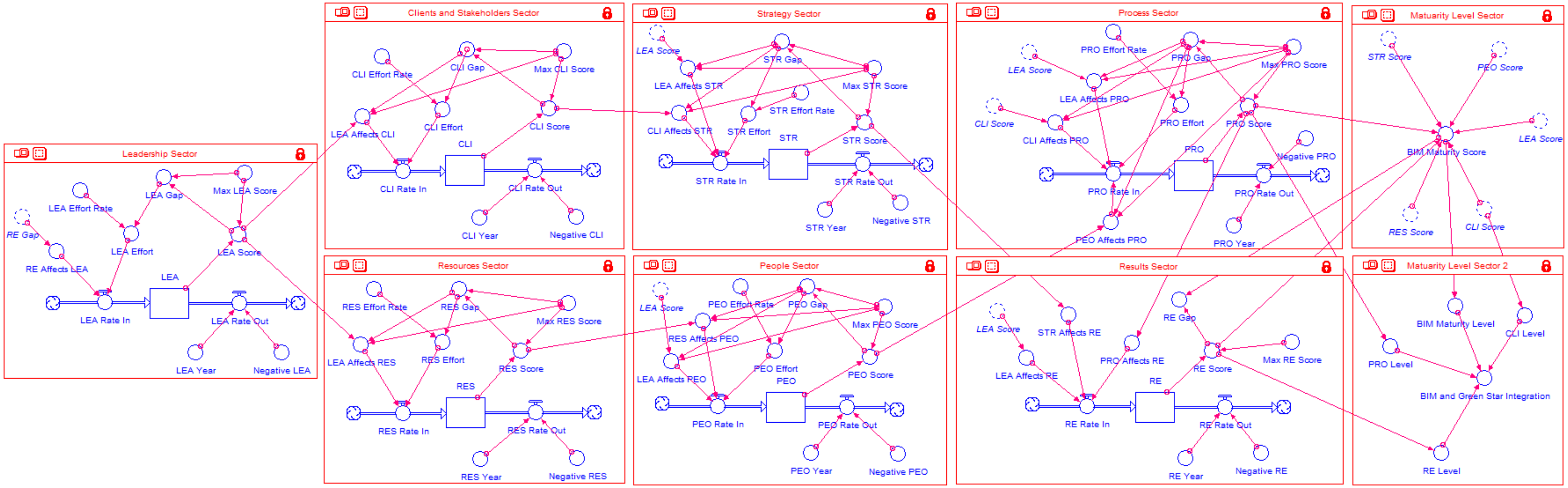



Figure 7.6. BIM adoption and its relationship with Green Star SD model

## 7.5 Simulation Results and Discussion

The SD model of BIM adoption and its relationship with Green Star was run, and the simulation results are illustrated in Figure 7.7 and Figure 7.8.

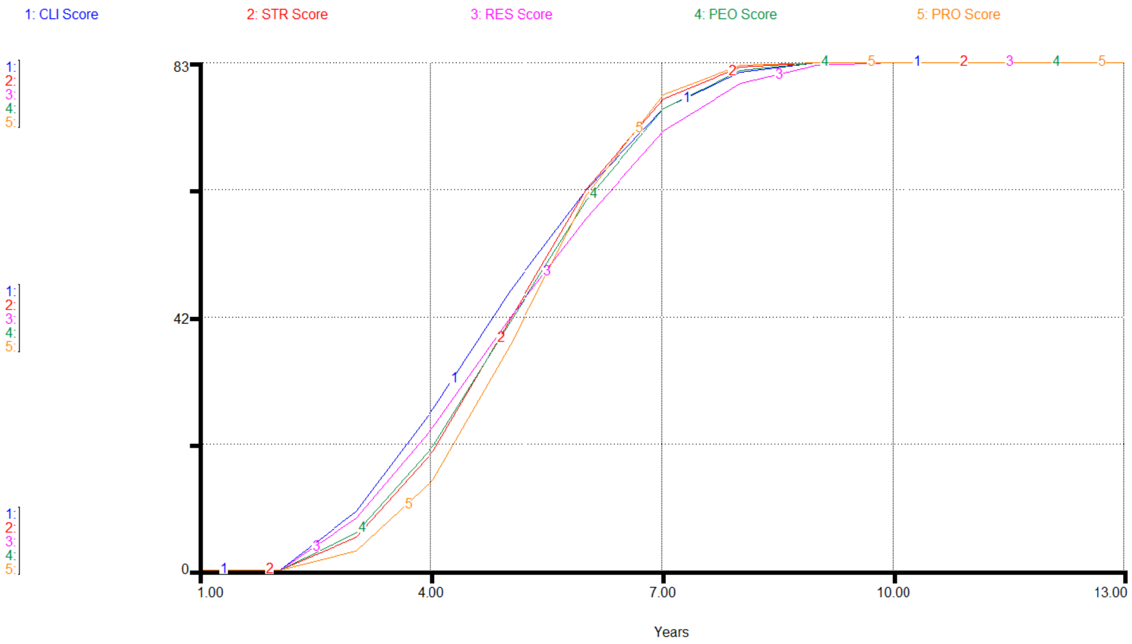



Figure 7.7. Results of *CLI Score*, *STR Score*, *RES Score*, *PEO Score*, and *PRO Score*

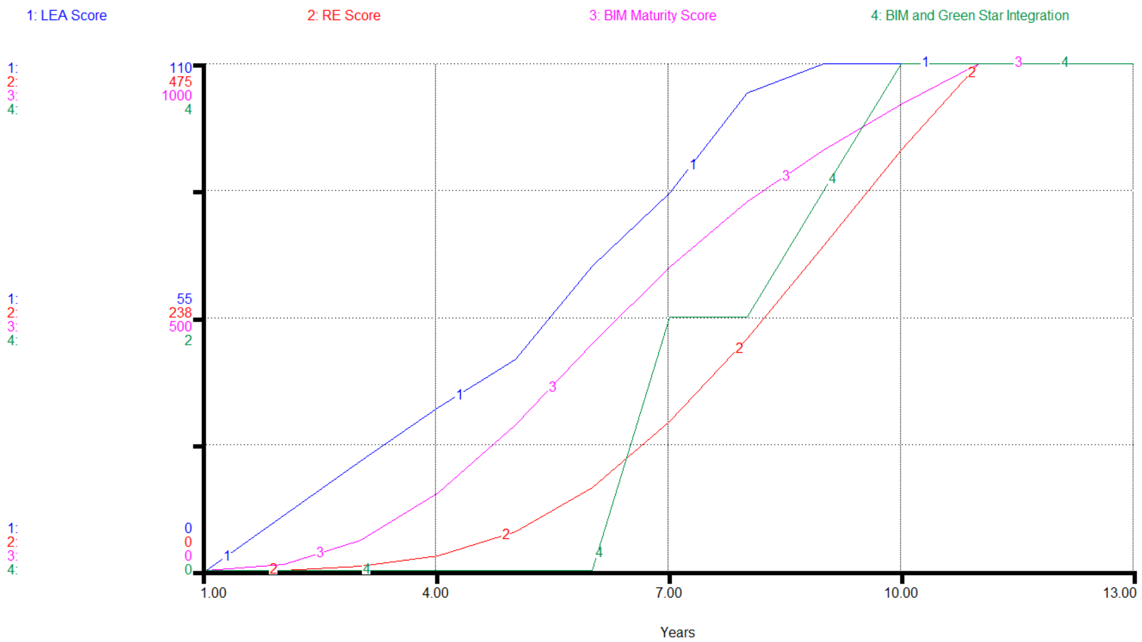



Figure 7.8. Results of *LEA Score*, *RE Score*, *BIM Maturity Score*, and *BIM and Green Star Integration*

It is clear from Figure 7.7 and Figure 7.8 that the values of *LEA Score*, *CLI Score*, *STR Score*, *RES Score*, *PEO Score*, and *PRO Score* are maximum almost simultaneously at the end of year 8. Also, they show a similar trend in their development. Whereas, *RE Score* and *BIM Maturity Score* achieve their highest scores at the end of year 10. BIM level 3 is completed at the end of year 8 when the value of *BIM Maturity Score* is higher than 750. In other words, it takes 8 years for a construction organisation to reach BIM level 3 from BIM level 0. It is worth noticing that BIM level 2 is achieved after 5 years adopting BIM. Regarding *BIM and Green Star Integration*, BIM could be integrated with Green Star after year 5 when the values of *CLI Score* and *PRO Score* are appropriate. At the end of year 9 is a perfect time for integrating BIM with Green Star when all requisite criteria are achieved for the integration. In other words, BIM level 3 should be completed before incorporating it with Green Star.

The research results are considered appropriate because they are consistent with existing literature. CO (2011) proposed a five-year 2011-2016 BIM plan to mandate BIM level 2 by 2016, which is precisely the same as the simulation results. Also, Infrastructure and Projects Authority (IPA) (2016) set up an objective to gradually move to BIM level 3 during 2017-2020. Furthermore, a few construction organisations have achieved BIM level 3 in Australia (Dainty et al., 2017; M Reza Hosseini et al., 2016) and New Zealand (Doan et al., 2019b).

Regarding the integration of BIM and Green Star, the results are similar to the current practice. Using BIM to support green rating systems was researched a decade ago (Azhar & Brown, 2009). Around a third of LEED (Leadership in Energy & Environmental Design) credits were expected to be achieved with the use of BIM in the research conducted in 2011 (Azhar et al., 2011). Whereas, adopting BIM could help to achieve around a quarter of BEAM (Building Environmental Assessment Method) Plus in the research conducted in 2014 (J. K.-W. Wong & Kuan, 2014). In 2016, Solla, Ismail, and Yunus (2016) stated that 44% of BEAM Plus credits could be attained by using BIM. These studies validate the results of this research in which BIM could be integrated with Green Star to a certain level during the first 7 years.

It is noticed that there is still no evidence showing the integration of BIM and green rating systems in practice currently. This is because 6D BIM, utilising BIM to improve the sustainability of construction projects related to integrating BIM with green rating systems, has not been reached (Olawumi, Chan, Wong, & Chan, 2018). According to the BIM maturity model developed by Bew and Richards (2008), 6D BIM can be reached when BIM level 3 is achieved.

The SD model forecasts that a construction organisation could achieve BIM level at the end of year 8 in case they focus on promoting BIM adoption. However, it is worth noticing that achieving BIM level 3 could be a challenge in reality. Besides facing technological challenges, Gupta, Cemesova, Hopfe, Rezgui, and Sweet (2014) highlighted the fact that the organisations hesitate to go for level 3, which could be because of the legal issues such as intellectual property. Therefore, it may take a longer time for an organisation to achieve BIM level 3 in reality. Philp (2015) revealed that it could take twice as long to reach a higher BIM level.

Consequently, the variables of the SD model were adjusted. *LEA Rate In* now, for example, not only depends on *RE Affects LEA* and *LEA Effort* but also *BIM Maturity Level*. Figure 7.9 shows the results of *BIM Maturity Score* when the variables were adjusted. Although *BIM Maturity Score* has a similar pattern in both Figure 7.8 and Figure 7.9, it takes a longer time to achieve level 3 in Figure 7.9. Specifically, the value of *BIM Maturity Score* is higher than 750 at the end of year 14. Interestingly, the results are identical with the strategy planned by the Centre for Digital Built Britain (CDBB) (2015). In other words, BIM level 3 is expected to be attained in 14 years, from 2011 to 2025 (CDBB, 2015).

