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

Research Article

Abstract

- **Purpose:** In New Zealand, BIM prevalence is still in its early stages and faces many challenges. This research aims to develop a Building Information Modelling (BIM) adoption framework to determine the key factors affecting the success of a BIM project.
- **Design/methodology/approach:** Both primary and secondary data were employed in this research, including 21 semi-structured interviews and industry guidelines from the 3 most well-known global Building Excellent Models (BEMs). Data were analysed through content analysis due to its recognised benefits as a transparent and reliable approach.
- **Findings:** Leadership, Clients & Other Stakeholders, Strategic Planning, People, Resources, Process, and Results were identified as 7 main categories along with 39 indicators in the BIM adoption framework. Based on interviewees' perspectives, Leadership is considered the most significant category impacting all of the remaining categories.
- **Originality:** 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 practice improvement.
- **Practical implications:** Using the developed framework will enhance comprehension of BIM, offering directives for those embracing BIM. This will aid construction stakeholders in being better equipped for BIM projects. Having a skilled BIM manager can lead to the success of construction projects.

Keywords: Building Information Modelling (BIM); Baldrige Excellence Framework (BEF); European Foundation for Quality Management Excellence Model (EFQMEM); Australian Business Excellence Framework (ABEF); New Zealand

1 Introduction

The benefits of Building Information Modelling (BIM) adoption are widely recognised for revolutionising the construction industry. BIM adoption has been found to potentially bring 14 benefits (Doan et al., 2021), 9 main benefits in South Australia (Newton and Chileshe, 2012), and 18 drivers in the UK (Eadie et al., 2013). Ghaffarianhoseini et al. (2017) categorised the wide range of BIM benefits into nine different types. Among the benefits frequently cited are time reduction, cost savings, improvement in construction quality, and contributions to sustainable building practices (Tang, 2023). Notably, gains in competitiveness and enhancements in health and safety protocols have also been emphasised in these studies (Aladağ et al., 2023).

However, barriers to BIM adoption should be managed or eliminated for better implementation. Okakpu et al. (2022) highlighted five types of risks in refurbishment projects, including socio-cultural, financial, technical, skill, and contractual risks. Durdyev et al. (2022) researched 20 barriers to BIM implementation but only focused on their impacts on facility management and did not examine relationships among the barriers or categorise them for improved BIM management.

Recently, research has focused on the links between BIM and sustainable development, with the benefits being undebatable but efforts required to minimise preventable factors. Abdelaal and Guo (2022) found that integrating BIM and life cycle assessment (LCA) can bring potential gains to construction projects, but their current implementation is not aligned. Among barriers to lean and BIM adoption, cultural resistance, lack of understanding, resistance to change, lack of knowledge and support are essential (Likita et al., 2022).

While several studies have endeavoured to clarify the factors essential for the successful adoption of BIM, the resultant frameworks have largely been constrained in their scope. For instance, specific research has honed in on a narrow selection of factors within three particular categories (Herr and Fischer, 2019, Hosseini et al., 2016). In New Zealand, additional studies have delved into various aspects, such as awareness, cost, technology, and legal considerations, which influence BIM adoption (Ma et al., 2023, Hall et al., 2022). Despite these advances, the absence of a comprehensive, multi-dimensional framework is evident. Existing models frequently overlook the complex relationships

between multiple factors and stakeholders, and their applicability across diverse organisational and cultural settings remains unverified. This highlights a palpable need for a more encompassing and adaptable BIM adoption framework. This research, therefore, aims to develop a framework to address the identified BIM barriers, including critical factors affecting BIM adoption in New Zealand, to enhance understanding and provide guidelines for effective implementation. The framework will also assist construction professionals in evaluating BIM adoption's success and maturity level.

2 Business Excellence Models (BEMs)

The exploration of BEMs in the context of BIM adoption becomes imperative when considering the inadequacies of existing BIM models in addressing the multifaceted nature of the adoption process. While some studies have made significant strides in developing BIM adoption models, these frameworks often focus on specific aspects or sectors within the construction industry. Herr and Fischer (2019) designed a model centred on the BIM procedures within the Chinese construction sector. Kassem and Succar (2017) devised five overarching BIM adoption models to evaluate pertinent policies. Hong et al. (2019) developed a BIM adoption model tailored for small to medium construction contracting firms in Australia. Based on Faisal Shehzad et al. (2022), there remains a conspicuous gap in the comprehensive exploration of the BIM adoption process, particularly in understanding the varied levels, organisations, and individuals involved. This gap underlines the necessity for a more holistic approach that BEMs can potentially provide.

BEMs, as noted by Gupta and Vrat (2020), offer a structured approach and a holistic perspective that could be vital for the effective implementation and integration of BIM. This holistic perspective is crucial as it encompasses a range of considerations from leadership and strategic planning to customer focus and measurement, analysis, and knowledge management. The framework developed by Bassioni et al. (2005) illustrates how BEM principles can be effectively applied to evaluate and enhance construction performance. By adopting a BEM-influenced approach to BIM adoption, it is possible to develop a framework that is not only comprehensive but also adaptable to the diverse needs and structures of different organisations in the construction sector. Such an approach can address the limitations of previous BIM models, ensuring a more thorough and inclusive adoption

process that spans all critical facets of organizational performance and change management in the context of BIM.

