Underperformance of Information and Communication Technology in Construction Organizations: A Correlational Study between the Performance and the Strategic Alignment

Hassan Khames Hassan Eliwa

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Building and Construction

Field of Building and Construction

Supervised by:

Dr Mostafa Babaeian Jelodar
Dr Mani Poshdar
Dr Azam Zavvari

School of Built Environment, College of Science
Massey University
New Zealand

August 2023

Abstract

The construction industry is applying information and communication technology (ICT), but it is evident that it does not realise its full potential and is underperforming, although other sectors are using the benefits of ICT and are extremely successful. Based on that, it is required to study and investigate the underperforming of the construction ICT and identify the problems and challenges leading to underperformance and shortcomings of ICT utilisation in construction organisations. Organisation and ICT alignment remains a top priority for businesses to improve operational efficiencies.

Various studies have concluded that applying the strategic alignment model (SAM) in construction organisations can achieve better performance outcomes from the project to the organisation level. A positive connection between the utilisation of ICT and project performance has been established and concluded. However, the effects of ICT infrastructure strategy alignment with the organisational ICT infrastructure on construction organisations' performance have not been investigated. This research evaluates and analyses the importance of the alignment between the ICT infrastructure and the organisational infrastructure to improve the underperforming construction ICT not just at the project level but also at the level of construction organisations.

The main objective of this research is to investigate whether the effect of ICT utilisation on project performance may be restricted and affected by its alignment with the ICT infrastructure level in the organisation. This research aims to develop guidance that assists construction organisations in solving the construction industry underperforming, the alignment of ICT in the construction industry, and improve the probability of arriving at a specific alignment solution for the construction organisation by determining the strategic alignment impact between ICT and business on organisational performance of construction organisations. A method of evaluating ICT utilisation in the construction industry and strategic alignment is proposed. The effects of this strategic alignment on project performance are discussed, and recommendations for optimal strategic utilisation are provided. The study is significant as it will introduce to the construction organisations the role of the ICT function, the method of operation of the ICT function and the sourcing options of the ICT function as antecedent variables to the alignment of business and ICT within the organisation. The research follows a practical process to understanding the complexity, challenges and requirements for ICT implementation.

Acknowledgements

I am deeply grateful to the many individuals, friends, and organizations who have helped me along the way on this research journey. I would especially like to thank Dr Mostafa Babaeian Jelodar for his outstanding support as my supervisor and academic mentor. His enlightened guidance and careful consideration have been instrumental in completing this thesis. Moreover, Dr Mostafa has also been a great friend and supporter throughout my time at Massey University.

I would also like to extend my appreciation to Dr Mani Poshdar and Dr Azam Zavvari for their advice and support as my co-supervisor. Their invaluable insights and immense care have been extremely reassuring and an anchor of encouragement.

I am genuinely grateful for the support of all of those who have helped me along the way. Without their help, this achievement would not have been possible. I would like to express my sincere respect and appreciation to all of those who participated in this study, including those who took part in the expert interviews and the surveys. Your insights and feedback were invaluable to the success of this project.

I am incredibly grateful to my parents, my dear mother, Shadia Ahmed (may she rest in peace) and my father, Khames Eliwa, for giving me the guidance, opportunity, and love to follow my dreams. They were my first supporters and guides in life, and they instilled in me the values that helped me achieve my goals. They have taught me the importance of hard work, perseverance, and love. I am so grateful for everything they have done for me.

Above all I would like to thank my wife, Hanan Alaiwah, for her love and constant support, for all the late nights and early mornings. She gave me support and help, taught me how to be patient, discussed ideas and prevented several wrong turns. She also supported the family during much of my

graduate studies. She has been my best friend, and my biggest fan. She has always believed in me, even when I didn't believe in myself.

I would also like to thank my brothers and sisters, Mohammed, Hend, Hussam, and Basmah, and my parents-in-law, for their love and support. They have always been there for me, no matter what. They have cheered me on, offered me advice, and helped me. I am so grateful for their love and support.

Finally, I would like to thank all of my family and friends for their love and support. You have all played a role in my journey, and I am so grateful for your presence in my life. Also, I would like to acknowledge my late friend, Dr Ayuba Jerry Likita (RIP), for his friendship and inspiration. Ayuba was a brilliant scholar and a kind soul. He was always willing to help others and had a passion for learning. I am so grateful for the time we spent together, and I will never forget his friendship.

I am truly blessed to have such a loving and supportive family. I could not have done this without you. Thank you.

Table of Contents

List of Tables

List of Figures

Glossary

AD	Actual Duration
BIM	Building information modelling
CAD	computer-aided design
CPSM	Critical path schedule method
CR	Change request
CRM	Customer Relationship Management
DPI	Duration Performance Index technique
DSS	Decision support system
ED	Earned Duration
EDM	Earned Duration Management
EIS	Executive support system
EPA	Engineering Plan Approval
EVM	Earned Value Management
GIS	Geographic Information System
ICT	Information and Communication Technology
IFC	Issue for construction (design)
IT	Information Technology
JCEM	Journal of Construction Engineering and Management

KMO	The Kaiser-Meyer-Olkin calculation factor
MBIE	Ministry of Business, Innovation and Employment
MRA	Multiple Regression Analysis
NCD	National construction demand
NZD	New Zealand Dollar
NZTA	NZ Transport Agency
OS	Operating systems
PCFA	Principal Component Factor Analysis
PPP	Public Private Partnership
RFID	Radio-frequency identification
SA	Strategic Alignment
SAM	Strategic Alignment Model
VIF	Variance inflation factor
WoS	Web of Science core

Chapter 1: Introduction

1.1 The underperformance of ICT in Construction: An Overview

The construction sector is one of the most significant sectors of investment worldwide, and it is one of the most influential sectors for New Zealand's economic development; according to the Ministry of business report 2021, it is ranked in the top five most contributing fields (Liu et al., 2017; Yang et al., 2018; MBIE, 2021; Evgenievich et al., 2018; Wilkinson, 2012). However, this industry faces significant challenges, including low productivity, chronic delays, cost overruns, and quality issues (Mbachu & Taylor, 2017; Poshdar et al., 2014; Rudolf et al., 2018).

In general, finding a solution to improve work productivity and project outcomes is a continuous challenge for organisations in the construction sector to achieve client demands (Xiao et al., 2018; Jelodar & Yiu, 2012; Jianhua et al., 2018). However, the client quality requirements, domestic competition, the local economy and market demand are the main factors that format this challenge (Love & MacSporran, 1996; Wilkinson, 2012; Enqing et al., 2017; Sohi et al. 2018). On the other hand; the construction organisations need to make their project management knowledge more efficient in addition to adopting modern methods and channels of applying new technologies (Jelodar, Yiu, & Wilkinson, 2016; Jia & Min, 2010; Onyegiri, Nwachukwu, & Jamike, 2011; Forcada & Matheu, 2017; Ingram & Kenny 2017). Furthermore, the studies show that using advanced project management methods combined with modern tools and systems such as information technology can deliver a 30% enhancement in total industry performance (Jia & Min, 2010). This situation calls for a reassessment of the state of the project management knowledge and the level of penetration of modern methods and technologies (Jelodar et al., 2016; Jia & Min, 2010; Onyegiri et al., 2011; Ingram & Kenny, 2017; Sohi et al. 2018).

Information and Communication Technology (ICT) supports the processing, storing, sharing and producing information (Bjork, 1997). Initially, it mainly depended on data processing. However, given its widespread adoption today, ICT can offer a higher level of cooperation, coordination and information integration to enhance construction performance (Forcada & Matheu, 2017). Implementing ICT can benefit all the construction phases, including the initial project planning, the execution stage, and the operational development. A review of the reports on the penetration of IT in construction shows that the adoption has started in projects (Weippert et al., 2003; Cepurnaite et al., 2017; Jeong & S. Y., 2018). However, the efficient expenditure of ICT in construction is not easy to achieve by quantifying these technologies' spending in the organisation's budget. Thus, to resolve this issue, it is essential to conduct more studies to understand the various conditions to link the performance with ICT operation into account (Gaith, Khalim, & Ismail, 2009; Zhanglu & Wenwen, 2014; Enqing et al. 2017; Milyutina 2018). However, a full establishment of ICT in construction remains subject to the institutionalisation of a strategic alignment between ICT applications and the business strategies adopted by the firm (Acar et al., 2005; Gaith et al., 2009; Stewart & Mohamed, 2003). According to Boddy et.al 2008, the strategy has been defined as diverse activities supporting the organisation's competitive status, such as monitoring, actions, planning, and performing pre-planned processes (Boddy, Boonstra & Kennedy, 2008).

On the other hand, Business strategy encapsulates a theory regarding the way in which a business will compete, its policies and the objectives required to achieve it. ICT strategy is a comprehensive plan that outlines how technology should be used to meet ICT and business goals (Luftman, 1996). The competitive strategy consists of policies and goals that shape those goals (Peansupap & Walker 2005). Alignment is the scope to which mission and objectives exist in the business strategy and are reinforced and shared by the ICT strategy (Luftman, 1996).

The alignment of ICT with the business targets of construction organisations is considered an essential subject (Stewart & Mohamed, 2003; Boddy, Boonstra & Kennedy, 2008; Jia & Min, 2010;

Andres & Poler, 2017). Researchers have compared and analysed the implementations of different ICT tools and their effect on the performance of construction organizations and found out that the improvement of the performance, in general, does not depend on the type of implemented ICT tools but on the way this implementation (Boddy, Boonstra & Kennedy, 2008; Andres & Poler, 2017; Amirtash et al., 2021; Huo et al., 2021). Other researchers have gone into a depth analysis and studied the processes and approaches for assessing ICT and business alignment based on the reality that ICT has not lived up to firms' expectations of improving performance and competitiveness based on the literature and other case studies analysis (Boddy, Boonstra & Kennedy, 2008; Andres & Poler, 2017; Eliwa et al., 2020; Dos Santos et al., 2021; Haniff et al., 2022; Gellweiler C., 2022; H. K. Eliwa et al., 2022). These researchers concluded a weakness in the ICT alignment with the business, which resulted in underperformance of the construction ICT based on extracted data from different organizations using different methodologies (Boddy, Boonstra & Kennedy, 2008; Andres & Poler, 2017; Eliwa et al., 2020; Dos Santos et al., 2021; Haniff et al., 2022; Gellweiler C., 2022; H. K. Eliwa et al., 2022). On the other hand, the ICT is widely acknowledged as an increasingly powerful tool for improving the delivery of private and public services as well as enhancing organisations' overall global reach and opportunities in other industries based on other studies and governmental finance reports (Boddy, Boonstra & Kennedy, 2008; Andres & Poler, 2017; SRG, 2017; CCC 2017; Eliwa et al., 2020; MBIE, 2021; Almajali et al., 2022; Evans M. and Farrell P., 2022).

As (Naoum S. G., 2016) defined, productivity is an organisation's ability to utilize its available resources to produce profitable services considering clients' requirements. It is productivity that measures the performance of an organisation's productivity and increases its overall efficiency. So, when the organisation's efficiency increases, the organisation's production capacity is utilized to the optimum level (Naoum S. G., 2016; Haniff et al., 2022). The value of ICT is difficult to explain on a balance sheet owing to its interweaving nature (Acar et al., 2005; Faltinsky & Tokunova, 2018).