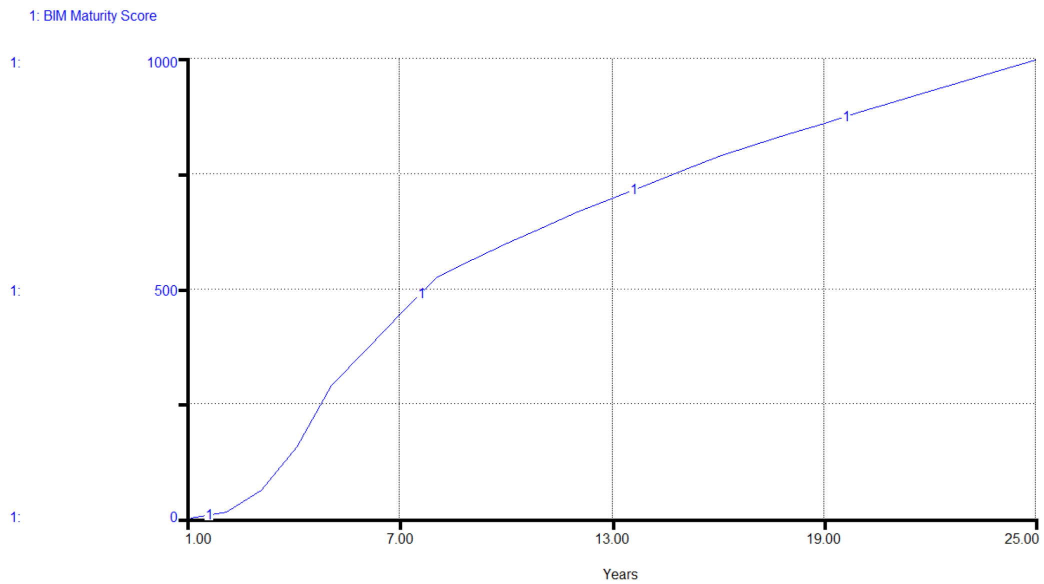



Figure 7.9. Results of *BIM Maturity Score*

## 7.6 Model Validation

Various tests were adopted in this research to build confidence for the SD model.

### 7.6.1 Structural verification test

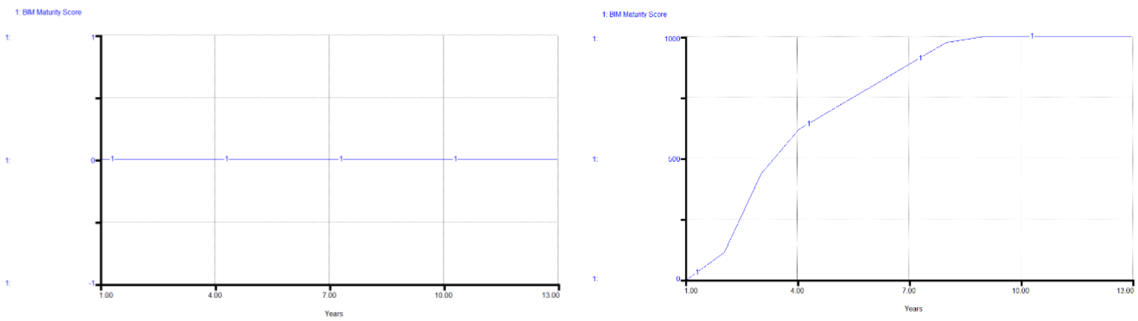
The purpose of this test is to compare the structure of the model to the structure of the real system (Bala, Arshad, & Noh, 2017; Ding et al., 2018; Forrester & Senge, 1980). The structure of this model was developed based on two elements, the BIM element and the BIM and Green Star element. The BIM element was established based on exploratory sequential mixed methods used in Doan et al. (2019c), Doan et al. (2019a), and Doan et al. (2019e). In other words, the BIM element was verified through qualitative and quantitative approaches in which the real system of BIM adoption was examined.

Exploratory sequential mixed methods with the combinations of qualitative and quantitative approaches were also used to examine the BIM and Green Star integration element. Specifically, the BIM and Green Star element was developed based on the findings of Doan et al. (2019d) and Doan et al. (2019b). Furthermore, the simulation results of the SD model proved the accuracy of the model when the BIM maturity level revealed from the results are the same with BIM adoption in the UK. As a result, the SD model structure was verified.

### 7.6.2 Extreme condition test

Extreme condition test has been considered as one of the most effective tests for building the confidence of the SD model (Bala et al., 2017; Ding et al., 2018; Forrester & Senge, 1980). It could detect flaws in the model and enhance the usefulness of the model by analysing policies forcing the model to operate outside historical regions of behaviour (Bala et al., 2017; Forrester & Senge, 1980).

In this research, two extreme conditions were set for *RE Affects LEA*, with extreme values of 0% and 100%. In other words, the purpose of the test is to examine how the models behave when an organisation does not want to invest in BIM and when they entirely focus on BIM to solve *RE Gap* 100%. The results of *BIM Maturity Score* are expected to be 0 for the first scenario. Whereas, the results of *BIM Maturity Score* are higher than the results provided in the based case in the simulation results in the same period.




a) Extreme value = 0% b) Extreme value = 100%

Figure 7.10. Results of the extreme condition test

It is clear from Figure 7.10 that the values for *BIM Maturity Score* are 0 for the 13-year period. While an organisation could achieve BIM level 3 in year 5 if they focus on solving 100% *RE Gap*, which is 3 years shorter than the based case. The results of the extreme condition test indicate that the model behaves reasonably and consistent with the real system.

### 7.6.3 Behaviour-sensitivity test

The purpose of this test is to examine the behaviour of the model when the values of the parameters are changed (Bala et al., 2017; Forrester & Senge, 1980). The behaviour-sensitivity test was conducted by changing the values of the parameters of 6 categories affecting the results of BIM adoption. Specifically, the values of *LEA Effort Rate*, *CLI Effort Rate*, *STR Effort Rate*, *RES Effort Rate*, *PEO Effort Rate*, and *Process Effort Rate* was changed. Similar scenarios were developed for those parameters as follows:

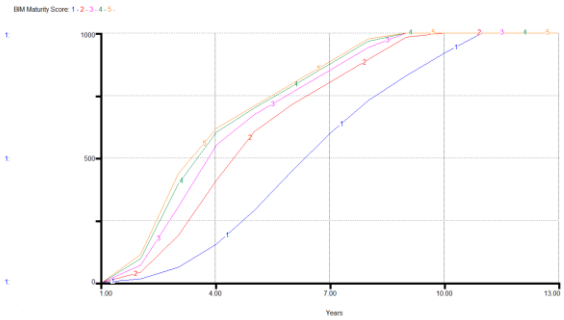
- Scenario 1: Parameter value = 0
- Scenario 2: Parameter value = 0.25
- Scenario 3: Parameter value = 0.5
- Scenario 4: Parameter value = 0.75
- Scenario 5: Parameter value = 1

In scenario 1, for example, *LEA Rate In* just depends on *RE Affects LEA*. In other words, the organisation only focuses on reducing *RE Gap* value without making additional effort to reduce *LEA Gap*. Whereas, the organisation heavily focuses on reducing *LEA*

*Gap* value besides *RE Gap value* in scenario 5. Consequently, BIM level 3 is expected to be achieved quicker in scenario 5 compared to scenario 1.

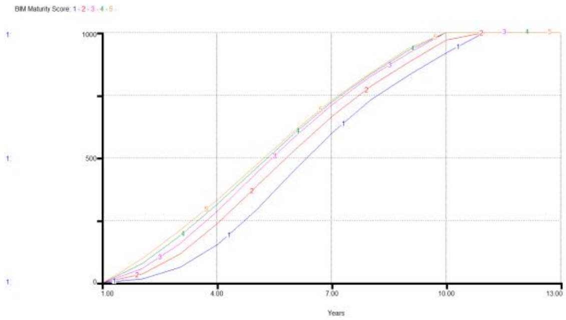
It is clear from Figure 7.11 that changing parameter values affects the values of *BIM Maturity Score* but not its pattern. In other words, the patterns of the model behaviour are not sensitive to the changes in the parameters. The model, therefore, passes the behaviour-sensitivity test. Furthermore, the results in Figure 7.11 reveal the importance of focusing on reducing *LEA Gap* leading to the sooner BIM level 3 could be achieved. There is a big gap between scenarios 1 and 2; focusing on reducing 25% of *LEA Gap* could reduce the time for the organisation to reach BIM level 3, 2 years shorter. Besides, reducing *CLI Gap* and *STR Gap* is suggested because of the gap between scenarios 1 and 2.

Consequently, the confidence of the model was confirmed with the use of structural verification, extreme condition test, and behaviour-sensitivity test.



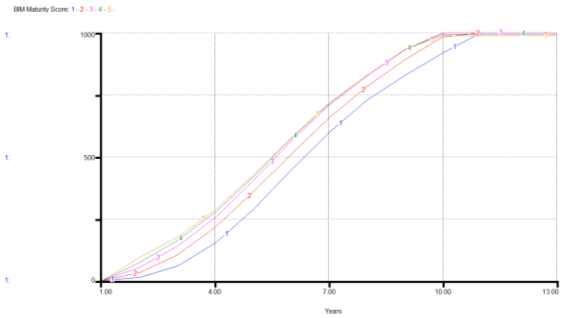
a) LEA Effort Rate

1: 0; 2: 0.25; 3: 0.5; 4: 0.75; 5: 1



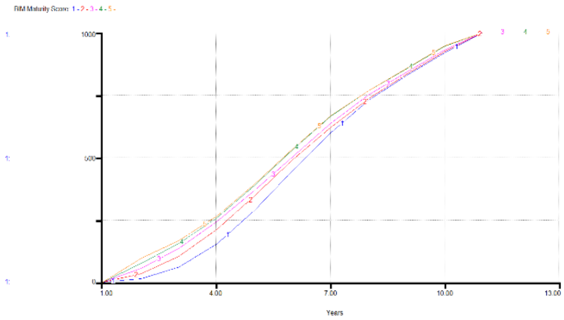
b) CLI Effort Rate

1: 0; 2: 0.25; 3: 0.5; 4: 0.75; 5: 1



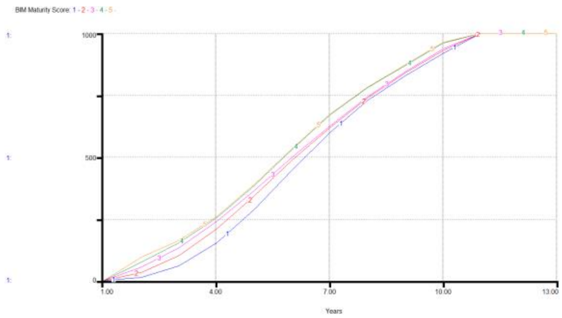
c) STR Effort Rate

1: 0; 2: 0.25; 3: 0.5; 4: 0.75; 5: 1



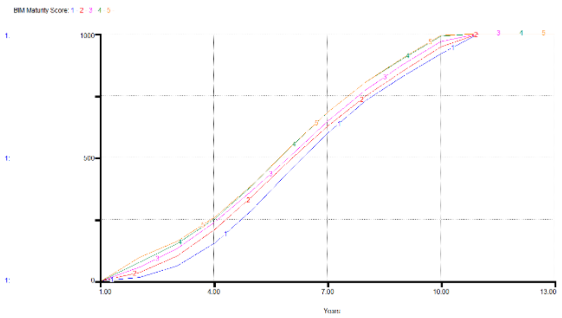
d) RES Effort Rate

1: 0; 2: 0.25; 3: 0.5; 4: 0.75; 5: 1



e) PEO Effort Rate

1: 0; 2: 0.25; 3: 0.5; 4: 0.75; 5: 1



f) PRO Effort Rate

1: 0; 2: 0.25; 3: 0.5; 4: 0.75; 5: 1

Figure 7.11. Results of the behaviour-sensitivity test

## 7.7 Further Discussion and Recommendations

The characteristics of BIM adoption between countries are not much different from each other (Doan et al., 2019c). BIM adoption in the UK was suggested as an example for the New Zealand construction industry to follow (Doan et al., 2019c). This is because "… New Zealand and the UK have a similar basis of law. They have a common democratic system, and they have the same types of legislation and regulations around investment and trade" (Doan et al., 2019c; Scheer, 2017). Furthermore, the results of the SD model developed based on the characteristics of BIM adoption in New Zealand in this research are the same as the development of BIM adoption in the UK. This confirmed not only the accuracy of the model but also the similar characteristics of BIM adoption between two countries.