Among the various BEMs, the Baldrige Excellence Framework (BEF) and the European Foundation for Quality Management Excellence Model (EFQMEM) are particularly noteworthy due to their global prevalence and application across over 80 countries (Mohammad et al., 2011, Tickle et al., 2016, Gómez-López et al., 2017). The New Zealand Business Excellence Foundation also adopts the BEF for organisational performance assessment (NZBEF, 2019). Compared to New Zealand, Australia has "a similar basis of law. They have a common democratic system and the same types of legislation and regulations around investment and trade" (Scheer, 2017). Therefore, the structure and model developments of BEF, EFQMEM, and the Australian Business Excellence Framework (ABEF) were analysed for further BIM adoption framework development.

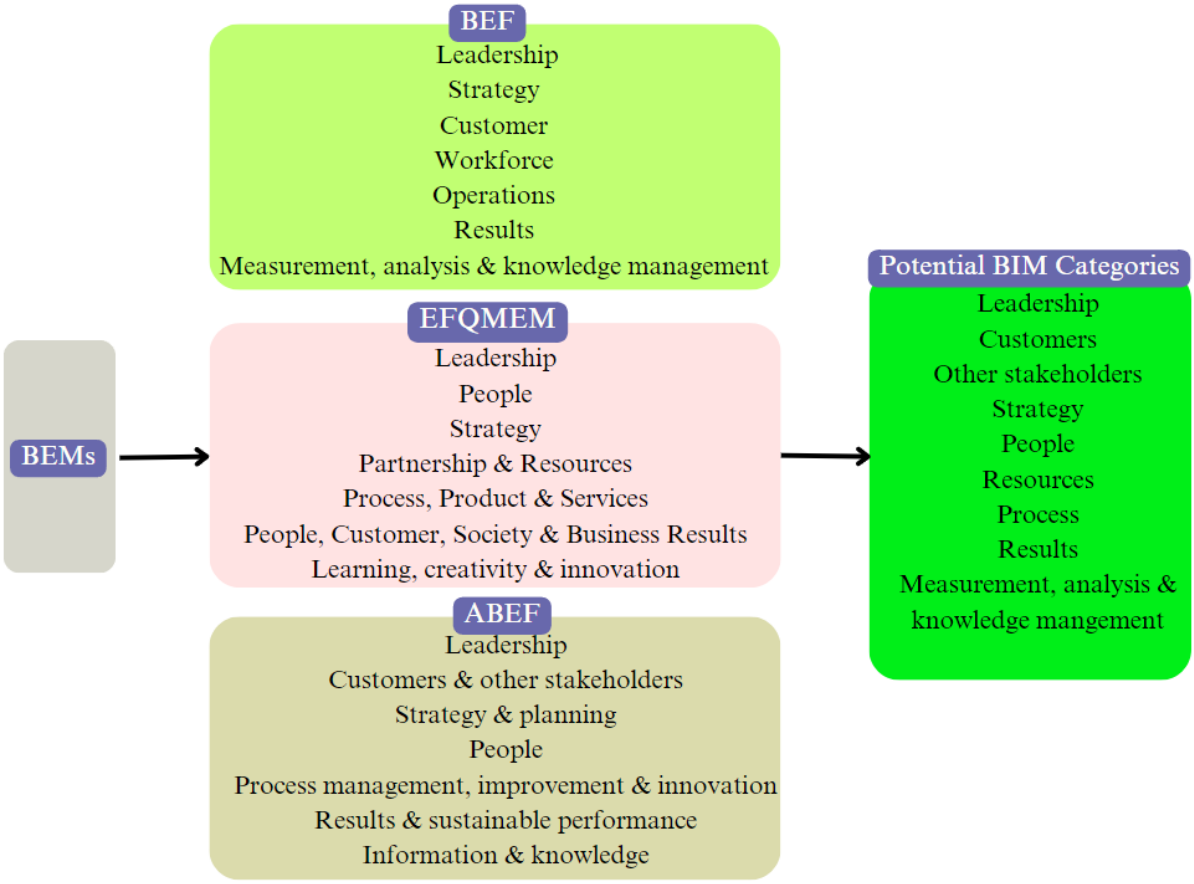

Figure 1. Categories of BEF, EFQMEM, and ABEF

The three frameworks are each divided into seven main categories, summarised in Figure 1. The final category in each framework, while not separate, measures and analyses the other categories for

continual improvement. Customers features in BEF and ABEF, Partnership/Other Stakeholders in EFQMEM and ABEF, and Resources solely in EFQMEM.

From this analysis, a BIM conceptual framework with nine categories was derived: Leadership, Customers, Other Stakeholders, Strategy, People, Resources, Process, Results, and Measurement, Analysis & Knowledge Management. These categories can be combined or eliminated to suit varying organisational structures.

3 Research Methodology

The research used primary and secondary data to develop the BIM adoption framework, employing methods proposed by Lu and Yuan (2011) and Ngacho and Das (2015). The process started with an initial analysis of interview data, followed by a literature review to form key BIM adoption themes. By starting with the interview data, the research remains grounded in the realities of BIM adoption as experienced by professionals in the field. This approach provided a rich, detailed, and nuanced understanding of the real-world BIM adoption process, the challenges encountered, and the strategies employed to overcome them. Based on the themes, the researchers searched and analysed relevant existing frameworks for BIM adoption and established a BIM conceptual framework from the literature. The rationale for this sequence is to ensure that the frameworks are informed by and reflect the insights gained from the interviews. This methodology addresses the identified research gap by ensuring that the developed BIM adoption framework is comprehensive, context-specific and reflects the realities of BIM adoption.