Faltinsky et al. (2018) have identified that organisational efficiency is achieved once the concentration is directed towards either cost efficiency or innovation through ICT but not both.

Every successful business has a plan and knows where it is heading in the future; without strategic planning, which is knowing the current state of your business and where you want it to go, most businesses will fail as the strategic plan allows the organisations to see what is important for its future (Almajali et al., 2022).

Similar to strategic planning, ICT planning can help organisations in the creative adoption of ICT in several ways: rationalising its investment (Andres & Poler; 2017), controlling expenditure (Andres & Poler; 2017), protecting existing ICT investments (Zhihe et al., 2018), resolving conflicting demands for limited ICT resources (Andres & Poler; 2017), obtaining joint ICT management/user commitment (Zhihe et al., 2018), and avoiding ad-hoc ICT projects (Boddy, Boonstra & Kennedy, 2008; Andres & Poler; 2017; Zhihe et al., 2018). Accordingly, researchers suggest that organisations that actively align their business and ICT strategies witness positive impacts in terms of ICT effectiveness (Chan, 1991; Henderson et al., 1996; Izanec, 1997), resulting in enhanced business performance (Li et al., 2018). However, ambiguity still exists regarding the impact, nature and characteristics of alignment and methods of linkage and integration, which remains one of the main concerns for organisations (Stewart & Mohamed, 2003; Milyutina, 2018). In this area have not yet been sufficient research on the factors affecting business-ICT alignment, especially the ones related to the culture and nature of the organisation as the organisation’s culture drives the behaviours of employees who are responsible for the execution of the business strategy. Therefore, if those assumptions, beliefs and behaviours are not aligned with the activities and intentions that support your strategy, it will lead to a lacking of performance (Chan, 1991; Izanec, 1997; Boddy, Boonstra & Kennedy, 2008; Gaith, 2009; Jelodar et al., 2016; Sohi et al., 2018).

New Zealand governmental report by the ministry of business identified that New Zealand businesses failed to utilise the full potential of information technology to improve business outcomes (MBIE, 2021). Another research by the Sapere experts research group - the largest data analytics expert in Australia and New Zealand - found that New Zealand organisations that make more comprehensive use of information technology are 6% more productive than their industry average (MBIE, 2021; SRG, 2017). However, this depends on the business sector; the researchers noted that the increased ICT use in firms working under service sectors such as retail, professional services, tourism and agriculture was driving business productivity improvement (MBIE, 2021; SRG, 2017; CCC 2017). A follow-up report by Sapere research group, one of the largest expert consulting firms in New Zealand, found that New Zealand organisations in the services and industrial sector make greater use of ICTs than the construction sector. Moreover, the report found that the use of the ICT in the services and industrial sector is more productive than its use in the construction sector (MBIE, 2021; SRG, 2017). On the other hand, the same researchers found that the construction and transportation sectors are the areas with the greatest chance for productivity improvement if they use information technology as a part of the business strategy. In general, the report concluded that the productivity differences between Australia and New Zealand in the construction industry might reflect variances in the uptake of information technology. However, New Zealand is notably more productive in the construction industry and has a comprehensive uptake of information technology, which is fairly similar to Australia (MBIE, 2021; Wilkinson, 2012).

The theory behind Strategic alignment is that a link between ICT and the firm's business strategy can provide strong solutions to the firm's strategic problems (Luftman, 1996). The implementation of ICT in construction firms worldwide has been the subject of extensive research especially in the recent decades. However, few of them analysed the strategic alignment of ICT with business strategies and discussed its effect on the organisation's performance (Stewart & Mohamed, 2003; Sarshar & Isikdag, 2004; Acar, Kocak, Sey & Arditi, 2005; Gaith et al., 2009; Wilkinson, 2012; Zhanglu & Wenwen, 2014; Enqing et al. 2017).

Even though the studies regarding the strategic alignment of ICT and Business are limited (Boddy, Boonstra, & Kennedy, 2008; Harris & Brown, 2010; Andres & Poler, 2017), there is a necessity for aligning the construction firm business strategy and ICT strategy to assist the specific organisation in current competitive markets and improve its performance (Sarshar & Isikdag, 2004; Acar et al., 2005; Boddy, Boonstra, & Kennedy, 2008; Jelodar & Yiu, 2012). According to Izanec (1997), the strategic alignment model's primary definition is composed of two main dimensions which are the strategic fit and the functional integration. the strategic fit refers to the concordance between internal and external domains and the functional integration refers to two types of integration between business and ICT domains (Henderson et al., 1996). The first type is termed strategic integration and reflects the link between business strategy and ICT Strategy. The second type is termed operational integration and deals with the link between organisational infrastructure and process, and ICT infrastructure and process (Henderson et al., 1996). However, to effectively implement the strategic alignment, the firm has to work on both the strategic fit, which is related to infrastructure-operation support and functional combination or integration, which is related to business plans and information technology support, to achieve the results for all internal and external domains within each element (Chan 1991; Henderson et al., 1996; Boddy, Boonstra, & Kennedy, 2008).

To efficiently implement ICT, it is necessary to analyse the relationship between the ICT strategy and the construction firm's strategy (Sarshar et al. 2004; Acar et al., 2005; Goh, 2006; Boddy et al., 2008; Enqing et al. 2017). It has been found that the predominant problem affecting the efficiency of construction organisations is a neglected relationship between the business strategy and the information technology strategy. (Peansupap & Walker, 2005; Goh, 2006; Harris & Brown, 2010; Andres & Poler 2017). Therefore, an in-depth investigation of the relationship between ICT strategy and existing business strategy is essential. This research aims to bridge the knowledge gap in the strategic alignment of construction information technology and business, as well as identify the factor influencing underperformance of ICT implementation in construction organisations.

1.2 Background

In the late 1960s, academia and industry in Japan emphasised the importance of ICT as a phase of economic development (Björk, 1999; Zhanglu & Wenwen, 2014). However, its application in engineering started in the 1970s as a computer-aided design (CAD) tool that facilitated the creating of engineering drawings (Forcada Matheu, 2017). However, this usage was limited to large-scale engineering projects. The development of personal computers (PC) in the 1980s increased computational power and facilitated its implementation in medium-scale projects (Forcada Matheu, 2017; Peansupap & Walker, 2005).

The core processes of organisation asset management involve the finalization of paper works and manual labour, which makes it more time-consuming and prone to human errors. Moreover, the transparency of the relevant information directly affects the economics and efficient operation of a utility business (Sinha et al., 2007; Huo et al., 2021). Both system performance and information transparency can be enhanced by designing and developing the ICT solution for managing the core business processes of asset management (Sinha et al., 2007; Huo et al., 2021). These requirements for information transparency and perfection in a competitive business calls for effective tools that could enable business efficiency (Sinha et al., 2007; Huo et al., 2021). The alignment of business efficiency with supporting technologies is the main concept of strategic alignment. Strategic alignment is proposed to support integrating information technology into business strategy and processes (Huo et al., 2021). Luftman (1996) defines strategic alignment as a concept that aligns information frameworks with the business strategy to shape a powerful competitive edge and produce strong solutions for the needs of the organisation and field. The Strategic Alignment Model has been established on the idea of "strategic fit", which is the vertical linkage between external and internal domains and explains the business requirement to make decisions. Figure 1.1 demonstrates another connection that can be established in the "functional integration" between firm and technology domains. It relates to information technology and the alignment of the business (Henderson et al., 1996). The concept of the strategic alignment model theorises the analytical scope of the firm strategy from the infrastructure and operation support (strategic fit) or business plans and ICT support which is called as the functional integration (Izanec, 1997). On the other hand, Henderson (1996) concluded that the organisation should work on both strategic fit with functional integration for better results (Henderson et al., 1996).

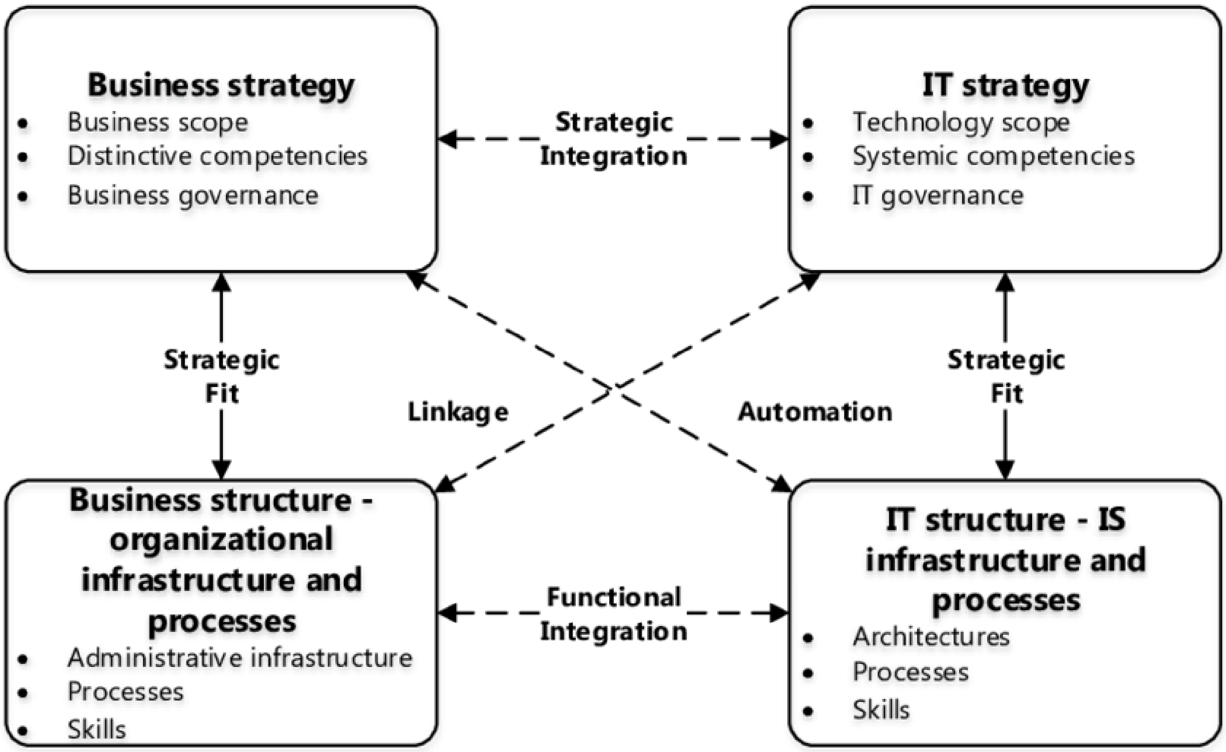

Figure 1.1: Strategic Alignment Model for Business. Source: Adapted from (Henderson & Venkatraman, 1989)

In the early years, ICT mainly employed the 'back office' of the firms, but as technology evolved at a rapid pace, the strategic role of information technology started to rise. An early attempt to capture the strategic power of information and communication technology was the "Massachusetts Institute of Technology (MIT)" Model created by Scott Morton (1991). The model hypothesises that revolutionary transformation actuated by the ICT investments can drive considerable rewards, but when strategy, management processes, technology, structure, individuals and roles are being aligned (Scott Morson, 1991).