However, BIM in the UK has developed quickly with appropriate strategies from the government. CO (2011) planned for mandating BIM level 2 by 2016; during that period, strategies were proposed to go for BIM level 3 (CDBB, 2015; IPA, 2016). Whereas, the New Zealand government is still inactive towards BIM adoption (Doan et al., 2019c). Politicians lack knowledge concerning the construction industry was revealed as a reason for this (Doan et al., 2019c). Therefore, it is suggested that the New Zealand government should collaborate with the construction industry to develop BIM adoption to gain its potential benefits.

Based on the strategies or scenarios developed for the behaviour-sensitivity test, LEA is the most crucial category amongst those affecting BIM adoption in New Zealand. It could reduce 2 years for the organisation to achieve BIM level 3 by focusing on reducing 25% of *LEA Gap*. Therefore, LEA should be the first and foremost category improved by the organisation. Besides, focusing on CLI and STR is recommended because it could improve the value of *BIM Maturity Score* considerably. As shown in Figure 7.8 that BIM and Green Star could be appropriately integrated after achieving BIM level 3, LEA, CLI, and STR are also the critical categories affecting the integration.

It is worth noticing that SD modelling is used to deal with complex dynamics systems (Tang et al., 2019). By adjusting the value of a parameter, the results of the model could be changed, see in extreme condition test and behaviour-sensitivity test. Although the model provided accurate results towards BIM adoption compared to the UK, the results for BIM adoption could be different between organisations. Therefore, it is suggested that the organisation should assess their BIM adoption based on the categories and indicators provided by Doan et al. (2019e) before adopting the developed model in this research. By doing that, the inputs of the model will reflect the circumstance of the organisation leading to the accurate results. Also, the organisation could adjust the values of the parameters to consider the results of the model towards those changes. From then, appropriate strategies to develop BIM adoption could be planned.

## 7.8 Conclusion

This research developed an SD model to examine BIM development over time and determine the appropriate time for BIM and Green Star integration. It consists of 2 elements, the BIM element, and the BIM and Green Star element, with 9 sectors. The results revealed that it takes 8 years for an organisation to achieve BIM level 3 from level 0. Whereas, at least 5 years should be spent to reach BIM level 2. Although BIM could be integrated with Green Star to a certain level after year 6, year 10 was determined as the perfect time for the integration.

The confidence of the SD model was gained by passing the structural verification test, extreme condition test, and behaviour-sensitivity test. By conducting the behaviour-sensitivity test, the critical categories and how the categories affecting BIM adoption were revealed. 5 strategies focusing on improving the LEA, CLI, STR, RES, PEO, PRO categories were conducted. The results indicate that LEA is the most significant categories which could improve BIM adoption performance, followed by CLI and STR categories. Integrating BIM with Green Star could only be fully achieved when the organisation reaches BIM level 3; therefore, LEA, CLI, and STR are also crucial to the integration of BIM and Green Star.

This research has important practical implications for construction organisations in New Zealand. It provides an SD model which could be adopted by the construction organisations for their BIM and Green Star development. Taking advantage of the SD approach with feedback effects, scenarios towards BIM and Green Star adoption could be simulated to determine the most appropriate strategy. In addition, they can adjust the model inputs by assessing their BIM adoption level based on the categories and indicators provided by Doan et al. (2019e). As a result, they can control and develop BIM adoption with the best strategies. Furthermore, the research pointed out the difference of BIM development between New Zealand and the UK, which is the involvement of the government. Therefore, it is suggested that the New Zealand government should be actively involved in develop strategies for BIM development.

Although the model focuses on BIM adoption in New Zealand, it could be adopted by other countries. The relationships between categories and inputs of the model could be modified based on the BIM adoption framework developed by Doan et al. (2019e).

Future research will forecast the BIM development of some organisations in New Zealand using the developed SD model and the data recorded from those organisations.

# Chapter 8 Discussions, Conclusions and Recommendations

## 8.1 Overview

This chapter reviews the research aim, research objectives, research questions, and significant findings of the research, which is followed by discussions. The contribution to knowledge is also presented. The limitation and recommendations for future research are discussed at the end of the chapter.

## 8.2 The Fulfilment of the Research Aim

This research aims to provide a platform to enhance Green Star certification uptake in the New Zealand context by improving BIM uptake. To achieve the research aim, four objectives were established as follows:

### 8.2.1 Objective 1: Examine the characteristics of BIM adoption in New Zealand

The purpose of this objective is to understand and provide insights into the characteristics of BIM adoption in the New Zealand context. Four aspects of BIM adoption were examined, which are also the research questions to the objective. They are 1) What is BIM?; 2) What are the benefits of BIM adoption?; 3) What are the barriers/challenges to BIM adoption?; and 4) What are the solutions for BIM adoption?

21 semi-structured interviews with 25 construction experts in New Zealand were conducted and analysed to achieve this objective, which was presented in Chapter 2 . The results indicate that there is a wide range of perceptions on the definition of BIM in which no one size fits all definition is currently being utilised. Specifically, 4 different definitions of BIM have been perceived by the construction experts in New Zealand; they are Building Information Model, Building Information Modelling, Building Information Management, and software/technology. The inconsistence of the BIM definition not only appears in New Zealand but also in other countries.

Mordue et al. (2015) indicated that BIM is generally understood as Building Information Modelling. However, Turk (2016) mentioned the other alternative definitions of BIM which are Building Information Model and Building Information Management. W. Wu, Mayo, McCuen, Issa, and Smith (2018) highlighted the diversity of the BIM definition in the US in which Building Information Model, Building

Information Modelling, and Building Information Management were mentioned. Also, an understanding of BIM as Revit was also revealed by M. King (2011) and Hongming et al. (2017).

The research also revealed 14 potential benefits of BIM adoption that can be achieved in the New Zealand context, see Figure 8.1. The 5 most strongly acknowledged benefits of BIM adoption are time-saving, collaboration and coordination improvement, efficiency improvement, clash reduction, and risk reduction.

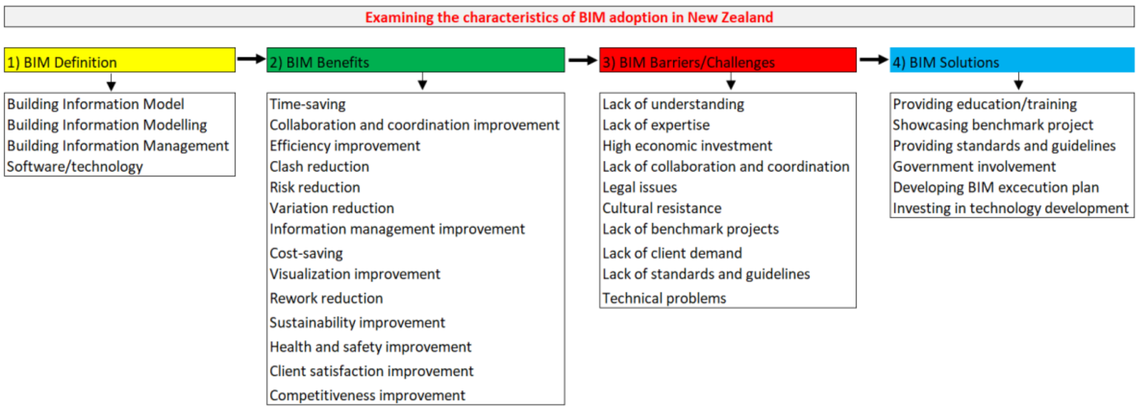



Figure 8.1. Results of objective 1

It is noticed that those five acknowledged benefits are also the most five popular benefits of BIM adoption in other countries. Time-saving was also considered as the most significant benefit of BIM adoption by Yan and Demian (2008). Eadie, Browne, et al. (2013) indicated that BIM adoption could save "half time at half cost" for the organisation. Besides, Eadie, Browne, et al. (2013) highlighted collaboration and coordination improvement as the most critical benefit of BIM adoption. This is similar to Thurairajah and Goucher (2013) findings stated that it is one of the most commonly perceived benefits.

Efficiency improvement was identified by Khosrowshahi and Arayici (2012) as one of the four main benefits of BIM adoption. While Sanchez, Hampson, and Vaux (2016) revealed efficiency improvement as one of the competitive advantage gains that could raise profitability and access to market as early adopters. In terms of clash reduction, it was perceived by 100 UK construction contractors as the most significant driver to BIM adoption (Eadie, Odeyinka, et al., 2013). The results of a survey with 305 directors of construction companies in the UK ranked risk reduction as the 2nd most acknowledged benefit of BIM adoption (Robson, Boyd, & Thurairajah, 2014).

It is worth noting that sustainability is one of the identified benefits of BIM adoption, which is also similar to Kivits and Furneaux (2013). This confirmed the potential link of BIM adoption to green rating systems, used to assess the sustainability of a construction project. In other words, the results here promote confidence for examining the relationship between BIM and Green Star, which was conducted in Chapter 3 and Chapter 4 .

After determining all the potential benefits, barriers/challenges were revealed to explain why BIM adoption is still in its early stages in New Zealand. The interviewees pointed out 10 different barriers/challenges to BIM adoption, see Figure 8.1. Lack of BIM understanding, lack of expertise, high economic investment, lack of collaboration and coordination, legal issues, and cultural resistance were perceived by at least two-thirds of them.

Almost all of the interviewees agreed that lack of understanding is the most significant barrier to BIM adoption. It is also one of the first and foremost barriers mentioned by Alreshidi et al. (2017), Alabdulqader et al. (2013), and Khosrowshahi and Arayici (2012). Regarding lack of expertise, it was identified as the most critical risk to BIM adoption (Zhao et al., 2016), which is also the case in Ashworth, Tucker, Druhmann, and Kassem (2016) research. High economic investment was indicated as a significant barrier to BIM adoption in both Singapore and the UK, 2nd place in Singapore and 3rd place in the UK (Khosrowshahi & Arayici, 2012; Zhao et al., 2016). Initial set up cost is a major financial concern to the organisation for BIM investment (Alreshidi et al., 2017). Software, training, and hardware were revealed as the three highest costs for the investment by Olatunji (2011).

Lack of collaboration and coordination was interestingly determined as the 2nd most significant barrier to BIM adoption in both Singapore and Sweden (Bosch-Sijtsema et al., 2017; Chan, 2015). Chan (2015) highlighted that “BIM does not help if our counterparties are not using BIM.” Legal uncertainty towards the technology used for BIM adoption was pointed out by Arensman and Ozbek (2012). Whereas, Eadie, McLernon, et al. (2015) classified legal issues into 16 different types indicating its essential role to BIM adoption. In the Middle East, cultural resistance was the 2nd commonly acknowledged barrier by the construction organisations (Gerges et al., 2017). Whereas, it was ranked top regarding the likelihood of occurrence in Singapore (Zhao et al., 2016).

Regarding the solutions for BIM adoption in New Zealand, 6 suggestions were proposed by the interviewees, see Figure 8.1. It is necessary to provide education and training to construction practitioners and potential clients to mitigate the barriers of lack of understanding, lack of expertise, and lack of client demand. In Taiwan, 90% of 224 architectural firms encouraged their employees to participate in education and training programs (Juan, Lai, & Shih, 2017). Those firms reacted to the policy of using BIM-based e-submission for the building permit review process of the Taiwanese government (Juan et al., 2017). To mandate BIM in Singapore, the government invested $6 million for training, consultancy, software, and hardware costs (McAuley et al., 2017).