The next two phases involved the development of main categories and detailed analysis of both primary and secondary data to determine the indicators within the categories. Finally, all the characteristics of the BIM adoption framework were finalised. This approach is similar to previous research that has used a combination of methods, such as literature review, expert interviews, focus groups, case studies, and surveys, to develop frameworks (Wang et al., 2004, Meng, 2010). For example, Donato and Shee (2015) developed a framework for increasing collaboration in the construction supply chain and the framework for social sustainability considerations was created by Valdes-Vasquez and Klotz (2012).

This study adopted 21 semi-structured transcribed interviews conducted in Doan et al. (2021) research, see Table I. The interview participants were prominent players in the construction sector in New Zealand, representing various sizes of enterprises ranging from large to small and medium-sized. Interviews were conducted with 25 participants, 18 of which were done in person and 3 over the phone. Two interviewees were present for each session during interviews #6, #11, #12, and #19. All the corresponding interviewees had a minimum of eight years of experience in the construction industry, indicating that the information obtained from these participants is trustworthy and valuable. The quantity of data used in this study is deemed suitable as it reached a point of saturation.

Table I. Interviewees demographics

Content analysis was used to analyse primary and secondary data because of its benefits recognised as a transparent and reliable method (Kuckartz, 2019). Specifically, a five-step approach was employed to analyse data, including 1) Data preparation, 2) Creation of main categories, 3) Data coding, 4) Consolidation of text passages of the main categories and subcategories, and 5) Category-based analyses and results presentation (Kuckartz, 2019).

4 Results

4.1 Categories influencing BIM adoption

The initial analysis of interview data revealed five main possible categories affecting BIM adoption in New Zealand. Firstly, the importance of having qualified BIM managers was noted, as interviewee 7 stated, “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 role of clients was also identified as a crucial category. “The clients are sort of lacking behind on saying they want a BIM project” in New Zealand, stated by interviewee 15. The third category is strategic planning which includes BIM standards, policies, etc., as highlighted by interviewee 4, “there is probably no New Zealand standard” for BIM adoption.

The lack of BIM skills among construction practitioners is another crucial category impacting BIM adoption. Interviewee 19 stated, “we are desperately short of good expertise.” The availability of resources, such as software and hardware, is also an important factor to consider. Interviewee 17 outlined “the investment in hardware and software … a significant capital investment cost” for BIM adoption.

4.2 Categories of the final BIM adoption 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. All five identified categories in the interview results also appear in the BIM conceptual framework established in section 3.2, see Figure 2.