Other researchers have analysed the barriers that control the spread and the implementation of ICT in construction organisations, such as the nature of the application itself and considering the business strategy over the ICT infrastructure (Henderson et al., 1996; Peansupap & Walker, 2005). Regarding the strategic alignment, they concluded that the business strategy, ICT strategy, firm infrastructure and ICT infrastructure should have a level of integration for best results as it was illustrated in Figure 1.1 (Henderson & Venkatraman, 1989; Henderson et al., 1996; Peansupap & Walker, 2005).

The alignment between business and ICT has been a major topic in engineering construction literature for many years. Early research considered this alignment as the fit between the business policy and the ICT plan. As construction projects became more complicated and expensive, and affected a greater number of other businesses, doing effective planning became of utmost importance (Mclean, 1977). Throughout the years, literature has defined the business and the ICT alignment as the level of coherence between recognised ICT strategy and business strategy (Henderson & Venkatraman, 1989; Chan, 1991).

Henderson and Venkatraman (1993) defined the strategic fit in terms of the linkage between the internal infrastructure process and external business strategy. However, Reich (1996) described the strategic fit as the linkage between the business and ICT domains (Henderson & Venkatraman, 1989; Reich, 1996).

As explained, Henderson et al. (1996) concluded that the organisation should work on both the infrastructure and operation support (strategic fit) with business plans and ICT support (functional integration) for better results, and there are internal and external domains within each element. The internal domain in the business strategy area is described as "organisational infrastructure and processes”. It is mainly concerned with options that determine the structure or restructure of critical business procedures, the executive structure, and the development of resource skills. The external domain in this area is described as "business strategy", which involves governance decisions, business scope decisions and distinctive competency (Goh, 2006; Henderson et al., 1996). The internal domain in the ICT strategy area is described as "ICT infrastructure and processes", and it is concerned with managing the ICT infrastructure in regard to its architecture, processes and skills. On the other side, the external domain in this area is described as "ICT strategy", and it relates to the organisation's place in the ICT marketplace in relation to its technology scope, ICT governance and systemic competencies (Goh, 2006; Henderson et al., 1996). A wide range of tools and techniques have been proposed to process the alignment issue using measurement methods or modelling techniques, and one of the benefit models was the Strategic Alignment Model (Andres & Poler, 2017). Using the strategic alignment model the ICT domain and business domain are integrated at a strategic scale, relates ICT strategy and business strategy and the operational scale, and relates organisational infrastructure and ICT infrastructure. However, one of the four dominant alignment perspectives - presented in Figure 1.2 - must be considered to operationalise the model (Goh, 2006; Henderson et al., 1996). The latter argument was confirmed by Tulenheimo (2017), who demonstrated that the project budget and management culture have significant shortcomings. The study also demonstrated that it was difficult to penetrate the construction industry due to the inability to implement new technologies (Tulenheimo, 2017).

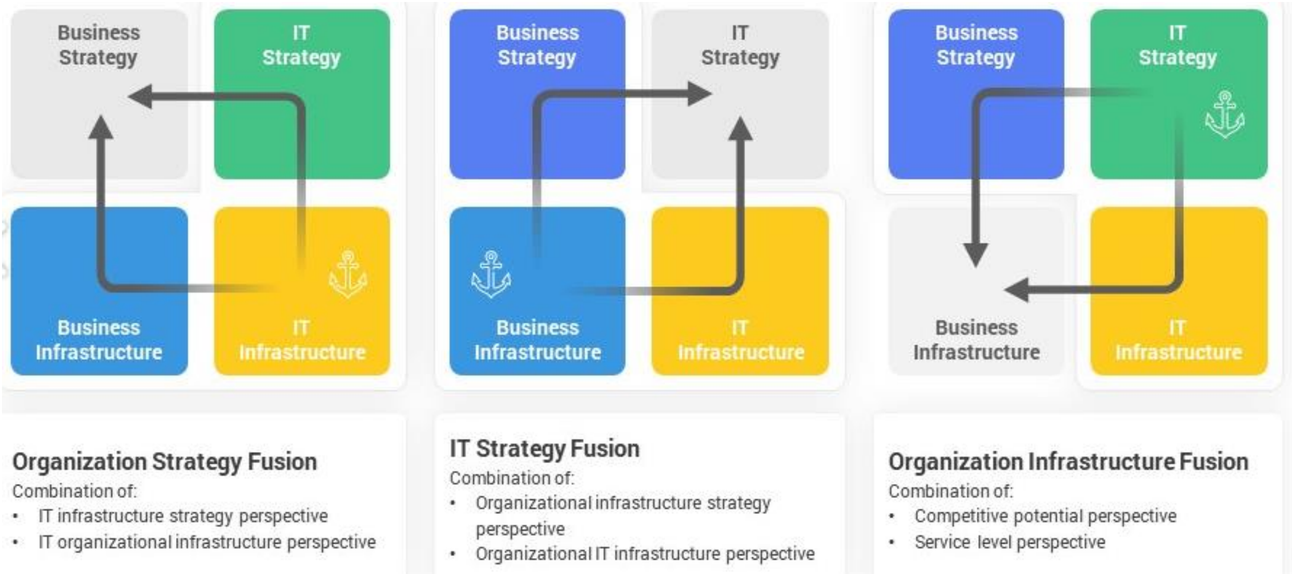

Figure 1.2: Four dominant alignment perspective of the strategic alignment model.

Moreover, the level of organisation was considered an obstacle in terms of ICT implementation, especially if the national use of ICT as a project management tool had not been considered during the early stage of the project cycle e (Jia & Min, 2010). Zhanglu and Wenwen (2014) have suggested that the impact of information and communication technology implementation on project performance and cost saving depends on the hosting country's growth and organisational culture towards ICT (Zhanglu & Wenwen, 2014). Thus, the effective use of ICT starts from the structure and the development of the construction firms. Wilkinson (2012) confirmed this finding after studying the volume of information technology applications; within construction project management of New Zealand during project phases and the acceptance of those organisations to invest in specialised ICT applications. It was found that companies with a large number of employees are more likely to use the information technology application and consider it as strategic to their firm (Acar et al., 2005; Sarshar & Isikdag, 2004; Wilkinson, 2012; Poshdar et al., 2018).

Although there are obstacles and barriers to implementing new ICT in the construction industry, there are direct and indirect relationships between ICT implementation and project performance (Peansupap & Walker, 2005). Some researchers found that ICT, in general, has a direct positive effect on the construction organisation's performance by improving work efficiency and facilitating project management (Sun et al., 2008; Gellweiler C., 2022). However, the positive impact of ICT on performance was offset by a negative impact on the organisation's workforce, such as limiting the options for employment, the effect on work-life balance experienced by employees, the effect on workforce attitudes and the creation of "technostress", which is stress results from working on technology for a long time (Sun et al., 2008).

As the above statement considers the application of ICT globally, however, some studies consider the breadth of application and volume of ICT in the New Zealand construction industry without considering its impact on the project outcomes. For instance, Wilkinson (2012) studied the usage and importance of ICT application corresponding to project management in New Zealand construction organisations during project phases and the organisational acceptance towards specialised investments in ICT applications. Based on a survey, the researchers found that 58% of the construction companies in Auckland used the ICT application related to project management during planning and monitoring works; around 21% of those construction companies created their project management applications that reflect the company's needs (Wilkinson, 2012). Thus, construction-related ICT applications in the New Zealand construction industry have a definite acceptance. However, more in-depth analysis and empirical evidence through the sector, organisation and project-based research are required to observe and identify the efficiency of using ICT tools and applications and determine the challenges around that (Liu et al., 2017).

Moreover, as per annual innovation and employment reports, New Zealand construction organisations appear to be underutilising the real possibility of ICT to improve business productivity. The Digital Economy sector in the New Zealand ministry of business supported research to understand the relationship and link between ICT use and business outcomes growth. It was reported that construction firms fall under one of three general models of ICT use; the low-density which uses ICT to obtain low business outcomes; the mid-density model, which uses ICT to obtain business outcomes; and the high-density model, which uses ICT to obtain great outcomes. From 2006 to 2021, construction organisations with high and medium ICT density use were more productive than low ICT density firms, but not as expected (MBIE, 2021).

The research also found that construction organisations with high ICT density were 6% more likely to improve their business outcomes over a two-year period than other construction organisations with low ICT density. However, construction organisations with medium ICT density use were less likely to improve their business outcomes than firms with low ICT density. Moreover, Small to medium-sized construction firms with employees between 6 and 49 that increased their ICT use was more likely to have business outcomes improved over the following two years. The research concluded that organisations with a high intensity of ICT use were more likely to improve their business outcomes if they had a clear strategy for using ICT in their business (MBIE, 2021).

1.3 Problem Statement

Even though the construction industry uses ICT, its full potential is not being realised, and it is underperforming, while other industries have benefited greatly from the use of ICT (Sarshar et al., 2004; Acar et al., 2005; Goh, 2006; Boddy et al., 2008; Wilkinson, 2012; MBIE, 2021; SRG, 2017; CCC, 2017; Enqing et al. 2017; Churbanov, 2018). ICT is recognised as the primary force influencing the performance and responsiveness of construction organisations, taking into account the fact that construction organisations and their management are under pressure to perform more with less. (Acar et al., 2005; Boddy & Kennedy, 2008; MBIE, 2021; SRG, 2017; CCC, 2017; Churbanov, 2018). However, the application of ICT systems may not automatically improve firm profitability (Bernat & Karabag, 2018).

Recent studies and governmental reports in New Zealand have revised the picture of declining performance in the construction sector. It appears the construction sector's performance has flatlined for 50 years of the science ICT revolution, and there is still a growing performance deficit relative to other industries. As ICT application has dramatically impacted the performance of different industries, the underperformance of the construction industries could be mainly due to the underperformance of ICT in the construction industry and the implementation of these technologies (Kang, 2012; Andres & Poler, 2017; MBIE, 2021; SRG, 2017; CCC, 2017; Alberto et al., 2018; Churbanov, 2018). Prior to the ICT revolution, organisations developed their fit-for-purpose information systems; however, after ICT, information systems were commercialised and developed by a third party. Hence, alignment becomes a necessity within the organisation because they often use products not developed (Sarshar & Isikdag, 2004).

The literature demonstrates that the natural reaction of researchers in the construction field of study is to align the efforts of business and ICT so that ICT delivers properly what a construction organisation expects and to promotes a culture of integration towards mutual objectives (Acar et al., 2005; Boddy, Boonstra, & Kennedy, 2008; Kang, 2012; Andres & Poler, 2017; Alberto et al., 2018). Organisations are encouraged to align their ICT strategies with business strategies to benefit from ICT opportunities since ICT is considered one of the critical organisational resources (Jorfi, Nor & Najjar, 2017).