Showcasing BIM benchmark projects also plays an essential role in BIM development. Recognising its impact on BIM adoption, an award was given to a multination data centre project that record BIM best practices in the BIM Excellence category (ICEA, 2018). BIM standards and guidelines in New Zealand were compared to the UK to highlight their shortage implying the need for more resources to shape the direction of BIM implementation. Only two documents, International BIM Object Standard (Masterspec, 2016) and New Zealand BIM Handbook (BAC, 2016), have been released for BIM development in New Zealand. Moreover, the active involvement of the governments in BIM adoption amongst the countries was mentioned to indicate the passive resistance from the New Zealand government towards BIM adoption. Travaglini et al. (2014) pointed out the effort of the European government to promote BIM development in their countries. Whereas, "there is a little bit of lack of direction of what we are going to do. We want to do the same as the rest of the world, but the rest of the world have different standards," mentioned by the interviewees. Therefore, it is suggested that the New Zealand government should be more active in collaborating with construction stakeholders to develop strategies to assist BIM implementation. Specifically, BIM standards and guidelines released from the government would be necessary at the moment. It sends a signal to the construction industry that BIM is essential to the development of the industry, and the government is promoting BIM. The example from Taiwan above indicated the effectiveness of the government role in BIM development; the construction organisations immediately reacted to the government policies and direction (Juan et al., 2017).

To mitigate the lack of collaboration and coordination, BIM Execution Plan (BEP) was suggested as an effective solution. Wei Lu, Zhang, and Rowlinson (2013) indicated developing BEP as a priority before BIM implementation. This is because it "provides a standardised workflow and general guidance for strategic BIM implementation in a holistic approach for a particular project or a group of projects" (McArthur & Sun, 2015). It clarifies the roles, responsibilities, and information transferring between stakeholders to make BIM collaboration successfully (Wei Lu et al., 2013; McArthur & Sun, 2015). Besides, investing in technology is necessary to reduce the weaknesses of the current BIM software and hardware. According to Ignatova et al. (2018), "none of the BIM software can provide solutions to all specialised tasks." Whereas, the need for strong power of computers for BIM adoption was highlighted by Tulenheimo (2015).

The first objective was achieved in Chapter 2 to discover the characteristics of BIM adoption in New Zealand. It found out that the BIM characteristics regarding BIM definitions, benefits, barriers/challenges, and solutions are not much different between New Zealand and other countries. It, therefore, is appropriate for New Zealand to adapt BIM lessons and practices from other countries for BIM development. It is worth noticing that the involvement of the government is the major difference between New Zealand and other BIM pioneer countries. Therefore, the New Zealand government should be active in releasing BIM guidelines, standards, plans, and strategies to pass through the current early stages of BIM adoption.

Besides providing insights into BIM adoption in New Zealand, Chapter 2 also provides the rationale for examining the relationship between BIM and Green Star, presented in Chapter 3 and Chapter 4 . It confirmed the link between BIM and green rating system by revealing the impact of BIM adoption on sustainable practice.

### 8.2.2 Objective 2: Examine the characteristics of Green Star uptake in New Zealand

This objective aims to explore the current practice of Green Star certification uptake in New Zealand. Three research questions were answered in Chapter 3 and Chapter 4 . They are 1) What are the benefits of Green Star uptake?; 2) What are the barriers/challenges to Green Star uptake?; 3) What are the solutions for Green Star uptake? The qualitative approach, conducting 21 interviews, was adopted to discover the perspectives of 25 construction experts towards Green Star uptake, presented and validated in Chapter 3 . However, the validation stages provided in Chapter 3 may be slightly inaccurate due to the use of research results of other green rating systems for the triangulation approach. A further validation stage, therefore, was conducted in Chapter 4 through the quantitative approach. 76 responses were analysed after distributing the questionnaire to construction practitioners in New Zealand.

The results in Chapter 3 revealed six types of potential benefits of adoption Green Star certification, see Figure 8.2. Benefits to the environment and occupants were the most commonly perceived by construction experts. This is also the case for construction practitioners in New Zealand; Chapter 4 revealed that they are the two most significant benefits of Green Star certification uptake. It is reasonable when green-certified buildings can ensure sustainability and a healthy place for building occupants (A. King, 2017). Whereas, the other four benefits pointed out in Chapter 3 were also confirmed in Chapter 4 .

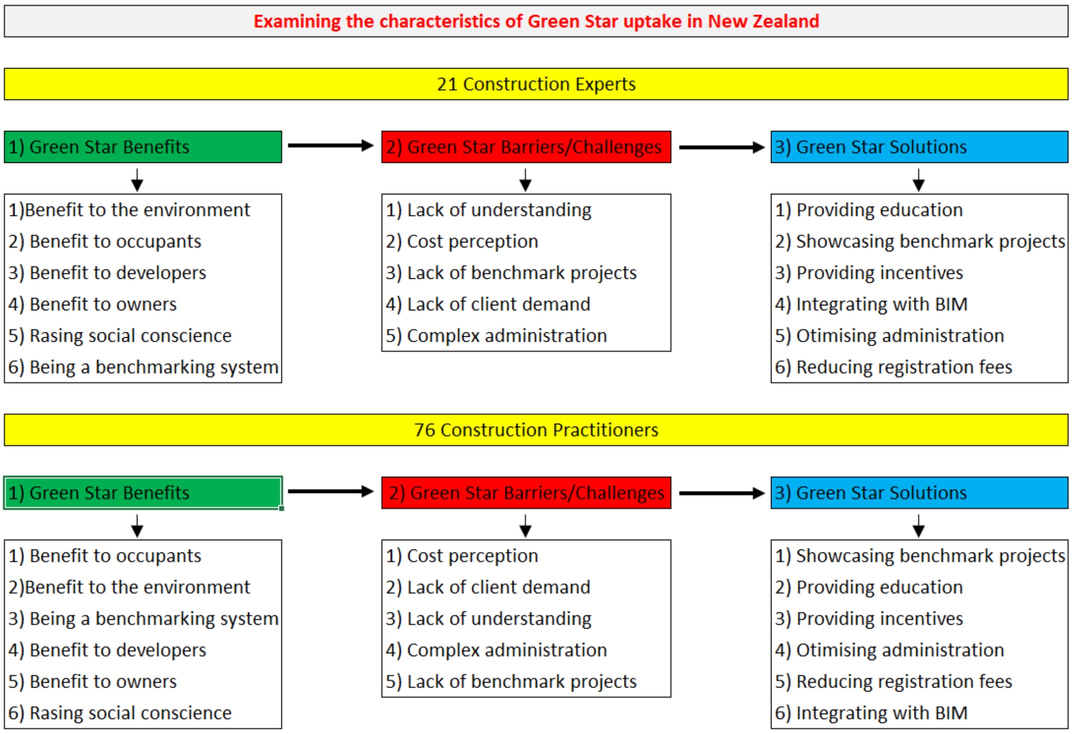



Figure 8.2. Results of objective 2

Amongst five barriers/challenges highlighted in Chapter 3 , lack of understanding and cost perception were considered as the crucial problems to Green Star, with the agreement of over three-quarters of the interviewees, see Figure 8.2. Cost perception was determined as the most significant barrier/challenge to Green Star by construction practitioners, presented in Chapter 4 . This is consistent with Dwaikat and Ali (2016). After reviewing studies focusing on green cost premiums, Dwaikat and Ali (2016) concluded that 80% of the studies highlighted the higher costs of green buildings compared to conventional buildings. Besides New Zealand, cost perception was also perceived as the most significant barrier/challenge to green building in Australia (Morris et al., 2018), US (Ahn et al., 2013), and China (P. T. Lam et al., 2009).

Lack of understanding was at 3rd place regarding its significant barrier to Green Star based on the construction practitioners' perspective. It is a common barrier to green building in other countries such as Malaysia (Samari et al., 2013) and Singapore (B. G. Hwang & Tan, 2012). Whereas, it was highlighted as the most significant barrier in Kuwait (AlSanad, 2015) and second in the US (Darko et al., 2017). Although lack of client demand was indicated by a third of construction experts, see Chapter 3 , it was acknowledged by most of the construction practitioners, see Chapter 4 . It was identified as the second most significant barrier to Green Star in New Zealand. This is similar to the situation of green rating systems in Singapore (B. G. Hwang & Tan, 2012) and Malaysia (Samari et al., 2013). It is worth noticing that the number of Green Star certified buildings in New Zealand is still modest, with only 254 buildings since 2007 (NZGBC, 2019c).

6 solutions were suggested by 21 construction experts, see Figure 8.2. Providing education was the most commonly mentioned, followed by showcasing benchmark projects and providing incentives. Construction practitioners also agreed with construction experts that those 3 mentioned solutions are the 3 most effective ones to improve Green Star uptake. Not only in New Zealand but those 3 solutions were also suggested to improve green rating uptake in the US (Darko et al., 2017), Singapore (B. G. Hwang & Tan, 2012), and Ghana (Ayarkwa et al., 2017).

Integrating BIM with Green Star was suggested as an effective solution by both construction experts and practitioners in New Zealand. By reviewing studies focusing on green BIM topic, Y. Lu et al. (2017) indicated the potential of using BIM for Green Star uptake. This establishes the foundation to explore the relationship between Green Star and BIM adoption, the next objective.

### 8.2.3 Objective 3: Explore the relationship between BIM and Green Star in New Zealand

The purpose of this objective is to discover whether BIM has impacts on Green Star in New Zealand and vice versa. 3 research questions set up to achieve this objective were answered, presented in Chapter 3 and Chapter 4 . They are 1) What is the relationship between BIM and Green Star?; 2) What are the barriers/challenges to the integration of BIM and Green Star?; and 3) What are the solutions for the integration of BIM and Green Star? Similar to objective 2, this objective was achieved with the use of exploratory sequential mixed methods. 21 interviews were conducted to explore the perspectives of 25 construction experts on the relationship between BIM and Green Star. The results were then validated by 68 construction practitioners in New Zealand.

Most of the interviewees, 20/21, indicated the potential impacts of BIM adoption on Green Star uptake. The research is consistent with the existing literature. Ryu and Park (2016) highlighted the usefulness of BIM adoption to LEED regarding the energy simulation process. Whereas, an IFC-based framework was developed by Ilhan and Yaman (2016) to integrate BIM with BREEAM. The ninth BIM Use, Sustainability (Green Star/NABERS) Evaluation, in the BIM New Zealand handbook (BAC, 2016) also implied the potential of the integration between BIM and Green Star.

Two-thirds of the interviewees agreed that Green Star uptake could affect BIM adoption. “Green Star should affect BIM because Green Star offers better design, BIM is a tool to achieve the design, so Green Star should be leading, and BIM supports that” (#2). This parallels with GhaffarianHoseini, Tien Doan, et al. (2017) in which the potential impacts of Green Star on BIM were pointed out in the conceptual framework. The relationship between BIM and Green Star was verified and determined as significance by construction practitioners.

Although the interviewees did not deny the possibility of integrating BIM with Green Star, 13 of them highlighted the fact that the relationship has not occurred in New Zealand yet. 5 barriers/challenges were pointed out by the interviewees to explain that, see

Figure 8.3. Separate processes and lack of understanding are the 2 most common barriers/challenges. BIM and Green Star having 2 different processes was acknowledged by 68 construction practitioners in New Zealand as the most significant barrier/challenge. Researchers have made efforts to incorporate BIM and green rating systems. Siddiqui et al. (2009) provided sustainable metrics that could be integrated with BIM for sustainable design. J. K.-W. Wong and Kuan (2014) tried to streamline the BEAM Plus process to have it integrated with BIM. However, the number of green credits is still achieved limitedly with the use of BIM. Specifically, a third of LEED credits could be attained by using BIM (Azhar et al., 2011) which is the same for BEAM Plus credits (J. K.-W. Wong & Kuan, 2014).