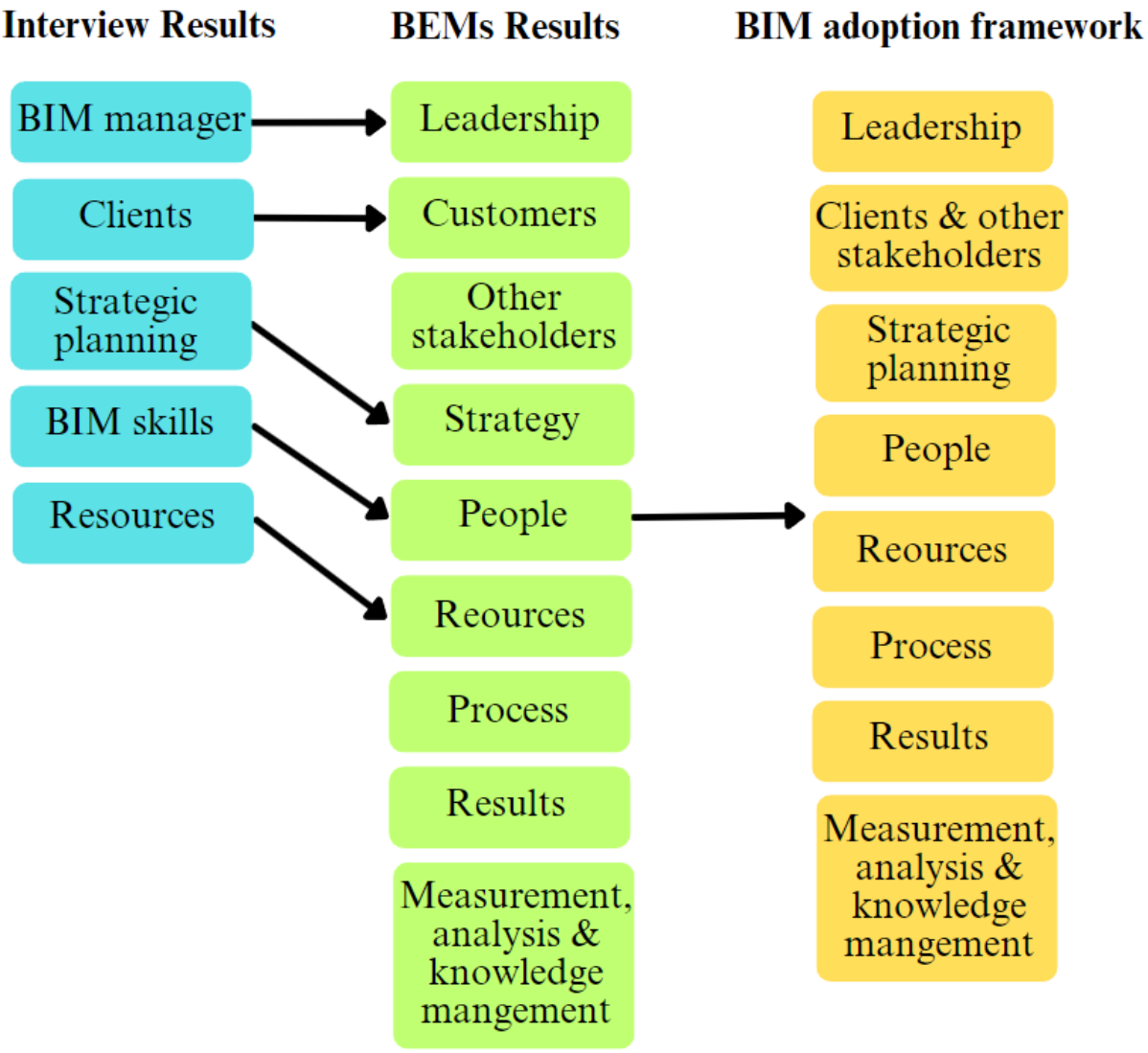

Figure 2. Main categories of the BIM adoption framework

According to NIST (2019), EFQM (2018), and SAI-Global (2011), the Leadership category assesses the leaders' efficiency in directing and motivating employees for organisational success. This aligns with the role of BIM managers, as stated by interviewee 13, “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 highlights the lack of clients' requirement. Interviewee 2 suggested that the organisation needs to “understand who the client is, and what they really want”, which is also defined as the Customers category, exploring how the organisation engages and understands their clients to satisfy their requirements (SAI-Global, 2011, NIST, 2019).

ABEF considers Customers & the Other Stakeholders as one category, a concept applicable to the BIM adoption framework. Interviewee 3 observed, “the contractors are not taking the BIM model, and using it necessarily to coordinate throughout the construction.” Chan (2015) and Bosch-Sijtsema et al. (2017) remarked that “BIM does not help if our counterparties are not using BIM.” Therefore, it is crucial to understand and collaborate with stakeholders to fulfil the clients' needs.

The Strategy category involves developing organisational objectives, policies, and project plans (NIST, 2019, SAI-Global, 2011, EFQM, 2018). Interviewee 20 emphasised, “it is about engaging a professional in BIM and then helping them create a BIM strategy” to have a successful BIM project. Interviewee 12 underscored the need for a strategic plan, querying, “how you run your BIM project if you do not have a strategic plan?”

In 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. To address this, upskilling and training the employees is essential. This aligns with the People category in BEFs, which focuses on creating a high-performance workplace and developing employee skills for organisational success (NIST, 2019, SAI-Global, 2011, EFQM, 2018). Therefore, the BIM skills category will be renamed People for better representation in the BIM adoption framework.

The Resources category was deemed relevant from the interview analysis. Interviewee 3 noted that implementing BIM requires “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.” Interviewee 17 emphasised the need for “the investment in IT, hardware and software.” This category, vital in securing and managing finances, equipment, and technology to support operations, was also recognised by EFQM (2018).

Process, Results, and Measurement, Analysis & Knowledge Management categories were identified after the analysis of BEMs and used as themes to further analyse interview data before confirming them as necessary categories for the BIM adoption framework. NIST (2019), EFQM (2018), and SAI-Global (2011) defined Process as a key category for designing, managing, and improving processes for enhanced output quality and organisational success. Upon reanalysing the interview data, the

Process category was confirmed as pertinent 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. Consequently, Process was included in the framework.

Results is a necessary category to gauge the success of a project or organisation. All categories - Leadership, Customers & Other Stakeholders, Strategy, People, Resources, and Process - must be evaluated to see if the organisation meets or surpasses expectations (NIST, 2019, SAI-Global, 2011, EFQM, 2018). Financial results are equally critical. As interviewee 1 queried, "will they get the return on their investment?" while interviewee 5 raised a contemporary challenge in BIM implementation, "people do not see the return on the investment, they just see the outgoing costs." Hence, the Results category is necessary for the BIM adoption framework.

The Measurement, Analysis & Knowledge Management category is not standalone but integral to all other categories, enabling the measurement, analysis, review, and improvement of organisational performance (NIST, 2019). 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." Interviewee 19 supported, "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, eight 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.

4.3 Detailed analysis of both primary and secondary data

This section entails a detailed comparative analysis of both interview transcripts and the criteria established by the BEMs. The information gleaned from the interviews elucidates and validates the factors within the categories per the guidelines set by the BEMs.

Leadership

The transcripts were analysed to emphasise Leadership in BIM management. The analysis compared Leadership within BEMs to the interview outcomes.

Interviewee 13 stated that a BIM manager is crucial for successful projects. 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, the BIM manager, “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, “do you have a BIM Manager who is not the architect, who is not one of the engineers in the building, an actual person who coordinates the entire process?” Based on EFQM (2018)’s criteria for Leadership, leaders of top organisations act as role models and respond promptly. Therefore, clear BIM leadership is a primary criterion for the Leadership category.