Furthermore, it has been noted from the past decade that most organisations, especially in the construction sector in New Zealand, are focusing on integrating ICT and business strategy, ensuring the companies can be more competitive (MBIE, 2015; MBIE, 2021; SRG, 2017; CCC, 2017). This is because they believed that ICT plays vital roles regardless of other strategies and functions that could equally be as important as ICT (MBIE, 2017; SRG, 2017). However, some construction organisations recognise the critical role of other organisational functions, such as the marketing strategy, and the need to improve the alignment between two strategies into a more sophisticated alignment (SRG, 2017). Thus, it is required to provide a theoretical understanding to support short-term and long-term decision-making effectively and timely via the utilisation and application of improved strategic alignment.

According to previous studies by researchers such as of Acar (2005), Goh (2006), boddy (2008), Kang (2012), Bhattacharya (2017), and Churbanov (2018), it is necessary to analyse the connection between ICT strategy and construction organisation or construction project strategy before ICT implementation in the construction organisations. However, most of the previous researchers concluded that the common problem of construction organisations is the soft link between the organisation's infrastructure and ICT infrastructure, which affects the efficiency of ICT implementation (Bernat & Karabag, 2018).

1.4 Research Questions

The mixed results across various studies appealed for more empirical research to investigate the link between strategic alignment and organisational performance. In addition, there is a lack of research and empirical evidence on the strategic alignment of ICT in the construction industry and the challenges in adopting these technologies. Thus, it is required to study this area in depth and present it in an empirical manner which can benefit the construction industry in the future and the other researchers in this field of study. Accordingly, the current study has focused on answering the following main research questions rigorously:

- Why has the construction been underperforming in the application of information systems and technology?
- How can Functional Integration or the alignment between ICT infrastructure and organisation infrastructure improve the construction organisation performance?
- Furthermore, to follow a systematic approach and acquire well-structured answers to the main question, the following research questions also need to be addressed:

- What is the current practice and utilisation of ICT infrastructure in the construction industry?
- What are the strength and weaknesses of ICT utilisation among construction industry professionals and organisations?
- How are structure, process and skills elements within ICT and organisational infrastructure aligned in the construction industry?
- How are organisational requirements evaluated and ICT infrastructure application decisions made?

1.5 Research Objectives

This research aims to investigate the underperformance of information and communication technology in construction organisations through a correlational study between the construction organisation's performance and strategic alignment. To achieve this aim, the research objectives have been outlined below:

1. Provide current status, a comprehensive knowledge framework, and future directions of the construction industry body of knowledge by exploring and classifying the existing ICT-related research and evolutionary trends.
2. Identify problems and challenges leading to ICT underperformance by studying construction organisations' weakest strategic alignment domains empirically.
3. Identify the impact of ICT infrastructure and organisational infrastructure alignment on construction organisation performance.
4. Evaluate the alignment of ICT infrastructure and organisational infrastructure within construction industry.
5. Assess the construction industry decision-making process regarding ICT infrastructure and organisational infrastructure requirements, procurement, and alignment.

6. Provide recommendations to achieve the targeted alignment in construction organisations and suggestions for future research.

1.6 Rationale and Significance of the Study

This research has potential significance to both the theory and the practice of construction performance. It examines fundamental problems and issues, such as performance and strategic planning, while discussing the significant function of strategic alignment in improving organisational performance. It bridges the knowledge gap in strategic alignment of construction ICT and business strategy and accordingly studies the applicability of the relationship between organisational performance and strategic alignment across construction organisations. It will allow engineers, construction managers, researchers, and construction organisation executives to identify the impact of strategic alignment on construction organisation productivity performance and assess the organisational and alignment decision-making regarding ICT and organisational infrastructure. This research, therefore, presents a practical use of the Strategic Alignment Model (SAM), facilitating businesses in managing factors affecting alignment and providing scholars with empirical data on strategic alignment and organisational performance of construction organisations, paving the way for further research in this area.

In problem-solving, spending more time in the problem area is required before moving to the solution area (Bjork, 1997). This study attempts to apply this philosophy in addressing the continual business-ICT alignment problem. The idea is to develop a structured framework that will force the users to completely understand the situation in which it exists before attempting to find a solution, which is the primary significance of this study.

In trying to achieve the research objectives, this study will introduce to the construction organisations the role of the ICT function, the method of operation of the ICT function and the sourcing options of the ICT function as antecedent variables to the alignment of the organisation infrastructure with ICT infrastructure within the organisation. It is suggested that evaluating these variables should set the boundary conditions for the business-ICT alignment problem.

This study also determines the strategic focus areas or sources within the organisation that provide the goals to align as an important factor to be considered in the alignment process. Yet another factor that is particular to the organisation's culture within which the ICT function exists is to determine who should initiate alignment-related actions such as planning, communication and sharing of visions. Finally, this research has a potential significance to both the theory and the practice of construction performance. It determines fundamental problems and issues, such as performance and strategic planning, while discussing the significant function of strategic alignment in improving organisational performance. It tries to fill the discussed gaps in the problem statement part above and, accordingly, studies the applicability of the relationship between organisational performance and strategic alignment across construction organisations.

1.7 Research Methodology and Framework

This section discusses the adopted research methodology based on the research objectives, which have been stated in the objectives section, so a mixed method approach will be adopted in this research. It has substantial advantages, especially when using qualitative and quantitative methods (Jia & Min, 2010; Wilkinson, 2012; Liu et al., 2017; Rudolf et al., 2018). The qualitative research evaluates expert opinions regarding performance variables (Jelodar et al., 2016; Jia & Min, 2010; Onyegiri et al., 2011). The study is also quantitative since it utilises quantitative methods in data analysis and establishes quantitative relationships between the various concepts (Mbachu & Taylor, 2014; Poshdar et al., 2014). Therefore, the research will be carried out using five specific methodologies or stages:

1.7.1 ***Stage 1: Literature review:***

An overall review of related literature from journals, conference proceedings, official reports, textbooks and government reports was performed to recognise different characteristics and advantages of ICT implementation in the construction industry (Jia & Min, 2010; Onyegiri et al., 2011; Jelodar et al., 2015; Tulenheimo, 2017; Liu et al., 2017; Evgenievich et al., 2018; Alberto et al., 2018; Rudolf et al., 2018; Poshdar et al., 2018).

The literature review mainly concentrated on the quantitative analysis in regard to articles frequently emerging in the knowledge domain and were used to indicate the trends, timelines and hot topics. It explores the construction industry body of knowledge by classifying the existing ICT-related research and evolutionary trends, providing current status, a comprehensive knowledge framework, and future directions. This methodology provides a comprehensive and scientometric review of ICT application within the construction organisations' context based on high-impact studies performed in the last two decades. Therefore, it presents a critical literature review on the application of ICT in construction organisations. It also gives an overview of the available and trending ICT in construction organisations and their adaptions to different work and project processes.

1.7.2 ***Stage 2: Expert Interviews:***

The expert interview field study part of this research focus mainly on how Functional Integration is used by experts that help the organisation with strategic alignment, as this is the specific element of uncertainty that can be found in this research. By interviewing these people, detailed information was obtained on how they asked about the particular abilities of the consultant. The questions in the interview have been designed to determine how a consultant uses Functional Integration and ICT applications in his job and whether or not he analyses the strategy for possible errors (or uses what is given to him).

This methodology has been implemented by asking the experts questions about situations in practice information and how they look at the ICT-business alignment, Functional Integration and ICT infrastructure sides of strategic alignment. However, a consultant with several years of working experience is preferred to obtain this information. The interview method is generally used to acquire subjective information that cannot easily be translated into numbers. Interviews can be used to record attitudes, feelings, desires, thinking processes and knowledge. As explained, expert interviews are targeted at individuals who can be considered experts on a particular subject and thus possess above-average knowledge (Flick, 2009).

A significant advantage of using interviews as a research technique is that it is not restricted by location (Flick, 2009). Also, interviews can be used for fundamental and problem-solving research questions (Flick, 2009). Three types of interviews can be identified (Gubrium & Holstein, 2002; Glaser, 2009; Martin, 2011; Jelodar et al., 2018). The first type is the structured interview which the interviewer uses a pre-defined list of questions. The second type is semi-structured, in which the interviewer uses a list of guidelines and helper questions but not a fixed list of questions. The semi-structured interview method provides an equilibrium between the elasticity of open-ended questions and the concentration of a structured interview. The data during the semi-structured interviews can convert the study process from domain topics to more particular views (Harris & Brown, 2010). This type of qualitative study supplies key expert results with the same training and experience and can analyse multiple ways of problem management (Flick, 2009). Furthermore, using Expert Semi-structured interviews provides a foundation for validating other results from other research in the same field of study (Gubrium & Holstein, 2002; Jelodar et al., 2018). The last type is the unstructured interview; in this type, the researcher does not use pre-defined questions or points of interest but interacts with the expert to further the conversation.

For this research, expert Semi-structured open-ended interviews were selected as the most appropriate instrument for collecting the necessary data from construction organisations based in

Auckland, New Zealand. The focus of these interviews was on some particular methods: the methods that handle Functional Integration and how the strategy 'as given' is dealt with. The expert likely needs to be steered in this direction, which is why an unstructured interview is unsuitable. The interviews were conducted with the project managers, planning managers and senior engineers from each construction organisation. The interview responses rate was based on the theoretical saturation principle, which has been performed in similar research (Jelodar, 2016; Martin, 2011; Glaser, 2009).

Therefore, the selection process considered that all the interviewees worked in construction organisations in the higher tier of management roles and used ICT daily. The sample population holds high-ranked positions in their organisations, making them well-informed and experienced individuals. Therefore, the expectation that respondents must have a good understanding and demand of current practices and processes within their organisations and the wider construction industry is fulfilled. The expert face-to-face interviews were structured with foundation questions related to the relationship between the ICT implementation strategy and construction organisation strategy, followed by complementary open-ended questions for better tangibility responses.

1.7.3 Stage 3: The Structured Survey Questionnaire:

This research methodology aimed to develop a framework to evaluate the impact of functional integration of the internal domains in the strategic alignment model on the construction organisations' performance and outcomes. To achieve that, the researchers constructed a 3-parts self-administered quantitative expert survey questionnaire into two phases to accomplish this development goal. The first part contained questions regarding the participants' judgment, which was required to filter the quality results out of the total responses. The second part of the survey involved the ICT category selection based on the survey's users' experience in the ICT application in the construction industry. in this section, the users have the opportunity to rate the involvement of each ICT category in the construction field. This categorisation of the ICT considers the most critical factors that can affect the organisation and ICT infrastructure level (H. K. Eliwa et al., 2022; Ezcan, Goulding, & Arif, 2020). The final part of the survey was developed with questions that can estimate the strength of the functional integration domains for each ICT category considering the users' selection of the ICT applications as presented in the previous part. The questionnaire development structure and the selection criteria considered that all the participants worked at a professional level within the construction industry with at least five years of experience in the construction field and any ICT usage experience. The survey population has considered the position of the participants in their organisations; therefore, the results accuracy can be discussed based on the percentage of the participants' positions (Grassini & Laumann, 2020).

Based on the survey condition, each participant has answered the same number of questions multiple times based on their ICT classification selection. This type of question structure has increased the number of results for each question as each participant can be equivalent to a maximum of nine participants if they selected that they have an experience in all the ICT classifications mentioned above during the survey collection. Based on the survey development, 14 independent variables have been considered to determine the strength of the organisational and ICT infrastructure domains. On the other hand, the dependent variable has been identified as the organisational performance and outcomes, and it was concluded through seven structured questions during the survey.