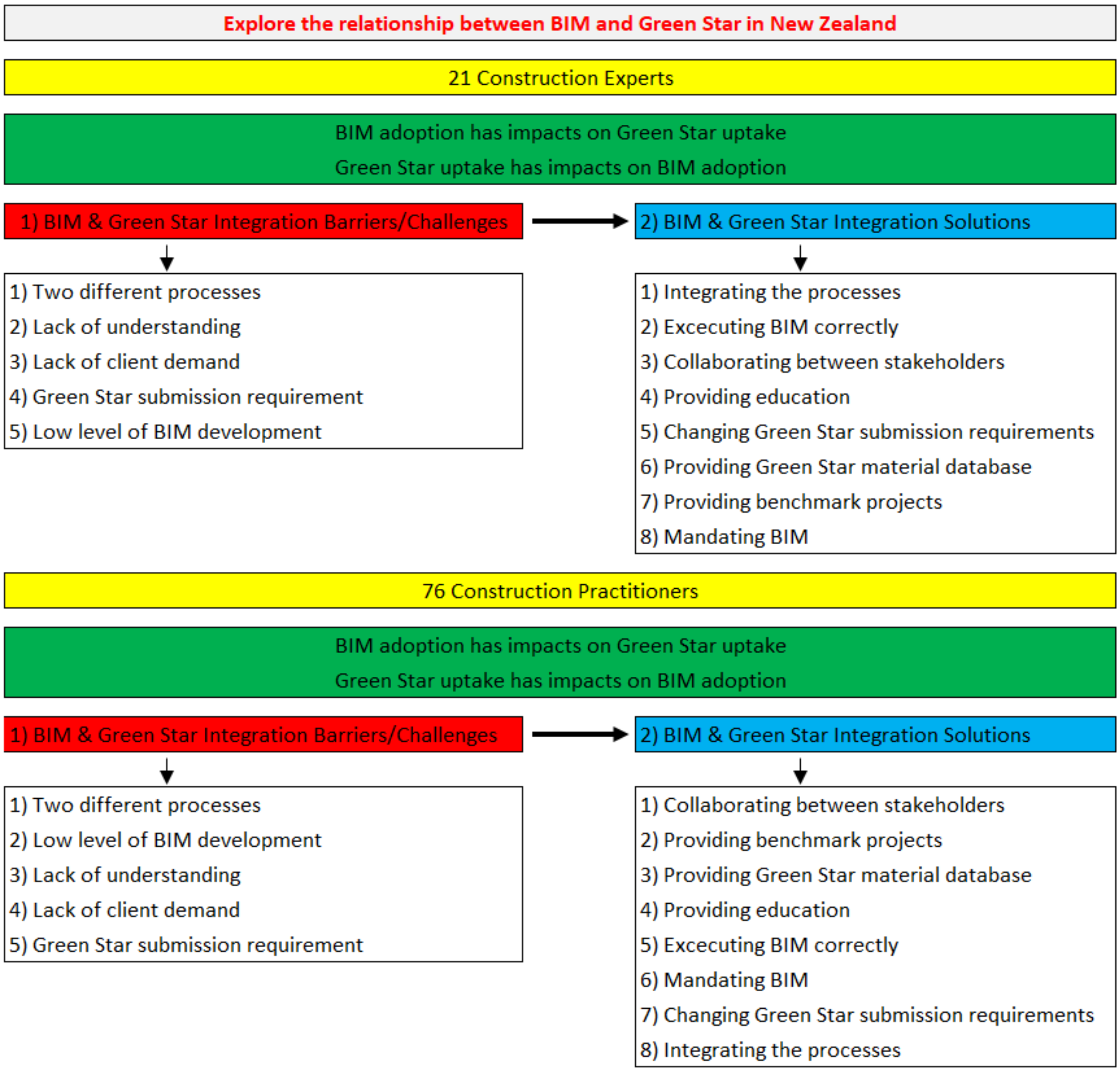



Figure 8.3. Results of objective 3

Lack of understanding was ranked at 3$^{rd}$ place regarding its significance by construction practitioners. It is understandable when a lack of understanding was revealed as the most significant barrier/challenge to BIM adoption, presented in Chapter 2 . Whereas, a lack of understanding was also pointed out as the most serious barrier/challenge to Green Star uptake, presented in Chapter 3 . It, therefore, is reasonable to be considered as a significant problem to the integration.

It is noticed that BIM maturity level should be considered prior to the integration. It was ranked at 2$^{nd}$ place by construction practitioners due to its key role to the integration. BIM could be completely integrated with green rating systems when BIM maturity reaches level 3 to achieve 6D BIM (Bew & Richards, 2008). The UK, one of BIM pioneers in the world, is still struggling with BIM level 3. They are planning to reach BIM level 3 in 2025 (CDBB, 2015). Therefore, BIM maturity level was pointed out as a significant barrier/challenge to the integration in New Zealand.

To solve the mentioned barriers/challenges, 8 solutions were provided by construction experts, see

Figure 8.3. Integrating the processes, executing BIM correctly, and collaborating between construction practitioners to optimise the Green Star process are the three most common solutions shared. The construction practitioners also confirmed the effectiveness of integrating the BIM and Green processes and executing BIM correctly. Whereas, optimising the Green Star process with the support from construction stakeholders was highlighted as the most effective solution to the integration. This is in line with the research results provided in objective 2; complex administration process is one of the significant barrier/challenge preventing people from uptaking Green Star.

Besides pointing out the relationship between BIM and Green Star, the results of this objective highlighted the necessity of BIM development in New Zealand. In other words, the barriers/challenges and solutions provided in objective 1 should be considered to have appropriate strategies for the construction industry to reach BIM level 3. This provides the rationale for the next objective to develop a BIM adoption framework to assess the BIM maturity level of BIM adopters.

### 8.2.4 Objective 4: Develop and validate a BIM adoption framework to improve BIM understanding and BIM practice in New Zealand

This objective aims to determine the main categories and indicators affecting BIM adoption in New Zealand. Based on those categories and indicators, the BIM adoption framework was developed and validated to assess the current BIM practice of BIM adopters. 3 research questions were expected to be answered to achieve this objective. They are 1) What are the critical categories affecting BIM adoption?; 2) What are the critical indicators of each category affecting BIM adoption?; and 3) What are the relationships amongst those critical categories affecting BIM adoption?

The BIM adoption framework was developed in Chapter 5 . Chapter 5  analysed the information collected from both primary and secondary data to identify the main categories and indicators of the framework. BEF, EFQMEM, and ABEF were used as standard frameworks to establish the structure of the BIM adoption framework. The perspectives of 21 construction experts were also analysed to detail each category in the framework. As a result, 7 categories with 39 indicators were determined. Five hypotheses to the relationships between categories were also developed. Furthermore, a certain number of points was allocated for each category of the framework, based on the point systems of BEF and EFQMEM, to assess the BIM maturity level of BIM adopters.

The BIM adoption was validated in Chapter 6 with the use of structural equation modelling (SEM). After collecting information from 66 construction practitioners, PLS-SEM was used to analyse the significance of the identified categories, indicators, and the relationships amongst those categories. The results confirmed the effectiveness of 7 categories towards BIM assessment. They are 1) Leadership; 2) Clients & Other Stakeholders; 3) Strategic Planning; 4) Resources; 5) People; 6) Process; and 7) Results. Every factor within each category was also checked to ensure its significance to the framework; 8 indicators were removed due to their poor relative contribution to the model.

Amongst the indicators of Leadership, having a clear BIM leadership role was highlighted as the most important one. It was also pointed out by Deutsch (2018) as the most essential factor to implement BIM successfully. Whereas, focusing on client understanding plays a crucial role in Clients & Other Stakeholders, which was also confirmed by Rodgers et al. (2015). In Strategic Planning, reviewing and updating the BIM strategic plan regularly was determined as the most necessary factor, which is consistent with Chunduri et al. (2013). Not surprisingly, BIM software should be focused most heavily in Resources; software costs account for 55% of the BIM adoption costs (Olatunji, 2011).

Regarding People, the most significant factor belongs to encouraging employees to share their ideas to improve BIM adoption, which was indicated by Ho et al. (2013). Providing adequate training to improve employees BIM skills during the BIM implementation process should be carried out to ensure the smoothness of the BIM process. In other words, it is the most significant indicator of Process. Zhao et al. (2016) highlighted the risk of the lack of expertise of the employees during adoption BIM. Whereas, the effectiveness of the BIM leadership team could strongly affect the results of BIM adoption. In summary, having a clear BIM leadership role, focusing on client understanding, reviewing and updating the BIM strategic plan, investing in BIM software, encouraging employees to share their ideas, and providing adequate training are the indicators that should be focused and prioritised.

The relationships between categories or five hypotheses developed were examined. The results indicated that Leadership is the most important category in the BIM adoption framework; it affects all other categories. BIM adopters, therefore, should pay more attention to Leadership and its indicators. Besides Leadership, Strategic Planning was proved to be depended on Clients & Other Stakeholders. Leadership and Resources have impacts on People while Process is influenced by Leadership, Clients & Other Stakeholders, and People. Whereas, Leadership, Strategic Planning, and Process have direct impacts on Results.

The objective was achieved when the BIM adoption framework, with 7 categories and 31 indicators, was developed and validated. The critical categories and indicators of the framework were also revealed. Furthermore, how the categories relate to each other was determined. This provides a foundation for the next objective in which a BIM-Green Star system dynamics (SD) model was developed based on the established BIM framework.

### 8.2.5 Objective 5: Develop and validate a BIM-Green Star SD model to improve BIM and Green Star understanding and BIM and Green Star practice in New Zealand

This objective aims to develop and validate an SD model of BIM and its relationship with Green Star to provide insights into BIM and Green Star understanding. Three research questions used to achieve the objective were answered. The research questions are 1) What are the critical categories affecting BIM and Green Star uptake?; 2) How do those categories affect BIM and Green Star uptake?; and 3) What is the most important category affecting BIM and Green Star uptake?

An SD model with 2 main elements and 9 sectors was developed and validated in Chapter 7 . Based on the results of objectives 1 and 4, the BIM element of the model was developed with 8 sectors. 7 sectors represent 7 categories affecting BIM adoption in New Zealand; they are 1) Leadership; 2) Clients & Other Stakeholders; 3) Strategic Planning; 4) Resources; 5) People; 6) Process; and 7) Results. Whereas, the last sector was used to calculate the value of *BIM Maturity Score* to determine the current level of

BIM adoption of BIM adopters. Regarding the BIM and Green Star element, the last sector was developed based on the results of objectives 2 and 3 in which the relationship between BIM and Green Star was explored.

The results of the SD model indicated that it takes at least 8 years for an organisation to achieve BIM level 3. Whereas, a minimum of 5 years is expected for the organisation to reach BIM level 2. The results are precisely the same as the strategies proposed by the UK government. A five-year 2011-2016 BIM plan was developed by CO (2011) to force the UK construction organisations to adopt BIM level 2 by 2016. Once BIM level 2 was achieved by 2016, IPA (2016) established the next plan to move to BIM level 3 in 2017-2020. BIM level 3 is achievable at the moment when a few organisations stated that they have reached BIM level 3 in some projects in Australia (Dainty et al., 2017; M Reza Hosseini et al., 2016) and New Zealand (Doan et al., 2019b).

Philp (2015) and Gupta et al. (2014) mentioned the problems preventing the organisations from going for BIM level 3. Philp (2015) anticipated that it could take twice as long to reach a higher BIM level. In other words, the organisation needs to increase its effort twice to reach the next level. The SD model was adjusted to the situation in which the organisation hesitates to accelerate its effort to BIM adoption. The results showed that it could take 14 years for them to reach level 3, which is identical to the BIM plan developed by CDBB (2015).