According to NIST (2019), EFQM (2018), and SAI-Global (2011), leaders should set a vision and values to guide employees towards success. Interviewee 7 suggested successful BIM adoption by “employing 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 supports the need for open communication between leaders and employees as suggested by BEF, EFQMEM, and ABEF (NIST, 2019, SAI-Global, 2011, EFQM, 2018). The BIM leadership team, therefore, needs clear goals and open communication for successful BIM adoption.

Lack of expertise was highlighted by interviewee 6, “we have to have enough expertise in the industry, but we are not ready for it yet.” To address this, leadership must commit to improving BIM skills and educating employees. 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.” The importance of enhancing leaders' and employees' skills is also noted in the Leadership category by NIST (2019), EFQM (2018), and SAI-Global (2011).

The Leadership category for the BIM adoption framework contains five criteria: clear BIM leadership role, strategic BIM adoption, open communication, leadership commitment to BIM skills improvement, and commitment to improving employee BIM skills.

Clients & Other Stakeholders

When the role of the clients was mentioned in 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 … 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."*

Hence, educating clients about BIM is crucial for project success. This aligns with the significant criteria of the Customer category of BEF and ABEF (NIST, 2019, SAI-Global, 2011), emphasising understanding and relationship building with customers.

The role of stakeholders was highlighted. "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). All stakeholders need to understand each other's expectations and work in a collaborative environment. This reflects the Partnership & Resources category of EFQMEM (EFQM, 2018) and the Customers and other Stakeholders category of ABEF (SAI-Global, 2011). 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."

Five criteria for the Clients & Other Stakeholders category are: understanding client expectations, understanding other stakeholder expectations, educating clients on BIM, sharing information about BIM adoption, and having a standard form of contract for BIM procurement.

Strategic Planning

According to interviewee 1, "one of the big problems is that BIM is difficult for SMEs," accounting 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. These elements align with the Strategy category featured in the BEF, EFQMEM, and ABEF frameworks (NIST, 2019, SAI-Global, 2011, EFQM, 2018).

Interviewee 19 emphasised early stakeholder collaboration and shared direction, "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).

Stakeholder involvement in developing the BIM strategic plan is crucial for success, as both EFQMEM and ABEF emphasise (SAI-Global, 2011, EFQM, 2018). The plan should accommodate specific stakeholder needs. Issues such as translating the plan and sharing information across stakeholders must be addressed. 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). Effective resource allocation is thus essential, as per the criteria in BEF, EFQMEM, and ABEF (NIST, 2019, SAI-Global, 2011, EFQM, 2018).

The Strategic Planning category of the BIM adoption framework includes four criteria: developing a BIM strategic plan, involving all stakeholders in its development, allocating resources effectively, and translating the plan into specific requirements for each stakeholder.

People

Lack of expertise is one of the significant challenges to BIM adoption, pointed out by most 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.”*

Employee training before BIM implementation is crucial. 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.”

Half of the interviewees highlighted entrenched behaviour as a significant barrier. 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.” Providing training and ensuring employee adherence to company strategies are critical criteria in the People/Workforce category of the BEF, EFQMEM, and ABEF (NIST, 2019, SAI-Global, 2011, EFQM, 2018).

The industry's current capacity poses 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, "the construction industry is already running at 110%, just trying to build whatever we got to build.” Hence, fostering an environment that enables employees to enhance their BIM skills and training is imperative.

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.” Therefore, it is crucial to encourage employees to share ideas. This concept of fostering a collaborative work environment that promotes creativity and innovation aligns with the principles of BEF, EFQMEM, and ABEF (NIST, 2019, SAI-Global, 2011, EFQM, 2018).

Four criteria for the People category in the BIM adoption framework are: providing necessary training, employees committing to BIM strategies, fostering a supportive environment, and promoting idea-sharing for improvement.

Resources

EFQMEM outlines three essential factors for the Resources category: finances, equipment, and technology (EFQM, 2018). The results from the interviewees also support this. Interviewee 15 stated, "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 a 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.”

The Resources category for the BIM adoption framework examines four criteria: available software, hardware, skilled employees, and financial resources for investment.

Process

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

> *“having a proper BEP, 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.”*

A key criterion in the Processes/Operations category is work process design. This is emphasised in the BEF, EFQMEM, and ABEF as crucial for BIM project success (NIST, 2019, SAI-Global, 2011, EFQM, 2018). An ongoing process of continuously developing the BEP for a final comprehensive plan is essential, as stated by interviewee 19 “you can never write an execution plan on day one.”

EFQMEM and ABEF also highlight the significance of ensuring employee competence and ongoing learning (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 the BEF also mentioned towards the requirements of the collaborators (NIST, 2019).

The Process category in the BIM adoption framework evaluates three criteria: development of a comprehensive BEP, provision of adequate training during the BIM implementation process, and communication of changes to all employees involved.