The first step was using the principal component factor analysis method for selecting variables. The idea was to choose the optimal question for the dependent variable and three of the most ranked questions for each independent variable. Finally, the stepwise multiple regression analysis was used to evaluate the relationship between the construction organisations' performance and the improvement of the functional integration for both strategic alignment model domains, which are organisation infrastructure and ICT infrastructure. Stepwise multiple regression, compared with the other multivariate techniques, has the advantage that the number of prospect subset models tested or checked before the model for each subset is decided. Thus, there is a better chance of selecting the best subsets in the initial data when there are a large number of potentially relevant regressor variables (Armstrong & Hilton, 2010; Jelodar et al., 2015; Whittingham, Stephens, Bradbury, & Freckleton, 2006; Yasar, Bilgili, & Simsek, 2012).

1.7.4 Stage 4: The Case Study Methodology:

The structure of the research questions and objectives, the degree of the researcher's control over the data sources or study conditions, and the degree to which the focus is on historical rather than current events are just a few of the variables that must be considered while selecting an appropriate research methodology to meet the study objectives (Pandey et al., 2021). Historical approaches might be helpful when the researcher has little control over the data sources. However, experiments are favoured if the researcher can directly, precisely, and consistently regulate the research behaviour (Pandey et al., 2021; Noor, 2008). On the other hand, the case study technique is chosen when the research involves analysing current or ongoing occurrences, and the connected behaviour of these events cannot be controlled or altered (Noor, 2008).

This methodology has been used to qualitatively investigate the effect of the alignment of the organisational infrastructure and ICT infrastructure on the construction organisations' performance. It is crucial to choose the appropriate situations to make the most of the study's limited time and to optimise the quantity of knowledge absorbed and learned (Noor, 2008). There are generally three kinds of case study methodology: explanatory, exploratory, and descriptive (Pandey et al., 2021). The exploratory study has been used here, motivated by inquiries about operational problems and things that need to be tracked down; it brings to light the issues that are difficult to define only from experimental data (Snyder, 2012). However, it is feasible to plan research based on the case study approach in a particular framework that analyses secondary data (information related to the organisation and project) and primary data (organisational infrastructure and ICT infrastructure) (Pandey et al., 2021; Snyder, 2012). To better understand the use of the functional integration alignment system at the organisation level, this method of study has been implemented as a qualitative exploratory case study approach, as stated above (Pandey et al., 2021; Snyder, 2012).

The case study method was chosen for this study for three key reasons. First, depending on the circumstances of the research, this approach enables comparison between two or more empirical examples in various contexts, choosing specific outcomes for this comparison (Noor, 2008). Second, as is our intention for this research, this study method enables the collection of certain data that supports the debate process and leads to a theoretical conclusion (Snyder, 2012; Johansson, 2007; Meyer, 2001). Third, using this methodology, the researcher may also examine the operational and strategic involvement of the study cases in a particular place or region (Noor, 2008).

Table 1.1 and Figure 1.3 briefly summarise the relationship between the research design, objectives and methodology, including the method of analysis used to achieve the research objectives.

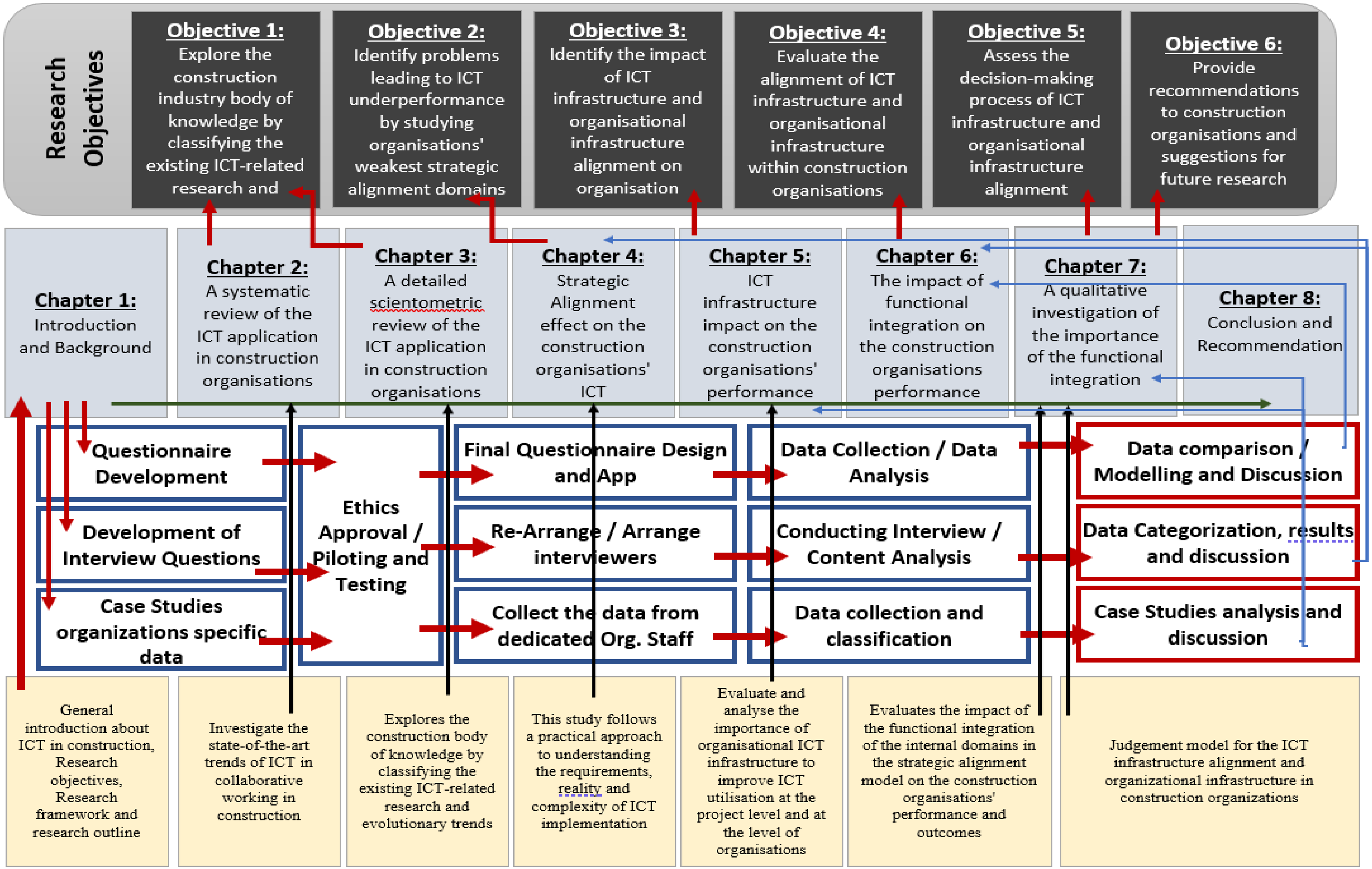

Figure 1.3: Research Framework

Table 1.1: Dissertation methodology according to each chapter

CH#	Chapter Title	Related paper title	Aims / Research Objectives	Research Methodology	Method of Analysis	Key Deliverables
1	Introduction and Background		Establishes the scope, context, and significance of the research			General introduction about ICT in construction, Research objectives, Research framework and research outline
2	A systematic review of the ICT application in construction organisations	Information Technology Applications in Construction Organisations: A Systematic Review	studying the holistic research status and evolutionary trend from the perspective of publications	Literature review	Systematic analysis	Investigate the state-of-the-art trends of ICT in collaborative working in the construction
3	A detailed scientometric review of the ICT application in construction organisations	Information And Communication Technology Applications in Construction Organisations: A Scientometric Review	Presents a critical literature review on the application of ICT in construction organisations and analyse the holistic research	Literature review	Citation Analysis and Cluster Analysis	Explores the construction body of knowledge by classifying the existing ICT-related research and evolutionary trends
4	Strategic Alignment effect on the construction organisations' ICT	Information technology and New Zealand construction industry: An empirical study towards strategic alignment of project and organisation	Identify problems and challenges leading to ICT underperformance by empirically studying construction organisations' weakest strategic alignment domains	Expert Interview	Content Analysis	This study follows a practical approach to understanding the requirements, reality and complexity of ICT implementation
5	ICT infrastructure impact on the construction organisations' performance	Information and Communication Technology (ICT) Utilization and Infrastructure Alignment in Construction Organisations	Investigate whether the effect of ICT utilisation on project performance may be restricted and affected by its alignment with the ICT infrastructure level in the organisation	Case Studies	Case Reviews	Evaluate and analyse the importance of organisational ICT infrastructure to improve ICT utilisation not just at the project level but also at the level of construction organisations
6	The impact of functional integration on the construction organisational performance	Organisational Infrastructure and Information and Communication Technology (ICT) Infrastructure Alignment in Construction Organisations	Investigating whether the construction organisations' performance may be restricted by the strength of the alignment between the ICT infrastructure and the organisational infrastructure	Expert Structured Questionnaire Expert Interview	Factor analysis / Multiple regression analysis Content Analysis	Evaluates the impact of the functional integration of the internal domains in the strategic alignment model on the construction organisations' performance and outcomes
7	A qualitative investigation of the importance of the functional integration	A qualitative study on the effect of the functional integration of the strategic alignment model domains on the construction organisations' performance	Qualitatively investigating the effect of the alignment of the organisational infrastructure and ICT infrastructure on the construction organisations' performance	Case Studies	Case Reviews	Judgement model for the ICT infrastructure alignment and organisational infrastructure in construction organisations.
8	Conclusion and Recommendation		Provide recommendations to construction organisations and suggestions for future research			

1.8 Thesis Organisation

This PhD thesis follows the thesis with publication format considering Massey university guidance. Based on the guidelines, these types of theses must contain at least two publications produced during candidature that are intended to be published, publications in their original wording or have been revised to fit the thesis, a mix of both non-published and published materials, and non-published discussion segments and contextual framework (Todd-Williamson, 2021). This thesis contains 6 publications. Moreover, the thesis must contain a body of work that presents a consistent referencing style, formatting standard and font style, and an academic body of work (Todd-Williamson, 2021). Therefore, this thesis consists of an introductory chapter, a conclusion chapter, and six core chapters which have been developed to achieve the thesis objectives as the following:

Chapter 2: A systematic review of the ICT application in construction organisations:

Using the first stage of this thesis methodology, this part of the study performed a systematic and quantitative review of the construction ICT study field. This review aims to investigate the state-of-the-art trends of ICT in collaborative working in construction. Based on the overall aim, this study achieves phase one of this thesis's first objective by studying the holistic research status and evolutionary trend from the perspective of published journal articles, document co-citation, and keyword co-occurrence.

Manuscript: Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. Information Technology Applications in Construction Organizations: A Systematic Review. In Proceedings of the 6th New Zealand Built Environment Research Symposium, Auckland, New Zealand (Vol. 26). 2020.