Besides, the results of the model indicated that BIM could be appropriately integrated with Green Star at the end of year 9. This is the time when the values of Clients & Other Stakeholders, Process, and Results sectors reached the appropriate level while BIM level 3 was achieved. In other words, the integration of BIM and Green Star depends heavily on the BIM maturity level, which was pointed out in objectives 2 and 3. Because only a few organisations achieved BIM level 3, as mentioned above, the benefits of the current integration of BIM and green rating systems are still limited. However, they show a positive trend. For example, J. K.-W. Wong and Kuan (2014) revealed that a quarter of BEAM Plus credits could be achieved in 2014. While 44% of them were highlighted as achievable with the use of BIM in 2016. This is reasonable when BIM is developed year by year (Solla et al., 2016).

The developed SD model was validated through 3 different tests including structural verification test, extreme condition test, and behaviour-sensitivity test. The structural verification test confirmed the consistency of the model with the real system. Whereas, the extreme condition test analysed extreme policies to detect flaws in the model and to enhance the usefulness of the model. Finally, 5 scenarios were proposed to test the behaviour-sensitivity of the model. Those 5 scenarios were also used to determine the effectiveness of each category/sector to BIM and Green Star integration. The results show that Leadership is the most important category; focusing on Leadership by 25% could achieve BIM level 3 quicker by 3 years. In other words, organisations need to focus on having a clear BIM leadership role besides other indicators in the Leadership category. Also, Clients & Other Stakeholders and Strategic Planning should be focused owing to their considerable impacts on the BIM maturity level. Because the integration of BIM and Green Star depends on the BIM maturity level, Leadership, Clients & Other Stakeholders, and Strategic Planning also have strong impacts on the integration.

## 8.3 Contribution and Significance of the Research

This research contributes to the existing body of knowledge in both research and practical ways. As mentioned, BIM and Green Star in New Zealand are still in their early stages in which the recognition of their importance to the New Zealand construction industry has not been achieved. In other words, this research is a pioneering effort to provide insights into BIM and Green Star practice in New Zealand. It also proposes an innovative approach to improve BIM and Green Star simultaneously in which BIM development is the skeleton.

This research added to the existing knowledge by providing the characteristics of BIM and Green Star uptake. The results concluded that BIM adoption has similar characteristics despite the difference of regions. Therefore, it is suggested that BIM strategies and plans used by BIM early adopters should be researched to be adapted by the late majority and laggards. The research also revealed the sustainable aspect of a construction project as the common benefit of BIM and Green Star uptake. Besides pointing out the barriers/challenges and solutions for Green Star uptake, the research highlighted the potential impact of BIM on Green Star uptake. In other words, using BIM can reduce a considerable of time for Green Star assessment with a possible automatic tool. Furthermore, Green Star uptake affecting BIM adoption was also pointed out. There are no studies that examine the impacts of green rating systems on BIM adoption yet.

Recognising the essential role of BIM development, the BIM adoption framework was developed to provide insights into BIM understanding. By identifying the critical categories and indicators affecting BIM adoption, the framework could be considered as the guidelines for BIM adopters to evaluate their BIM practice. To enhance the usefulness of the BIM adoption framework, an SD model was created to examine BIM development over time and also the integration of BIM and Green Star. By testing different strategies for BIM development in New Zealand through SD modelling, the most important categories and strategies were determined. Specifically, the inputs of the model including the score for each category of the BIM adoption framework, effort invested in improving BIM implementation, and the BIM maturity level could be adjusted by organisations to anticipate the level and direction of BIM implementation of the organisations. The level of impacts of the categories on BIM development was also revealed with the use of a user-friendly graphical format. Besides, when BIM could be appropriately integrated with Green Star was identified. A certain number of studies have focused on green BIM topic. They have made an effort to examine "how" BIM could support green rating systems; however, none of them determines "when" BIM could support green rating systems.

The results of this research could be useful for strategic plans established by the New Zealand government and local authorities. For example, 20% of productivity was aimed to be increased by the New Zealand construction industry by 2020 (Noktehdan et al., 2015). BIM was suggested as a factor pushing the increase of productivity or efficiency. Therefore, the developed strategies and the BIM adoption framework could be used to enhance the current BIM practice leading to an increase in construction productivity. 30% and 60% of waste was aimed to reduce by 2020 and 2030 by Auckland-Council (2018) respectively. It is noticed that waste reduction is one of the criteria of Green Star. In other words, enhancing Green Star uptake could reduce the amount of waste. Therefore, the Auckland organisations could use the research results as guidelines for their future strategies to reduce waste. Furthermore, Wellington City Council offers 50% remission of levies to 5 Star or higher Green Star certified project (WCC, 2015).

Construction organisations could use the developed BIM adoption framework and the SD model to evaluate their BIM and Green Star practice. From then, strategies could be planned to achieve the remission provided by Wellington City Council.

The research provided valuable information regarding BIM and Green Star uptake in New Zealand, which has not been researched by the others. The research results, therefore, could be used by other researchers as references for future research.

## 8.4 Research Limitations and Recommendations for Future Research

The scope of the research is limited to the New Zealand construction industry. Therefore, the results of the research should be reanalysed to be adapted for the other countries despite the similar characteristics of BIM adoption proved in Chapter 2 . The UK, Australia, and New Zealand could learn the lessons from each other because of their similar traits in terms of the basis of law, democratic system, types of legislation and regulation. Also, further research should be conducted to explore the level of difference of BIM and green rating systems between New Zealand and other countries to apply the developed BIM adoption framework and SD model appropriately in a global context.

The research presented in Chapter 2 and Chapter 3 has limitations. Firstly, the data analysed from the interviewees was mainly collected from the construction experts working in Auckland. The results, therefore, could be not completely appropriate to the whole New Zealand. In other words, extensive research to examine the perspectives of construction experts working in other regions of New Zealand should be conducted. Secondly, the number of interviewees having experience in both BIM and Green Star is limited even though they satisfied requirements based on the saturation of the collected data. Also, the perspectives of one of the main construction stakeholders, clients, were not investigated. Further research should add clients to the list of potential interviewees owing to their key role to BIM and Green Star development.

The sample size used to validate the significance of the characteristics of Green Star and its relationship with BIM, presented in Chapter 4 , is limited. It is noticed that the sample size was assured to the type of the selected analysis and other research.

However, a larger sample size could be more beneficial to represent the wider perspectives of construction practitioners in New Zealand.

Chapter 5 and Chapter 6 developed and validated a BIM adoption framework based on the information from the conducted interviews and BEF, EFQMEM, and ABEF frameworks. It may miss some categories or factors that have impacts on BIM adoption. For example, the impacts of the government or the development of BIM technology should be further analysed in the framework.

Finally, the SD model was developed and validated in Chapter 7 . BIM strategies and BIM practice of the UK governments were used as the evidence showing the appropriateness of the model. Further research is suggested to record the strategies and practice towards BIM adoption in New Zealand to consider them as the baseline information for the comparison. Furthermore, the developed BIM adoption framework and the SD model should be adopted to analyse BIM current practice of some organisations to prove its usefulness to the New Zealand construction industry.

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# Glossary

| | |
|---|---|
| ABEF | Australian Business Excellence Framework |
| ADNZ | Architectural Designers New Zealand |
| BEAM | Building Environmental Assessment Method |
| BEF | Baldrige Excellence Framework |
| BEMs | Business Excellence Models |
| BEP | BIM execution plan |
| BIM | Building information modelling |
| BREEAM | Building Research Establishment Assessment Method |
| CASBEE | Comprehensive Assessment System for Building Environmental Efficiency |
| CDBB | Centre for Digital Built Britain |
| CLI | Clients & Other Stakeholders |
| CO | Cabinet Office |
| EFQMEM | European Foundation for Quality Management Excellence Model |
| FM | Facility management |
| GBCA | Green Building Council Australia |
| GSAP | Green Star Accredited Professionals |
| HVAC | Heating, ventilation, and air conditioning |
| ICEA | Irish Construction Excellence Awards |
| IEQ | Indoor Environmental Quality |
| IPA | Infrastructure and Projects Authority |

| | |
|---|---|
| LEA | Leadership |
| LEED | Leadership in Energy and Environmental Design |
| LOD | Level of development |
| MEP | Mechanical, electrical, and plumbing |
| NZGBC | New Zealand Green Building Council |
| OECD | Organisation for Economic Co-operation and Development |
| OPEX | Operating expenditure |
| PEO | People |
| PLS | Partial least squares |
| PRO | Process |
| RE | Results |
| RES | Resources |
| SEM | Structural equation modelling |
| SD | System dynamics |
| SMEs | Small and medium enterprises |
| STR | Strategic Planning |
| VIF | Variance inflation factor |
| WMIF | Waste Minimisation and Innovation Fund |

# Appendix A: Ethics Approval and Documents

## Ethics Approval (for interview)

## AUTEC Secretariat

Auckland University of Technology
D-88, WU406 Level 4 WU Building City Campus
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

31 August 2017

Ali GhaffarianHoseini

Faculty of Design and Creative Technologies

Dear Ali

Ethics Application: 17/309 **Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling**

I wish to advise you that a subcommittee of the Auckland University of Technology Ethics Committee (AUTEC) has **approved** your ethics application.

This approval is for three years, expiring 31 August 2020.

**Standard Conditions of Approval**

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

**Non-Standard Conditions of Approval**

1. Note: The Information Sheet would benefit for a review for correct written English.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation then you are responsible for obtaining it. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor

Executive Manager

**Auckland University of Technology Ethics Committee**

Cc: ddoan@aut.ac.nz; Nicola Naismith; John Tookey

## Ethics Approval (for survey)

## AUTEC Secretariat

Auckland University of Technology
D-88, WU406 Level 4 WU Building City Campus
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

6 March 2018

Ali GhaffarianHoseini

Faculty of Design and Creative Technologies

Dear Ali

Re: Ethics Application: 17/309 **Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling**

Thank you for submitting your ethics application for the additional stage of your research.

The second stage involving the use of an anonymous survey is approved.

I remind you of the Standard Conditions of Approval.

6. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/researchethics.
7. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/researchethics.
8. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/researchethics.
9. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
10. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation then you are responsible for obtaining it. If the research is undertaken outside New Zealand, you need to meet all locality legal and ethical obligations and requirements.

For any enquiries please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor

Executive Manager

**Auckland University of Technology Ethics Committee**

Cc: ddoan@aut.ac.nz; Nicola Naismith; John Tookey

## Consent Form (for Interview)

*Project title:* ***Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling***

*Project Supervisor:* ***Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey***

*Researcher:* ***Dat Tien Doan***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated dd mmmm yyyy.
- ○ 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 Contact Details (if appropriate):

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Date:

***Approved by the Auckland University of Technology Ethics Committee on 31/08/2017***

***AUTEC Reference number 17/309***

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

## Participant Information Sheet (for interview)

## Date Information Sheet Produced:

21/08/2017

## Project Title

Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling

An Invitation

Dear [insert name]

You received this document [email] as I would like to invite you to participate in an in-depth interview.

I currently work as a PhD researcher at the School of Engineering, Computer and Mathematical Sciences, Built Environment Engineering Department, Auckland University of Technology. My supervisors are Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey.

My research study aims to provide a platform to enhance Green Star certification by improving BIM uptake through System Dynamics Modelling. The outcomes of this research are expected to prove that BIM and Green Star have a proportional relationship. It means that BIM implementation rate increases could raise the number of Green Star certified buildings and vice versa. In other words, many Green Star credits could be achieved by BIM implementation and aiming to achieve Green Star certified buildings could also affect the BIM implementation rate. Besides, this research also examines all of the benefits and barriers of BIM and Green Star in New Zealand. Potential approaches will be drawn to improve the current situation of the construction industry in New Zealand. From then, investors, developers, practitioners could have clear visions for shifting the country further towards the development of sustainable future cities

I would highly value your contribution but please do not oblige to participate. Your participation will be anonymised in my research results and will be organised as efficiently as possible. Please note that this is voluntary and may withdraw at any time before completing the data collection. If there is any conflict of interest at any point of time, you are able to choose whether to proceed with the research or not, your decision will neither advantage you nor disadvantage you.