Results

The BIM project's success, as indicated by interviewees, depends on two main factors. First, BIM should meet client expectations. Interviewee 9 indicated, “it depends on our clients. They think that it can profit or not … it will cost them less and reduce their risk by using BIM on their projects.” Second, return on investment (ROI) is a concern. Interviewee 1 asked a rhetorical question: "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 (NIST, 2019, SAI-Global, 2011, EFQM, 2018). The BEF, EFQMEM, and ABEF also considered four other factors: effective leadership team, strategy, process, and competent employees (NIST, 2019, SAI-Global, 2011, EFQM, 2018). While satisfying stakeholders' expectations was included in the EFQMEM, and ABEF (SAI-Global, 2011, EFQM, 2018). Consequently, seven factors were included in the BIM adoption framework.

Measurement, Analysis & Knowledge Management

The Measurement, Analysis & Knowledge Management category, outlined in BEF and ABEF (NIST, 2019, SAI-Global, 2011), advocates for systems and processes that collect data to enhance organisational performance continually. Agreeing with the sharing from interviewees 9 and 19 above, interviewee 8 stated, "you have to get to the point where they go, learn the lessons, and then try again on another project." However, they did not provide specific information, leading to reliance on BEF and ABEF's guidelines.

The Leadership category focuses on having a leader who develops a strategic plan to improve the organisation's performance, focusing on BIM adoption (NIST, 2019, SAI-Global, 2011). The BIM leadership team must monitor and review the plan (NIST, 2019), and collect data from customers and stakeholders for analysis and improvement (NIST, 2019, SAI-Global, 2011). The effectiveness of the BIM strategic plan and its implementation should be tracked through a formal process and regularly reviewed and updated (NIST, 2019). The assessment of the organisation's execution of the strategy is also essential in the Leadership category (NIST, 2019).

Unlike previous categories, Measurement, Analysis & Knowledge Management is not standalone; its aspects are distributed to relevant categories, leading to seven distinct categories. The subsequent section will summarise the BIM adoption framework's categories and factors.

4.4 Final BIM adoption framework

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

Table II. BIM adoption framework

Contrasted with models developed in prior studies, the framework in this research offers a thorough analysis of pertinent factors influencing the success of a BIM project. For instance, Hosseini et al. (2016) only scrutinised 13 factors across three categories while Herr and Fischer (2019) offered a broad model encompassing merely three aspects of BIM adoption. In contrast, this study delves deeper, providing a more comprehensive and nuanced exploration of the BIM adoption process.

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:

> *"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 …, 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 for BIM adoption, affecting the rest of the categories in the framework. Strategic Planning is impacted 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). Hence, Leadership and Clients & Other Stakeholders are crucial to the success of Strategic Planning.

Lack of expertise is a significant barrier to BIM adoption, acknowledged by most of the interviewees. Interviewee 7 indicated, "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). Thus, 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 noted by interviewees 8 and 9, BIM requires effort from everyone in the project, in which each BIM manager, client, stakeholder, and employee plays an essential role in 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 the BIM adoption: "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 points ranging 0-1000 to assess the organisation's performance. Figure 3 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 3. Frameworks' points

The point for each category is similar except Leadership of the BEF and Results of both BEF and EFQMEM, Figure 3. 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 constructing the point system, it is crucial to identify a few key limitations to ensure transparency and robustness. Primarily, the points allocated to Leadership and Results are averaged from two distinct frameworks, BEF and EFQMEM. This averaging process assumes that these frameworks are comparable in these specific categories, a presumption that may not hold universally. Another limitation is the framework's dependence on the quality of available data. Despite these constraints, the framework is designed to have broad applicability and should not be significantly compromised in its utility. Due consideration should be given when applying the framework to varied organisational and cultural settings.

In both BEF and EFQMEM, there are four levels of awards, including the Commitment Award, Proficiency Award, Mastery Award, and Excellence Award for the BEF (Veenstra and 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., 2021). 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 BIM maturity level 1, over 500 points for BIM maturity level 2, and over 750 for BIM maturity level 3.

5 Conclusion

This study significantly contributes to knowledge by delivering a thorough, qualitative exploration of the BIM adoption process. It bridges a gap in existing literature, offering a multifaceted understanding of the pivotal factors influencing BIM adoption. This is achieved through the identification of seven key categories from the analysis of 21 interview transcripts and well-recognised BIM models like BEF, EFQMEM, and ABEF, enriching the understanding of influences and determinants of BIM adoption and providing a basis for further academic investigation. It also illuminates new areas of enquiry, such as the interconnectedness amongst the seven identified categories and their collective effect on BIM adoption.

From a practical viewpoint, this research holds the potential to impact industry practices notably. It presents a BIM adoption framework as a strategic guide, assisting industry stakeholders in effectively preparing for BIM projects. Emphasising the role of leadership, this framework can play a crucial role in decision-making within construction firms, aiding them in identifying and addressing potential shortcomings. This tool allows organisations to measure their BIM adoption maturity and promotes a smoother transition to BIM. By enhancing planning and implementation, this research can boost project outcomes, increase efficiency, and decrease costs for companies implementing BIM. This could encourage more widespread BIM adoption across the construction industry, improving the quality of construction projects and outcomes.

Furthermore, the five hypotheses developed in this study pave the way for future research. They suggest paths for validating these hypotheses and exploring the interactions among the seven categories. Additionally, the point allocation system needs to be validated to ensure its suitability for the various categories within the framework. This sets the stage for a more detailed examination of each category's role in the success of a BIM project. The research, therefore, lays a precedent for subsequent studies, providing a strong base from which other researchers can further their investigations into BIM adoption. Consequently, it could lead to more comprehensive models and refined strategies that can further enhance the success rates of BIM adoption in the future.