Chapter 3: A detailed scientometric review of the ICT application in construction organisations:

Still using the first stage of the thesis methodology, relevant literature from reputable sources is reviewed and classified to create a comprehensive framework for ICT application in construction. Accordingly, a manual review of research titles, as well as abstracts, was conducted. Thus, five analysis steps were performed, including "Journals Selection, Publication Type and Name", "Citation Analysis", "Keywords Co-Occurrence Network", "Cluster Analysis", and "Keyword time analysis". A total of 376 research was selected for burst detection, co-citation analysis, cluster analysis, keyword co-releases, and ICT application analysis to provide a comprehensive knowledge summary of the ICT application in the construction industry. This study mainly concentrated on the quantitative analysis regarding articles frequently emerging in the knowledge domain and were used to indicate the trends, timelines and hot topics. This research explores the construction industry body of knowledge, which is the first objective of this thesis by classifying the existing ICT-related research and evolutionary trends, providing current status, a comprehensive knowledge framework, and future directions.

Manuscript: Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. (2023). Information and Communication Technology Applications In Construction Organisations: A Scientometric Review. Journal of Information Technology in Construction, ITcon Vol. 28 (2023), Eliwa et al., pg. 286.

Chapter 4: Strategic Alignment effect on the construction organisations' ICT

The second stage, expert interviews methodology, has been used in this chapter to assess the impact and challenges of implementing ICT tools, concepts and applications on New Zealand construction industry performance. This study is significant as it is a step towards the strategic alignment of ICT, construction projects, and organisations. This study follows a practical approach to understanding the requirements, reality and complexity of ICT implementation. Empirical data were obtained through interviews with senior engineers from different construction projects in New Zealand. This study achieves this thesis's second objective, which is to identify problems and challenges leading to ICT underperformance by empirically studying construction organisations' weakest strategic alignment domains.

Manuscript: Eliwa, H., M.B. Jelodar, and M. Poshdar. Information technology and New Zealand construction industry: An empirical study towards strategic alignment of project and organisation. in Proceedings of the 18th International Conference on Construction Applications of Virtual Reality (CONVR2018), Auckland, New Zealand. 2018.

Chapter 5: ICT infrastructure impact on the construction organisations' performance

In this research, the case study methodology has been used to evaluate and analyse the importance of organisational ICT infrastructure to improve ICT utilisation not just at the project level but also at the level of construction organisations. This study achieved part of the third objective of the thesis which was to investigate whether the effect of ICT utilisation on project performance may be restricted and affected by its alignment with the ICT infrastructure level in the organisation. The analyses of ICT infrastructure, ICT usage, and their associations with project performance are based on case studies of projects and organisations from the New Zealand construction sector. A method of evaluating ICT utilisation and ICT infrastructure is proposed.

Manuscript: Eliwa, H.K., M.B. Jelodar, and M. Poshdar, Information and Communication Technology (ICT) Utilization and Infrastructure Alignment in Construction Organizations. Buildings, 2022. 12(3): p. 281.

Chapter 6: The impact of functional integration on the construction organisations performance

Using mainly the third stage methodology in this thesis, this research evaluates the impact of the functional integration of the internal domains in the strategic alignment model on the construction organisations' performance and outcomes. The study achieves the fourth thesis objective by investigating whether the construction organisations' performance may be restricted and affected by the strength of the alignment between the ICT infrastructure and the organisational infrastructure domains. In this research, a two-stage research design was constructed. In the first stage, a 3-parts self-administered quantitative expert survey questionnaire has been developed and distributed to a targeted group of construction industry professionals. The survey results were then organised and analysed using the principal component factor analysis method for selecting variables. Then the multiple regression analysis was used for the final results and conclusion. The second stage of the research was verifying the analysed data from the survey questionnaire using qualitative research methods through semi-structured interviews from the New Zealand construction industry.

Manuscript: Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. Organizational Infrastructure and Information and Communication Technology (ICT) Infrastructure Alignment in Construction Organizations.

Submitted to ASCE - Journal of Construction Engineering and Management

Chapter 7: A qualitative investigation of the importance of the functional integration

This research achieves the fourth and fifth thesis objectives by qualitatively investigating the effect of the alignment of the organisational infrastructure and ICT infrastructure on the construction organisations' performance. To achieve that, a case study analysis has been conducted on three large-size construction organisations in New Zealand, with three projects selected from each. A method of evaluating the relationship between the organisation's performance and the alignment of the ICT infrastructure with the organisational infrastructure is proposed. The effects of this functional integration on construction organisation performance are discussed, and recommendations for optimal strategic utilisation are provided.

Manuscript: Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. Information and Communication Technology Capability for Construction Organisations; Effect of Strategic Alignment on Performance.

Submitted to International Journal of Project Management

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 2
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. Information Technology Applications in Construction Organizations: A Systematic Review. In Proceedings of the 6th New Zealand Built Environment Research Symposium, Auckland, New Zealand (Vol. 26). 2020.

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

Chapter 2: A systematic review of the ICT application in construction organisations

The current chapter is based on the following article:

Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. Information Technology Applications in Construction Organizations: A Systematic Review. In Proceedings of the 6th New Zealand Built Environment Research Symposium, Auckland, New Zealand (Vol. 26). 2020.

2.1 Introduction

The construction industry has traditionally lagged other industries in technology adoption (Negahban et al., 2012). However, in recent years, driven by the pressure to improve productivity, reduce costs, improve safety and increase sustainability, there is growing momentum to introduce new technologies into the construction industry (Oliveira et al., 2011). Lee, Yu and Jeong (2013) predict that we are moving towards a “machine-dominated” construction sector (Lee et al., 2013). However, it is well known that the construction industry is hesitant in adopting advanced technology (Peansupap et al., 2005; Pekericli et al., 2004; Perkinson et al., 2006). Lu et al. (2014) brought forward two main reasons for the reluctance to utilize innovative technologies: uncertainty in using new technologies and lack of information regarding technologies and corresponding benefits. With the development of various technologies, more and more researchers have realized that technology could be an effective solution to the issue of the construction process (Lu et al., 2014).

Implementing the information technologies in construction industry organizations create enormous opportunities for improving communication and work productivity to enhance the effectiveness of construction processes and for creating business innovation (Peansupap et al., 2005). Both technological and managerial advancements of the information technology application in the construction industry organizations have been significant (Ahmad, 2000; Perkinson et al., 2006; Sanders et al., 2002). Distinctive features of the construction industry make the task of managing construction projects particularly appropriate for applications of information technology tools (Jung et al., 2011).

This study provides a general and a systematic review of information technology application in the construction organizations based on mainstream studies performed during 2000–2019 in select journals.

The overall aim of this review is to investigate the state-of-the-art and trends of information technology in collaborative working in construction. Based on the overall aim, the objectives of this are to understand the holistic research status and evolutionary trend from the perspective of published journal articles, document co-citation, and keyword co-occurrence. To achieve these research goals, we employ the systematic analysis method, which is used to map the visualization review of a specific knowledge area. This paper provides valuable guidance and in-depth understanding for researchers, practitioner and policymakers to promote information technology implementation in construction organizations.

2.2 Research Methodology

2.2.1 Data Collection

Both the Web of Science core database and Scopus selected as the data source for this paper; because of their comprehensive collection of construction and management databases (Valderrama-Zurián et al., 2015).

Data extracted from the WoS Core collection database and Scopus between November and December 2019. In order to conduct a comprehensive analysis, the following steps have been followed. In the first stage, we go through several highly cited publications on the topic of information technology applications in construction organizations to identify the related key terms. Then, a combination of most frequently appearing search terms about construction information technology have been selected after reviewing preliminary papers.

Papers containing information technology, applications in construction organizations, digital technologies and information systems search terms in their titles, abstracts or keywords were selected. The final search terms included "TS = ("construction organizations *" OR "information technology *" OR "construction and information technology *" OR "construction IT" OR "construction&IT") AND TS = ("information technology" OR "IT applications" OR "technology applications" OR "innovation")". The language of the publications was limited to English and document type was limited to articles; the time span was set to 2000–2019. As a result, 512 bibliographic records were retrieved.

The boundary of information technology applications in construction organizations has been defined as technology applications, construction productivity, construction IT, construction technology, information technology (IT) impact on construction, construction organizations, performance measurement, and tools assisting in construction organization (Oliveira et al., 2011;

Perkinson et al., 2006). Based on this boundary, a manual review of paper titles and abstracts was conducted to exclude articles concerning technology application in construction, such as computer-aided design, building information modelling, and tools software and communication networks. After manual review, a total of 376 papers were selected. Figure 2.1 displayed the time-trend analysis of 376 information technology applications in construction organisations studies. The number of publications relating to IT in construction increased significantly from 2009 to 2019. This is because of the impact of the information technology application in construction considered after 2009, and many researchers started to compare the impact of using technologies in other industries with the construction industry.

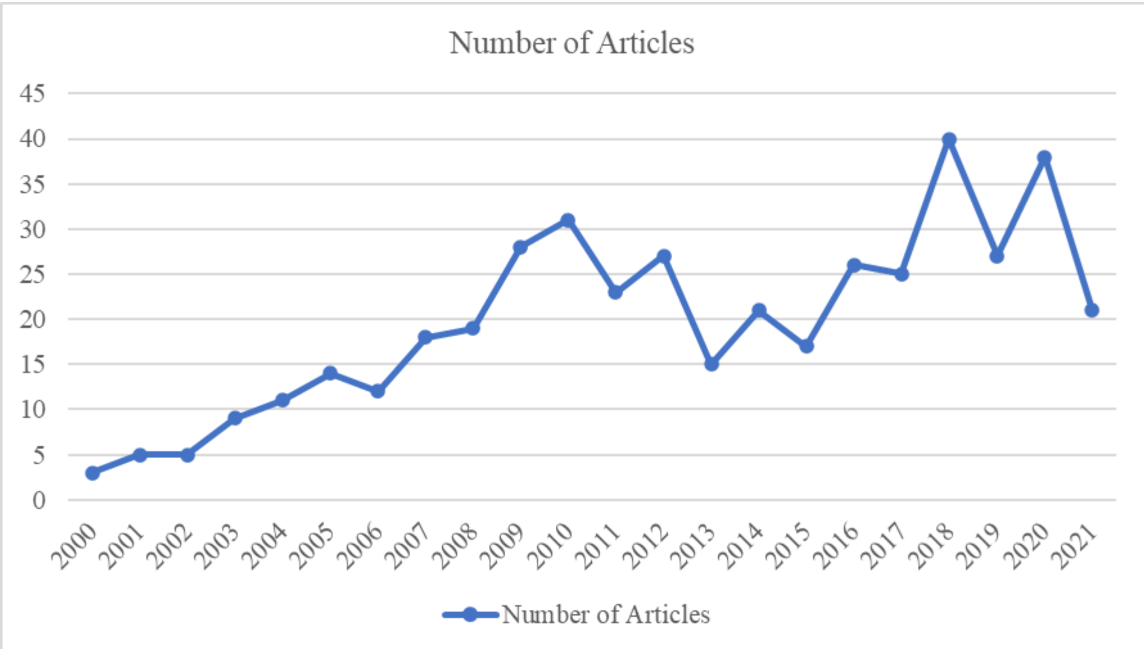

Figure 2.1: Number of studies on IT in construction from 2000 through 2019

2.2.2 Systematic literature review

Information technology application in construction literature focuses on multiple disciplines; however, little attention is paid to characterizing the whole field through manual and systematic review.