I look forward to your response.

Best regards,

Dat Tien Doan

PhD research candidate

## What is the purpose of this research?

This research aims to provide a platform to enhance Green Star certification by improving BIM uptake through System Dynamics Modelling. To be more specific, the research study will 1) examine the characteristics of BIM and Green Star; 2) Establish the level of industry engagement in NZ context; 3) Identify methods to increase industry uptake of BIM and Green Star simultaneously; 4) Identify challenges associated with enabling BIM and Green Star implementation. The outcomes of this research are expected to prove that BIM and Green Star have a proportional relationship.

A summary of my intermediate research findings (hard copies and soft copies) could be sent to you in case you request for it.

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

You will have responded to the email sent by the researcher or by NZIQS/CCNZ/NZGBC/PrefabNZ/IPENZ/ACENZ/ADNZ/DINZ/NZIA/NZLA or through one of your colleagues in your professional network were identified through your interest in the advertisement that was displayed on the NZIQS/CCNZ/NZGBC/PrefabNZ/IPENZ/ACENZ/ADNZ/DINZ/NZIA/NZLA website. You have been identified as you fit the criteria of the research which is a surveyor/contractor/civil engineer/Architects/Green Star Accredited Professional/ Green Star Practitioner/project manager involved in BIM and Green Star implementation in education, office, and industrial projects in New Zealand for at least 5 years for the interviews.

## How do I agree to participate in this research?

If you choose to participate in the study, then you would need to sign a consent form stating that you have accepted to participate. You will be sent a consent form at the same time as I send you this information sheet. You will have the opportunity to ask any further questions before you sign the consent form and commence the interview.

Your participation in this research is voluntary 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 before data collection is completed. 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, the removal of your data may not be possible.

## What will happen in this research?

This project involves a researcher conducting a face to face interviews with you if you are in Auckland. Interviews can be in a mutually agreed public place, your work office or an office at AUT. If you are outside of Auckland we will interview you by phone. It is expected that interviews will last between 45 and 60 minutes and I will record the interviews.

## What are the discomforts and risks?

It’s very unlikely that you will experience any discomfort. If you do not feel comfortable answering a question you are not obliged to answer it.

## How will these discomforts and risks be alleviated?

You have the right to refuse to answer any question you feel that you are not comfortable answering. You also have the option of withdrawing from the interview at any time within the data collection process.

## What are the benefits?

For you: The results from the research could assist you in increasing BIM adoption in your projects for achieving Green Star certifications. The summary of the research results could be sent to you so that you could have deep insights about the current practice and the scenarios of BIM and Green Star implementation in Auckland.

For the researcher: The study will be a qualification for my PhD degree. I also have a deep knowledge of using BIM to achieve Green Star certifications for construction projects.

For the wider community: The study provides a platform to encourage BIM adoption for achieving Green Star certifications.

The researchers will benefit from the project through the completion of a Doctor thesis and academic journal article publications. You are able to get a chance to be able to contribute to the body of knowledge with your experience in your career development in the construction industry and may benefit from the resulting guidelines.

## How will my privacy be protected?

The main issue that needs to be addressed is confidentiality. The research team can assure you that your identity will only be used to give you information on our project. This information will be only accessible to the researchers. The research findings will not disclose any personal information that could identify the participant or their organisation.

## What are the costs of participating in this research?

You will contribute your time and your experience in this research. It is expected that the interview will last from 45-60 minutes.

## What opportunity do I have to consider this invitation?

You will be given two weeks to consider this invitation.

## Will I receive feedback on the results of this research?

You are able to receive feedback on the results of this research, and this will be obtained in the journal article upon your request of this document to which you can get an electronic copy of the journal article.

## 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 GhaffarianHoseini, alighh@aut.ac.nz, 09 921 9999 ext 7968*

**Thesis supervisor:** *Dat Tien Doan, ddoan@aut.ac.nz, +64 210 823 5489*

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz*, 921 9999 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:

*Dat Tien Doan, dat.doan@aut.ac.nz, +64 210 823 5489*

## Project Supervisor Contact Details:

*Dr Ali GhaffarianHoseini – alighh@aut.ac.nz - 09 921 9999 ext 7968*

**Approved by the Auckland University of Technology Ethics Committee on 31/08/2017, AUTEC Reference number 17/309.**

## Participant Information Sheet (for survey)

## Date Information Sheet Produced:

6th March 2018

## Project Title

Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling

An Invitation

Dear Construction Practitioners,

I currently work as a PhD researcher at the School of Engineering, Computer and Mathematical Sciences, Built Environment Engineering Department, Auckland University of Technology. My supervisors are Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey.

In order to obtain your views, I would like to invite you to participate in our research on Enhancing Green Star certification by improving BIM uptake through System Dynamics Modelling. The outcome of the research will enhance BIM and Green Star adoption in the New Zealand construction sector. Your participation will be through an online survey. The online survey will last for 30 minutes. This will contribute to my thesis and our project overall. Please note that this is voluntary and may withdraw at any time.

The questionnaire comprises a series of statements relating to different aspects of BIM and Green Star. Please indicate your level of agreement or disagreement using a five-point Likert scale (from 1 = Strongly Disagree to 5 = Strongly Agree).

The information provided by you in the survey will be anonymous and used only for the research purpose. The information provided will not be utilised in a manner that would identify your individual responses. If there is any conflict of interest at any point in time, you are able to choose whether to proceed with the research or not; your decision will neither advantage you nor disadvantage you.

The study has been considered by the Ethics Committee of the Auckland University of Technology and has been given a favourable review.

Once again, I would like to thank you very much for agreeing to take part in this study. I look forward to your responses.

Best regards,

Dat Tien Doan

PhD research candidate

## What is the purpose of this research?

This research aims to provide a platform to enhance Green Star certification by improving BIM uptake through System Dynamics Modelling. To be more specific, the research study will 1) examine the characteristics of BIM and Green Star; 2) Establish the level of industry engagement in NZ context; 3) Identify methods to increase industry uptake of BIM and Green Star simultaneously; 4) Identify challenges associated with enabling BIM and Green Star implementation. The outcomes of this research are expected to prove that BIM and Green Star have a proportional relationship.

This research will result in my successfully completing his thesis. It will also contribute to academic publications and it is hoped that it will result in useful guidelines and recommendations for construction practitioners in construction.

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

You will have responded to the email sent by the email sent by the researcher or NZPI/PMINZ/NZIQS/CCNZ/NZGBC/CIOB/IPENZ/PrefabNZ/ACENZ/NZGBC or through one of your colleagues in your professional network were identified through your interest in the advertisement that was displayed on the NZPI/PMINZ/NZIQS/CCNZ/NZGBC/CIOB/IPENZ/PrefabNZ/ACENZ/NZGBC websites. You have been identified as you fit the criteria of the research, which is a quantity surveyor/contractor/structural engineer/architects/Green Star Assessor/Accredited Professionals/Practitioners/BIM managers/MEP engineers etc., those who have worked in the New Zealand construction industry for at least 3 years, and have experience in BIM and/or Green Star.

## How do I agree to participate in this research?

By participating in the online survey and completing the questionnaire. Completion of the attached questionnaire will be taken as indicating your consent to participate.

Your participation in this research is completely voluntary 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 before the submission of your completed responses. You can save your progress and return to the survey later if required within the specified three weeks of questionnaire completion time frame. However, the survey is anonymised, and once your responses are finally submitted, it will be used for the study because the participants are not identified.

## What will happen in this research?

This project involves you to complete the questionnaire through the online link provided by NZPI/PMINZ/NZIQS/CCNZ/NZGBC/CIOB/IPENZ/PrefabNZ/ACENZ/NZGBC or by the researcher.

## What are the discomforts and risks, and alleviation?

There will be no discomfort, and it is very unlikely that you will experience any discomfort. You have the right not to answer any question you feel uncomfortable answering. You also have the option of withdrawing from completing the survey.

## What are the benefits?

For you, the participant: the results of the research could assist you in increasing BIM adoption in your projects for achieving Green Star certifications. The summary of the research results could be sent to you so that you could have deep insights about the current practice and the scenarios of BIM and Green Star implementation in Auckland.

For the researcher: the study will be a qualification for my PhD degree.

For the wider community: the study provides a platform to encourage BIM adoption for achieving Green Star certifications.

## How will my privacy be protected?

The survey is completed anonymously, and all reasonable steps will be taken to ensure confidentiality. The participant is not identified. The research team can assure you that your identity will never be known if you choose to complete the online survey. The data you provided will be treated as confidential and used for the purpose of this research only. The research findings will not disclose any personal information that could identify you or your organisation. You will not be able to be identified by anything that is written in the text of the research paper.

## What are the costs of participating in this research?

You will contribute your time, around 30 minutes, and experience in partaking in this research.

## What opportunity do I have to consider this invitation?

You will be given two weeks to consider this invitation.

## Will I receive feedback on the results of this research?

You are able to get the summary and feedback on the results of the completed research, and this will be obtained from the online link which is provided by the researcher.

## 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 Supervisors:** *Dr Ali GhaffarianHoseini, alighh@aut.ac.nz, 09 921 9999 ext 7968; Nicola Naismith, nicola.naismith@aut.ac.nz, +64 9 921 9999*

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz*, 921 9999 ext 6038.

## Whom do I contact for further information about this research?

Please keep this Information Sheet for your future reference. You are also able to contact the research team as follows:

## Researcher Contact Details:

*Dat Tien Doan, dat.doan@aut.ac.nz, +64 210 823 5489*

## Project Supervisor Contact Details:

*Dr Ali GhaffarianHoseini – alighh@aut.ac.nz - 09 921 9999 ext 7968*

*Dr Nicola Naismith, nicola.naismith@aut.ac.nz, +64 9 921 9999 ext 7949*

**Approved by the Auckland University of Technology Ethics Committee on 06 March 2018, AUTEC Reference number 17/309.**

## Appendix A: BIM Interview Questions

1. Could you please introduce yourself? (qualifications, experience, your positions, your company)

2. What is BIM in your opinion?

3. Are the construction practitioners in NZ well-aware of BIM?

4. In NZ, which stakeholders strongly involve in BIM projects? Civil Engineering, architects, QS, contractors, customers, etc.?

5. What are the benefits of BIM in your opinion? Please give examples.

6. What are the barriers of BIM in your opinion? Please give examples. How to solve them?

7. Should BIM be mandatory? Why?

8. Will BIM be mandatory? Why?

## Green Star and BIM Interview Questions

1. Could you please introduce yourself? (qualifications, experience, your positions, your company)
2. What are the benefits of Green Star in your opinion? Please give examples
3. What are the barriers/challenges to Green Star in your opinion? Please give examples
4. What are the solutions for Green Star in your opinion?
5. Should Green Star be mandatory? Why?
6. Will Green Star be mandatory? Why?
7. How could BIM adoption affect the number of Green Star certification uptake?
8. How could Green Star certification affect the BIM adoption rate?
9. What are the challenges of using BIM to enhance the Green Star certification?
10. What are the solutions to mitigate the challenges of using BIM for Green Star certification uptake?

## Green Star and BIM Questionnaire Survey

# Survey

**By completing this questionnaire you are indicating your consent to participate in this research**

You can select more than 1 answer for each question in Part 1

## Part 1. Background Information

**1. Your position in the company**

☐ BIM Manager ☐ Architect ☐ Structural Engineer ☐ MEP Engineer

☐ Contractor ☐ Quantity Surveyor ☐ Green Star Assessor ☐ GSAP

☐ Client ☐ Others (Please specify)…………………………………..

**2. How many employees in your company?**

☐ 0 ☐ 1-5 ☐ 6-19 ☐ 20-49

☐ 50-99 ☐ 100+

**3. How many years have you worked in the NZ construction industry?**

…………………………..