Acknowledgements

This paper is a significant upgrade to the paper “Building Information Modelling (BIM) Framework for Practical Assessment” presented at the International Conference on Construction and Real Estate Management in Canada on 21–24 May 2019.

The authors are grateful to all respondents who participated in this study.

This research has been supported by a Vice Chancellor Doctoral Scholarship by Auckland University of Technology, New Zealand.

References

Abdelaal, F. and Guo, B. H. W. (2022), "Stakeholders' perspectives on BIM and LCA for green buildings", *Journal of Building Engineering,* Vol. 48, p. 103931.

Aladağ, H., Demirdöğen, G., Demirbağ, A. T. and Işık, Z. (2023), "Understanding the perception differences on BIM adoption factors across the professions of AEC industry", *Ain Shams Engineering Journal,* Vol. 14 No. 11, p. 102545.

Bassioni, H. A., Price, A. D. and Hassan, T. M. (2005), "Building a conceptual framework for measuring business performance in construction: An empirical evaluation", *Construction Management and Economics,* Vol. 23 No. 5, pp. 495-507.

Bosch-Sijtsema, P., Isaksson, A., Lennartsson, M. and Linderoth, H. C. (2017), "Barriers and facilitators for BIM use among Swedish medium-sized contractors - "We wait until someone tells us to use it"", *Visualization in engineering,* Vol. 5 No. 1, p. 3.

Chan, C. T. (2015), "BIM from design stage – Are Hong Kong designers ready?", in *3rd International Conference on Logistics, Informatics and Service Science (LISS 2013)*, 21-24 August 2013, Reading, UK, pp. 271-276.

Doan, D. T., GhaffarianHoseini, A., Naismith, N., Ghaffarianhoseini, A., Zhang, T. and Tookey, J. (2021), "Examining critical perspectives on Building Information Modelling (BIM) adoption in New Zealand", *Smart and Sustainable Built Environment,* Vol. 10 No. 4, pp. 594-615.

Donato, M. and Shee, H. (2015), "Resource dependency and collaboration in construction supply chain: Literature review and development of a conceptual framework", *International Journal of Procurement Management,* Vol. 8 No. 3, pp. 344-364.

Durdyev, S., Ashour, M., Connelly, S. and Mahdiyar, A. (2022), "Barriers to the implementation of Building Information Modelling (BIM) for facility management", *Journal of Building Engineering,* Vol. 46, p. 103736.

Eadie, R., Odeyinka, H., Browne, M., McKeown, C. and Yohanis, M. (2013), "An analysis of the drivers for adopting building information modelling", *Journal of Information Technology in Construction (ITcon),* Vol. 18 No. 17, pp. 338-352.

EFQM (2018), "EFQM excellence model", European Foundation for Quality Management (EFQM).

EFQM (2019), "EFQM recognition", European Foundation for Quality Management (EFQM).

Faisal Shehzad, H. M., Binti Ibrahim, R., Yusof, A. F., Mohamed khaidzir, K. A., Shawkat, S. and Ahmad, S. (2022), "Recent developments of BIM adoption based on categorization, identification and factors: A systematic literature review", *International Journal of Construction Management,* Vol. 22 No. 15, pp. 3001-3013.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O. and Raahemifar, K. (2017), "Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges", *Renewable and Sustainable Energy Reviews,* Vol. 75, pp. 1046-1053.

Gómez-López, R., López-Fernández, M. C. and Serrano-Bedia, A. M. (2017), "Implementation barriers of the EFQM excellence model within the Spanish private firms", *Total Quality Management & Business Excellence,* Vol. 28 No. 7-8, pp. 695-711.

Gupta, N. and Vrat, P. (2020), "An evaluation of alternative business excellence models using AHP", *Journal of Advances in Management Research,* Vol. 17 No. 2, pp. 305-331.

Hall, A. T., Durdyev, S., Koc, K., Ekmekcioglu, O. and Tupenaite, L. (2022), "Multi-criteria analysis of barriers to building information modeling (BIM) adoption for SMEs in New Zealand construction industry", *Engineering, Construction and Architectural Management,* Vol. ahead-of-print No. ahead-of-print.

Herr, C. M. and Fischer, T. (2019), "BIM adoption across the Chinese AEC industries: An extended BIM adoption model", *Journal of Computational Design and Engineering,* Vol. 6 No. 2, pp. 173-178.

Hong, Y., Hammad, A. W., Sepasgozar, S. and Akbarnezhad, A. (2019), "BIM adoption model for small and medium construction organisations in Australia", *Engineering, Construction and Architectural Management,* Vol. 26 No. 2, pp. 154-183.