Manual analysis tends to be subjective and limited in terms of the number of publications being reviewed, as well as the relationship between publications cannot be analysed (Surulinathi et al., 2013). A systematic review is essential for analyzing the knowledge domain for a particular subject with a large number of articles (Kaliyaperumal, 2015). It should be noted that the review and analysis process can be performed quantitatively, but the presentation of results can have qualitative characteristics. Different software has been developed in recent years, such as BibExcel, Ucinet, SCIMAT, VOSviewer, and CiteSpace which can assist the systematic review.

The general framework for this analysis requires researchers to combine software output information with manual interpretation. Furthermore, the depth and quality of the interpretation are subjected to the researchers' experience, knowledge, and academic background. CiteSpace, automated systematic analysis software for mapping and visualizing the intellectual structure of a scientific knowledge domain has been selected for the systematic review in this study.

2.3 Research Results

More than 75% of the identified articles have been extracted from 12 top journals and databases in the field. Table 2.1 presents the performance of these most productive journals that have published at least four articles on information technology application in construction from 2000 to 2019. The ratio of articles in the top 12 productive journals in addition to journal impact are also shown in Table 2.1. Moreover, the top five journals account for 79% of these articles which probably means that these five journals are the most famous and important publications on construction management and technology. Automation in construction published the highest quantity of articles with 18.1%, much higher than the second and third journals, Journal of Construction Engineering and Management 13.6%, and Journal of Computing in Civil Engineering 12.5%.

Table 2.1: The performance of top 12 journals from 2009 to 2019. Impact factor: Journal Impact Factor (Clarivate Analytics) in 2018.

No.	**Journal Name**	**% of the related articles**	**Journal Impact Factor**
1	Automation In Construction	18.1%	4.032
2	Journal Of Construction Engineering and Management	13.6%	3.711
3	Journal Of Computing in Civil Engineering	12.5%	1.798
4	Journal Of Management in Engineering	8.8%	2.282
5	Journal Of Civil Engineering and Management	7.4%	1.66
6	Aebmr Advances in Economics Business and Management Research	4.5%	0.428
7	Communications in Computer and Information Science	3.7%	1.996
8	Advanced Engineering Informatics	2.4%	3.358
9	Advanced Materials Research	1.6%	1.95
10	Communications in Computer and Information Science	1.6%	4.616
11	Advances In Education Research	1.1%	1.163
12	ACSR Advances in Computer Science Research	1.1%	4.41

The following high-frequent keywords "BIM" (frequency = 56), "impact" (53), "ICT" (49), “case study” (47), “management” (36), “use” (25), and “adoption” (19) represent the hot topics in construction management and information technology research, corresponding to the followed categories: (a) Building information modelling in construction, (b) The impact of technology on construction, (c) Information and communication technology in construction, (d) Case study on implementation of technology in construction, (e) Construction Management, (f) The use of IT in construction, and (g) IT adoption in construction. As a widely accepted strategy for IT in construction impact, adoption, management, and use are jointly included the categories. The topic of building information modelling in construction has attracted the most research efforts. The category of the impact of technology on construction also received considerable interest from researchers because of its significant and benefit in terms of calculating construction productivity and management assessment. In this paper, cluster labels are generated, which selects the top-ranked words occurring in each cluster and labels. Four clusters are identified based on research keywords, such as BIM, analysis, construction enterprise, application, case study, impact, building information modelling, and challenge as presented on the left side of Figure 2.2.

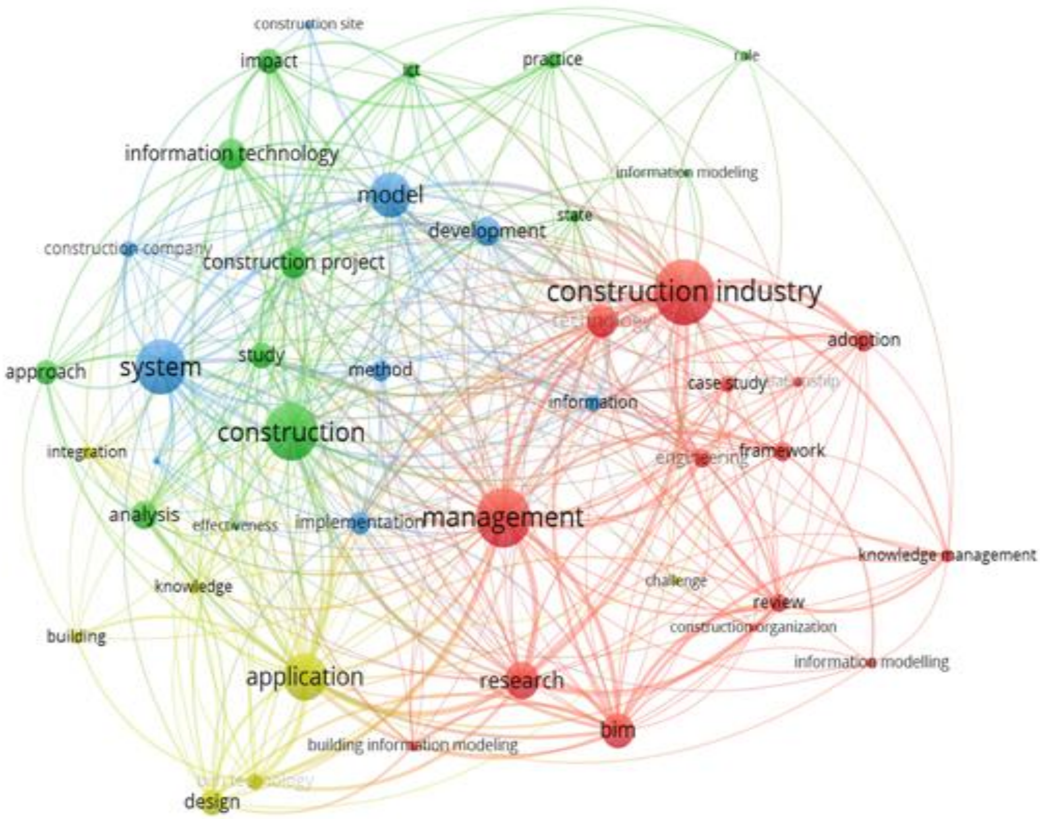

Figure 2.2: Grouping of Construction Information Technology research: 2009–2019

2.4 Conclusion

This study systematically reviewed publications related to IT in the construction industry from 2000 to 2019 by using the systematic analysis method. A total of 376 papers were selected for co-citation analysis, keyword co-occurrence, cluster analysis, and burst detection, in order to investigate the state-of-the-art and trends of information technology in collaborative working in construction. Automation in Construction, Journal of Management in Engineering, Advanced Engineering Informatics, and Journal of Intelligent & Robotic Systems were identified as the four major journals associated with research on the IT application in the construction industry. By measuring the high-frequent co-occurrence keywords, the major research topics in this area include "Building information modelling in construction", "The impact of technology on construction", "Information and communication technology in construction", "Case study on implementation of technology in construction", "Construction Management", "The use of IT in construction", and "IT adoption in construction".

These findings can help researchers and practitioners quickly understand the current research related to IT applications in the construction industry. In particular, knowledge domains and evolutionary trend can offer clear and in-deep cognition of construction IT research.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 3
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:
Lead author, conducted study and wrote the text

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:
Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. (2023). Information and Communication Technology Applications In Construction Organisations: A Scientometric Review. Journal of Information Technology in Construction, ITcon Vol. 28 (2023), Eliwa et al., pg. 286.

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

Chapter 3: A systematic review of the ICT application in construction organisations:

The current chapter is based on the following article:

Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. Information Technology Applications in Construction Organizations: A Systematic Review. In Proceedings of the 6th New Zealand Built Environment Research Symposium, Auckland, New Zealand (Vol. 26). 2020.

3.1 Introduction and Background

Based on studies, the construction and engineering field has lagged other industries in technology implementation and adoption (MBIE, 2010; Negahban et al., 2012; Amusan et al., 2018). Nevertheless, there is rising momentum to implement and introduce modern technologies into the construction and engineering industry during the last two decades which were driven by the potential to reduce costs, improve productivity, improve safety and increase sustainability (Lee et al., 2013; Oliveira and Martins, 2011; Eliwa et al., 2020). Oliveira and Martins (2011) expected that we are moving towards a “machine-dominated” construction sector (Oliveira and Martins, 2011). However, it is recognised that the construction industry is considered to be irresolute in adopting advanced technology (Pekericli et al., 2004; Peansupap and Walker, 2005; Perkinson and Ahmad, 2006; Jung and Joo, 2011; Eliwa et al., 2020). Lu et al. (2014) presented two main factors that cause the reluctance to utilise innovative technologies: the lack of information regarding technologies and corresponding benefits as well as the uncertainty in using new technologies (Lu et al., 2014). With the development of various technologies, a significant number of researchers have realised that technology utilisation could be an effective solution to the construction process issues (Jung and Joo, 2011; Eliwa et al., 2020).

The implementation of the information and communication technologies (ICT) in construction industry organisations results in formidable opportunities for improving the construction works productivity as well as the projects' internal communications to enhance the effectiveness of construction processes and for creating business innovation (Pekericli et al., 2004; Peansupap and Walker, 2005; Amusan et al., 2018; DG Azevêdo, 2020). The influence of the ICT has been developed from the improvement of the conventional construction work to an innovative process that necessarily simplifies recent and creative alternatives to organising and operating construction organisations (Amusan et al., 2018; Gunasekaran et al., 2017; Xiong et al., 2015). Moreover, according to global reports, ICT in different type of application has assist most of the construction organisation during COVI-19 restrictions as a mean of reducing indirect cost and enhancing project productivity (MBIE-COVID-19, 2020; DG Azevêdo, 2020).

During the last thirty years, information technology and especially ICT has attracted researcher's attention in the construction field seeking to address a vision of managerial and operational affairs within the construction organisation (Abdirad and Dossick, 2016; Ghaffarianhoseini et al., 2017; Lu et al., 2014). However, in the enormous body of current studies, a comprehensive and an accurate review of information technology and ICT application in the construction organisations is missing (Mutesi and Kyakula, 2011; Liu et al., 2021). Moreover, Various authors have specified an enormous domain of organisational, cultural and institutional obstacles to technology utilisation (Guo et al., 2017; Peansupap and Walker, 2005). Many of these studies show that a consciousness of modern technologies alone will not ensure that technology utilisation will happen and indicate the key to the technology utilisation is the performance by which modern technology is incorporated into an organisation's cultures, processes and systems, instead of the technology itself (Orlikowski, 2000; Pekericli et al., 2004). A deep and meaningful understanding questions general research trend in organisational ICT for construction firms has not been achieved. In addition, methods of aligning resources to organisational structure, ICT diffusion patterns in construction organisations, the popularity of the technologies, and taxonomy of ICT effects on construction organisational outcomes are still unclear (Son et al., 2015; Liu et al., 2021).