**4. How many BIM projects have you been involved in?**

…………………………..

**5. What is the BIM Maturity Level in your projects?**

☐ Level 1 ☐ Level 2 ☐ Level 3 ☐ Unsure

**6. What is the Level of Development (LOD) in your projects?**

☐ LOD 200 ☐ LOD 300 ☐ LOD 350 ☐ LOD 400

☐ LOD 500 ☐ Unsure

**7. How many Green Star certified projects have you been involved in?**

…………………………..

## Part 2. Green Star Information

Please select the answer that best reflects your opinion with each statement below

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Somewhat Disagree | Neither Agree nor Disagree | Somewhat Agree | Strongly Agree |

| **Benefits of Green Star certification uptake** | | | Scale | | |
|---|---|---|---|---|---|
| 1. The Green Star certified project reduces the environmental impact of the construction industry. | 1 | 2 | 3 | 4 | 5 |
| 2. The Green Star certified project provides a healthy place for end-users. | 1 | 2 | 3 | 4 | 5 |
| 3. The Green Star certified project saves operation costs for end-users. | 1 | 2 | 3 | 4 | 5 |
| 4. The Green Star certified project is generally sold for a higher price compared to the non-certified project. | 1 | 2 | 3 | 4 | 5 |
| 5. The Green Star certification is a marketing tool to attract end-users | 1 | 2 | 3 | 4 | 5 |
| 6. The Green Star certification raises the social conscience of sustainable construction. | 1 | 2 | 3 | 4 | 5 |
| 7. The Green Star certification is a benchmarking system for the design for better building performance modellings (e.g., energy, lighting). | 1 | 2 | 3 | 4 | 5 |
| **Barriers/challenges to Green Star certification uptake** | | | Scale | | |
| 1. Perception of the cost of investing in the Green Star certification. | 1 | 2 | 3 | 4 | 5 |
| 2. Lack of understanding of the Green Star benefits. | 1 | 2 | 3 | 4 | 5 |
| 3. Lack of benchmark projects which can showcase the benefits of the Green Star certification. | 1 | 2 | 3 | 4 | 5 |
| 4. Lack of client demand for the Green Star certification uptake. | 1 | 2 | 3 | 4 | 5 |
| 5. The complex administration process of the Green Star certification uptake. | 1 | 2 | 3 | 4 | 5 |
| **Solutions for Green Star certification uptake** | | | Scale | | |
| 1. Clients should be educated about the benefits of Green Star certification. | 1 | 2 | 3 | 4 | 5 |
| 2. Benchmark Green Star projects should be showcased widely. | 1 | 2 | 3 | 4 | 5 |
| 3. Incentives (e.g., tax reduction) should be provided for Green Star certified projects. | 1 | 2 | 3 | 4 | 5 |
| 4. The Green Star process should be optimized to simplify on the administration of getting Green Star certification. | 1 | 2 | 3 | 4 | 5 |
| 5. Green Star should be integrated with BIM. | 1 | 2 | 3 | 4 | 5 |
| 6. Green Star registration fees should be reduced from the current level. | 1 | 2 | 3 | 4 | 5 |

## Part 3. Green Star and BIM Information

Please select the answer that best reflects your opinion with each statement below

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Somewhat Disagree | Neither Agree nor Disagree | Somewhat Agree | Strongly Agree |

| **Benefits of Green Star and BIM integration** | Scale | | | | |
|---|---|---|---|---|---|
| 1. Building performance modellings (e.g., energy, lighting) used for Green Star assessment can be implemented using BIM. | 1 | 2 | 3 | 4 | 5 |
| 2. Building models can incorporate all the information (e.g., Building Users' Guide, Commissioning report) for Green Star assessment of the project. | 1 | 2 | 3 | 4 | 5 |
| 3. Green Star credits can be integrated with BIM for automatic Green Star assessment. | 1 | 2 | 3 | 4 | 5 |
| 4. Using BIM for Green Star certification uptake can potentially reduce the assessment time. | 1 | 2 | 3 | 4 | 5 |
| 5. Green Star certification uptake requires the building performance modellings and related information, which are the aspects of the BIM process. Therefore, increasing the Green Star certification uptake can potentially increase the BIM adoption rate. | 1 | 2 | 3 | 4 | 5 |
| **Barriers/challenges to Green Star and BIM integration** | Scale | | | | |
| 1. BIM implementation and Green Star certification have two completely separate processes. | 1 | 2 | 3 | 4 | 5 |
| 2. Lack of client demand for projects that required both BIM and Green Star. | 1 | 2 | 3 | 4 | 5 |
| 3. The New Zealand Green Building Council requires only 2D documents for the assessment process rather than a full BIM model. | 1 | 2 | 3 | 4 | 5 |
| 4. BIM maturity level in New Zealand is currently low. | 1 | 2 | 3 | 4 | 5 |
| 5. LOD in New Zealand is currently low. | 1 | 2 | 3 | 4 | 5 |
| 6. Lack of understanding on the positive potentials of integrating BIM with Green Star. | 1 | 2 | 3 | 4 | 5 |
| **Solutions for Green Star and BIM integration** | Scale | | | | |
| 1. Clients and stakeholders should be educated on both BIM implementation and Green Star certification processes. | 1 | 2 | 3 | 4 | 5 |
| 2. The Green Star certification and BIM implementation processes should be integrated. | 1 | 2 | 3 | 4 | 5 |
| 3. The New Zealand Green Building Council should change their document requirements to reflect BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 4. BIM should be executed properly first (the BIM maturity level and LOD have to be high enough) before the integration with Green Star. | 1 | 2 | 3 | 4 | 5 |
| 5. Green Building Council should work with construction | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| stakeholders to optimise the Green Star certification process. | | | | | |
| 6. A Green Star material database should be created for BIM integration. | 1 | 2 | 3 | 4 | 5 |
| 7. Benchmark projects based on BIM-Green Star integration should be showcased widely. | 1 | 2 | 3 | 4 | 5 |
| 8. BIM implementation should be mandated in New Zealand for certain types of projects (e.g., public projects). | 1 | 2 | 3 | 4 | 5 |

**Thank you very much for your time!**

# BIM Framework Questionnaire Survey

AUT UNIVERSITY
AUCKLAND, NEW ZEALAND

## Survey

**By completing this questionnaire you are indicating your consent to participate in this research**

You can select more than 1 answer for each question in Part 1

## Part 1. Background Information

**1. Your position in the company**

☐ BIM Manager ☐ Architect ☐ Structural Engineer ☐ MEP Engineer

☐ Contractor ☐ Quantity Surveyor ☐ Green Star Assessor ☐ GSAP

☐ Client ☐ Others (Please specify)……………………………….....

**2. How many employees in your company?**

☐ 0 ☐ 1-5 ☐ 6-19 ☐ 20-49

☐ 50-99 ☐ 100+

**3. How many years have you worked in the NZ construction industry?**

…………………………..

**4. How many BIM projects have you been involved in?**

…………………………..

**5. What is the BIM Maturity Level in your projects?**

☐ Level 1 ☐ Level 2 ☐ Level 3 ☐ Unsure

**6. What is the Level of Development (LOD) in your projects?**

☐ LOD 200 ☐ LOD 300 ☐ LOD 350 ☐ LOD 400

☐ LOD 500 ☐ Unsure

## Part 2. BIM Information

Please select the answer that best reflects your opinion with each statement below

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Somewhat Disagree | Neither Agree nor Disagree | Somewhat Agree | Strongly Agree |

| **Leadership** | Scale | | | | |
|---|---|---|---|---|---|
| 1. Our organisation has a clear BIM leadership role. | 1 | 2 | 3 | 4 | 5 |
| 2. Our BIM leadership team plays a strategic role (with goals and objectives) that will guide our organisation towards BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 3. Our BIM leadership team monitors and reviews the strategic plan regularly for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 4. Our BIM leadership team communicates openly with and engages employees for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 5. Our BIM leadership team is committed to continuous improvement in their own BIM skills. | 1 | 2 | 3 | 4 | 5 |
| 6. Our BIM leadership team is committed to continuous improvement in employees' own BIM skills. | 1 | 2 | 3 | 4 | 5 |
| **Clients & Other Stakeholders** (e.g., architects, contractors) | Scale | | | | |
| 1. Our organisation determines clients' expectations for planning the BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 2. Our organisation determines stakeholders' expectations for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 3. Our organisation has a clear approach to collect clients' feedback after completing BIM projects. | 1 | 2 | 3 | 4 | 5 |
| 4. Our organisation has a clear approach to collect stakeholders' feedback after completing BIM projects. | 1 | 2 | 3 | 4 | 5 |
| 5. Our organization educates clients on BIM. | 1 | 2 | 3 | 4 | 5 |
| 6. Our organisation employs a standard form of contract for the procurement of BIM. | 1 | 2 | 3 | 4 | 5 |
| 7. Our organisation is not reluctant to share information concerning BIM adoption with other stakeholders. | 1 | 2 | 3 | 4 | 5 |
| **Strategic Planning** | Scale | | | | |
| 1. Our organisation has a BIM strategic plan (e.g., BIM standards, BIM specifications, policies). | 1 | 2 | 3 | 4 | 5 |
| 2. Our organisation involves all stakeholders in developing the BIM strategic plan. | 1 | 2 | 3 | 4 | 5 |
| 3. Our organisation allocates the resources effectively to ensure the success of BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 4. Our organisation translates the strategic plan for BIM adoption into specific requirements for each stakeholder. | 1 | 2 | 3 | 4 | 5 |
| 5. Our organisation uses a formal process to track the effectiveness | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| of the BIM strategic plan. | | | | | |
| 6. Our organisation has its BIM strategic plan reviewed and updated regularly. | 1 | 2 | 3 | 4 | 5 |
| **Resources** | | | Scale | | |
| 1. Our organisation has available software for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 2. Our organisation has available software for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 3. Our employees have the required skills needed for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 4. Our organisation has the financial resources for further BIM investment. | 1 | 2 | 3 | 4 | 5 |
| **People** | | | Scale | | |
| 1. Our organisation provides the necessary training for BIM adoption (before implementing BIM). | 1 | 2 | 3 | 4 | 5 |
| 2. Our organisation creates an environment conducive for the employees to improve their BIM skills. | 1 | 2 | 3 | 4 | 5 |
| 3. Our organisation encourages employees to share their ideas to improve BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 4. Our employees are committed to the strategies for BIM adoption within our organisation. | 1 | 2 | 3 | 4 | 5 |
| **Process** | | | Scale | | |
| 1. Our organisation provides adequate training to improve our employees' BIM skills (during the BIM implementation process). | 1 | 2 | 3 | 4 | 5 |
| 2. Our organisation develops a comprehensive BIM Execution Plan for each BIM project. | 1 | 2 | 3 | 4 | 5 |
| 3. Our organisation uses a formal process to track the effectiveness of implementing BIM. | 1 | 2 | 3 | 4 | 5 |
| 4. Our organisation reviews the BIM implementation process regularly. | 1 | 2 | 3 | 4 | 5 |
| 5. Our organisation communicates changes in our BIM implementation process to all employees involved in the process. | 1 | 2 | 3 | 4 | 5 |
| **Results** | | | Scale | | |
| 1. In our organisation, projects implemented using BIM generally satisfy the clients' expectations. | 1 | 2 | 3 | 4 | 5 |
| 2. In our organisation, projects implemented using BIM generally satisfy the stakeholders' expectations. | 1 | 2 | 3 | 4 | 5 |
| 3. Our BIM leadership team is effective in BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 4. Our organisation developed an effective BM plan for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 5. Our organisation developed an effective BIM implementation process for BIM adoption. | 1 | 2 | 3 | 4 | 5 |
| 6. Our employees became capable of implementing BIM. | 1 | 2 | 3 | 4 | 5 |
| 7. Our organisation has a positive return on investment for BIM | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| adoption. |

**Thank you very much for your time!**