Hosseini, M., Banihashemi, S., Chileshe, N., Namzadi, M. O., Udaeja, C., Rameezdeen, R. and McCuen, T. (2016), "BIM adoption within Australian small and medium-sized enterprises

(SMEs): An innovation diffusion model", *Construction Economics and Building*, Vol. 16 No. 3, pp. 71-86.
Kassem, M. and Succar, B. (2017), "Macro BIM adoption: Comparative market analysis", *Automation in Construction*, Vol. 81, pp. 286-299.
Kuckartz, U. (2019), "Qualitative text analysis: A systematic approach", *Compendium for Early Career Researchers in Mathematics Education*, pp. 181-197.
Likita, A. J., Jelodar, M. B., Vishnupriya, V., Rotimi, J. O. B. and Vilasini, N. (2022), "Lean and BIM implementation barriers in New Zealand construction practice", *Buildings*, Vol. 12 No. 10, p. 1645.
Lu, W. and Yuan, H. (2011), "A framework for understanding waste management studies in construction", *Waste Management*, Vol. 31 No. 6, pp. 1252-1260.
Ma, L., Lovreglio, R., Yi, W., Yiu, T. W. and Shan, M. (2023), "Barriers and strategies for building information modelling implementation: a comparative study between New Zealand and China", *International Journal of Construction Management*, Vol. 23 No. 12, pp. 2067-2076.
MBIE (2017), "Small business in New Zealand: How do they compare with large firms?", New Zealand, Ministry of Business, Innovation & Employment (MBIE).
Meng, X. (2010), "Assessment framework for construction supply chain relationships: Development and evaluation", *International Journal of Project Management*, Vol. 28 No. 7, pp. 695-707.
Mohammad, M., Mann, R., Grigg, N. and Wagner, J. P. (2011), "Business excellence model: An overarching framework for managing and aligning multiple organisational improvement initiatives", *Total Quality Management & Business Excellence*, Vol. 22 No. 11, pp. 1213-1236.
Newton, K. and Chileshe, N. (2012), "Awareness, usage and benefits of building information modelling (BIM) adoption - The case of the South Australian construction organisations", in *28th Annual ARCOM Conference*, 3-5 September 2012, Edinburgh, UK, pp. 3-12.
Ngacho, C. and Das, D. (2015), "A performance evaluation framework of construction projects: Insights from literature", *International Journal of Project Organisation and Management*, Vol. 7 No. 2, pp. 151-173.
NIST (2019), "Baldrige criteria commentary", US, National Institute of Standards and Technology (NIST).
NZBEF (2019), "Performance excellence", New Zealand, New Zealand Business Excellence Foundation (NZBEF).
Okakpu, A., Ghaffarianhoseini, A., Tookey, J., Haar, J., Ghaffarianhoseini, A. and Rehman, A. U. (2022), "Risk factors that influence adoption of Building Information Modelling (BIM) for refurbishment of complex building projects: stakeholders perceptions", *International Journal of Construction Management*, Vol. 22 No. 13, pp. 2446-2458.
SAI-Global (2011), "The Australian business excellence framework 2011", Australia, SAI Global Pty Limited.
Scheer, A. (2017), "Conservative leadership debate in Vancouver", Vancouver, Canada.
Tang, W. (2023), "Application of BIM technology in the reinforcement and renovation of existing building inspection projects", *Alexandria Engineering Journal*, Vol. 82, pp. 240-247.
Tickle, M., Mann, R. and Adebanjo, D. (2016), "Deploying business excellence–success factors for high performance", *International Journal of Quality & Reliability Management*, Vol. 33 No. 2, pp. 197-230.
Valdes-Vasquez, R. and Klotz, L. E. (2012), "Social sustainability considerations during planning and design: Framework of processes for construction projects", *Journal of Construction Engineering and Management*, Vol. 139 No. 1, pp. 80-89.
Veenstra, C. and Furst-Bowe, J. (2017), "Feature Baldrige award", qualityprogress.com.
Wang, S. Q., Dulaimi, M. F. and Aguria, M. Y. (2004), "Risk management framework for construction projects in developing countries", *Construction Management and Economics*, Vol. 22 No. 3, pp. 237-252.

Table I. Interviewees demographics

No	Position	Years of	Construction	Company

		Experience	Type	Size
1	Senior Quantity Surveyor	10	Contractor	Large
2	BIM Manager	14	Design	Large
3	Director, Building Scientist	12	Consultancy	Large
4	Senior Architect	15	Design	Large
5	Technical Services Manager, Design Manager	22	Contractor	Large
6	1) Director & Building Surveyor[1] 2) Building Surveyor	14 04	Consultancy	SME[2]
7	Principal & Designer	30	Design	SME
8	Senior Cost Manager	20	Consultancy	Large
9	Building Services Technical Leader	08	Consultancy	Large
10	Director & Building Performance Expert	19	Consultancy	SME
11	1) BIM Manager[1] 2) Building Scientist	22 03	Design	Large
12	1) Associate & Structural Engineer[1] 2) Drawing Office Manager	10 19	Design	Large
13	Structural Technician	08	Design	Large
14	Sustainability Leader	13	Design	Large
15	BIM Construction Manager	11	Contractor	Large
16	Technical Lead & Senior Quantity Surveyor	12	Multidiscipline	Large
17	BIM Consultant, Application Engineer, & Business Analyst	17	Information Technology	SME
18	Associate Senior Architect	11	Design	Large
19	1) BIM Development Engineer[1] 2) Senior Structural &Sustainable Engineer	20 08	Consultancy	Large
20	Principal Quantity Surveyor	08	Multidiscipline	Large
21	Green Star Assessor	10	Non-profit	Large

Note: [1]Corresponding interviewee

[2]SME: Small and medium enterprise

Table II. 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.