ICT application in construction organisation literature involves multiple disciplines, which has made navigating the field very difficult and complex. The research trends and timeline of these trends are often difficult to identify. In addition, there has been no proper investigation into the progression of ICT research topics in construction and little attention is paid to characterising the whole field through in-depth systematic and scientometric review of literature. To address this problem, this paper provides a comprehensive and scientometric review of ICT application within the construction organisations context based on high impact studies performed in the last two decades. Therefore, the aim of this study is to presents a critical literature review on the application of ICT in construction organisations. This study presents an overview of the available and trending ICT in the construction organisations and their adaptions to different work and project process. This research adopts the quantitative and qualitative method of analysis to explicate the current studies in an effective way from a holistic viewpoint.

3.2 Research Methodology: Scientometric Analysis

The Web of Science (WoS) and Scopus are core global database for covering critical journals and studying literature in many fields and knowledge areas (Gingras and Khelfaoui, 2018; Martín-Martín et al., 2018) (Mongeon and Paul-Hus, 2016). Both the Web of Science (WOS) core database and Scopus were selected as primary sources for this investigation since they contain the most reputable publications on information technology and digitisation and other advanced technology applications in construction research (Harzing and Alakangas, 2016). Although these studies exist in the construction domain, they have not been classified based on ICT application in construction organisational theories, requirements and structure which is the aim of the current research. Manual analysis of literature tends is limited and restricted by the amount of publications which being reviewed and the relationship between publications cannot be analysed (Peansupap and Walker, 2005; Surulinathi et al., 2013). Scientometrics analysis method considers an implementation of statistical and mathematical processes for quantitative analysis of domain knowledge for a specific research subject with a large number of articles and outputs (Kaliyaperumal, 2015). Others have defined the scientometric method based on application quantitative analysis techniques to bibliometric data associated with academic publications (Chong et al., 2017). This method of analysis is applied widely in construction, management and architecture research to study the hot topics, structure, characteristics and research trend (Aswathy and Gopikuttan, 2013; Coccia et al., 2015; Hosseini et al., 2018). Although the final analysis results and presentation of the scientometric analysis has qualitative features, the method of analysis itself is quantitative (Hosseini et al., 2018; Chang et al., 2020).

There are many scientometric analysis software tools developed and considered to be used for research review purpose such as Ucinet, VOSviewer, CiteSpace and SCIMAT. Some of these software tools such as Ucinet, focus on data collection and processing which required a third-party visualisation software such as Gephi on NetBeans platform to use the processed data results for the network map presentation (He et al., 2017; Pollack and Adler, 2015). VOSviewer, CiteSpace and SCIMAT software are able to do the full scientometric analysis mission including data processing and results visualisation (Hosseini et al., 2018). The general network analysis and framework require a combination and integration of the manual review and classifications with the software results. Moreover, the quality and the depth of the classifications are affected by the researchers' academic background and field experience (Hosseini et al., 2018). Based on that, VOSviewer software has been selected in this research for scientometric analysis, and mapping visualisation (Heilig and Voß, 2014;

Chang et al., 2020). VOSviewer software provides several types of functions, including the co-occurrence analysis for the research keywords, analysing the collaboration network, deep analysis of researcher co-citation, and by integration, with CiteSpace it can provide document co-citation analysis (Hosseini et al., 2018).

The bibliographic data which export from WOS contains multiple domains, including research title, cited year, keywords, researchers name, abstract, journal identification, addresses and references. The higher number of citations mainly is perceived as an indication of higher impact, in addition to the subject discussed in the research receives comprehensive awareness. The research title, research keywords, and the research abstract can provide indications of the article content. Accordingly, three levels of scientometric analysis procedure have been considered in this research via VOSviewer. Starting by co-citation analysis of the research papers which filtering the top cited research and therefore recognise the domain of knowledge. Keywords analysis level has been used secondly to present and identify the trending subjects arranged by processing domains resulted from co-releases in topic titles, topic keywords, and the research summary or abstracts (Valderrama-Zurián et al., 2015). Finally, assemblage analysis has been proceeded to identify the primary cluster of the construction ICT knowledge domain (Valderrama-Zurián et al., 2015).

3.3 Data Collection

In this study, two stages have been followed to develop a comprehensive analysis. The first stage, a general literature search was conducted on the topic of ICT applications in construction organisations to explore the knowledge area for terminology and identify appropriate keywords for this investigation. In the second stage, an integration of the top frequently clarifying search phrases about construction ICT was selected after introductory studies reviewed. Papers including these search phrases in the research keywords, research summary or abstract and research title has been selected. Based on that, the concluded search phrases or terms was "TS = ("information and communication technology *" OR "construction organisations *" OR "construction and information technology *" OR "construction ICT" OR "construction&ICT") AND TS = ("information and communication technology" OR "ICT applications" OR "technology applications" OR "innovation")". The document type was limited to articles, the research main language was limited to the English language, and the time span was set to the previous two decades. As a result, 512 bibliographic records were retrieved.

Therefore, a manual review of research titles and abstracts conducted to assess the relevance to ICT research in construction engineering and management domain. Finally, a total of 376 articles were selected from the above pool of 512 research extracted from top journals of WOS and Scopus. Figure 3.1 displayed the time-trend analysis of 376 ICT associated research in constructions research. The number of publications relating to ICT in construction increased significantly from 2009 to 2021. This is because after 2009 many researchers started to compare the impact of using technologies in other industries with the construction industry (Zhong et al., 2019).

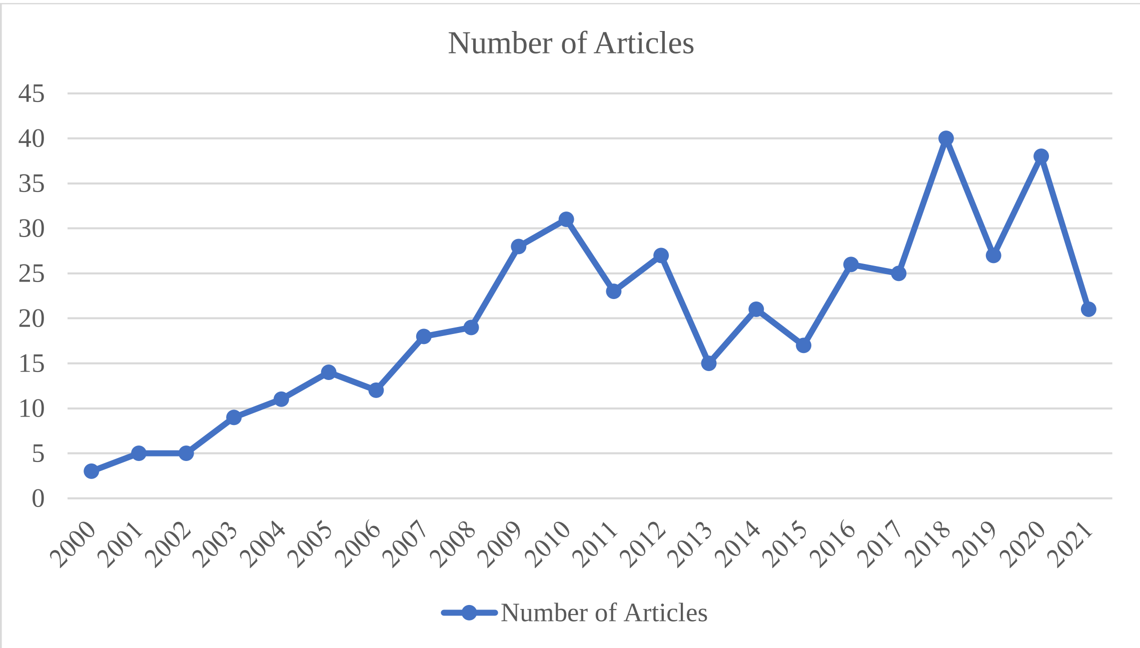

Figure 3.1: Number of studies on ICT in construction organisation during two decades period

3.4 Research Results

In this section, the results are presented based on "Journals Selection, Publication Type and Name", "Citation Analysis", "Keywords Co-Occurrence Network", "Cluster Analysis", "Keyword time analysis", and tools and software identification.

3.4.1 <u>Journals Selection, Publication Type and Name</u>

The 405 articles which have been extracted are published in 51 journals. Table 3.1 presents the achievement of the top 12 productive journals that published at least four articles on ICT Application in construction from 2009 to 2021. The top 12 journals account for 77% of the 405 articles indicting that these journals have a high density of articles on ICT Application in construction.

Moreover, the top five journals account for 73% of the total articles (228 articles), which indicates that these five journals are the significant disseminators of research in sophisticated technologies and ICT in construction engineering and management field. Automation in construction published the highest quantity of articles with 68 (21.8%), followed by Journal of Construction Engineering and Management 51 (16.3%), Journal of Computing in Civil Engineering 47 (15.0%), journal of management in engineering 33 (10.6%) and Journal of Information Technology in Construction (ITcon) 29 (9.3%).

It is also interesting to report that among the top 12 journals of Communications in Computer and Information Science and ACSR Advances in Computer Science Research have the highest impact factor. These journals are not in the field of construction engineering and management, which perhaps is an indication that in construction field technology and ICT research receive less attention among researchers. Lu and Wang (2014) also discovered 10 types of target journals related to ICT

Application in construction through ScienceDirect, the WoS, EI Compendex and other databases (Lu et al., 2014).

Table 3.1: The top 12 papers' performance from 2009 to 2021

No	Journal Name	No. of Articles	Percentage from total	Journal Impact Factor
1	Automation In Construction	68	21.8%	4.032
2	Journal Of Construction Engineering and Management	51	16.3%	3.711
3	Journal Of Computing in Civil Engineering	47	15.0%	1.798
4	Journal Of Management in Engineering	33	10.6%	2.282
5	Journal of Information Technology in Construction (ITcon)	29	9.3	1.94
6	Journal Of Civil Engineering and Management	28	9.0%	1.66
7	Advances In Economics Business and Management Research	17	5.4%	0.428
8	Communications In Computer and Information Science	14	4.5%	1.996
9	Advanced Engineering Informatics	9	2.9%	3.358
10	Advanced Materials Research	6	1.9%	1.95
11	Communications In Computer and Information Science	6	1.9%	4.616
12	Advances In Education Research	4	1.3%	1.163

3.4.2 Co-Citation Analysis

The papers co-citation network and density of the ICT application in the construction industry research are presented in Figure 3.2 generated by VOSviewer and "Publish or Perish" tools with 381 nodes and 1311 edge. The time range of the data is set to the previous two decades and the time range is set to two years as shown in Figure 3.2. Thus, 40 documents as the topmost cited are picked for producing of the posterior network map. The lines or nodes refer to the cited sources and bubbles between two lines – also called edges - present co-citation relationships Figure 3.2.

The nodes represent a publication by an author. The width of the bubbles is commensurate with the consensual of the resource's relationship, and the density of each node is commensurate with the amount of citations. X Wang et al. (2013) owned the top citations count, presenting the research trend for the IT and ICT application in the construction industry. The second cited article was by Y Zhang et al. (2012); who presented a model for the critical success factors of construction projects. As such, X Wang et al. (2013) estimated the volume of Building Information Modelling (BIM) application in construction projects and organisation from 2005 to 2013. Unlike Y Zhang et al. (2012), X Wang et al. (2013) further discussed the proposed benefits of implementing new technologies in construction organisations based on the volume of technology application in the construction industry.

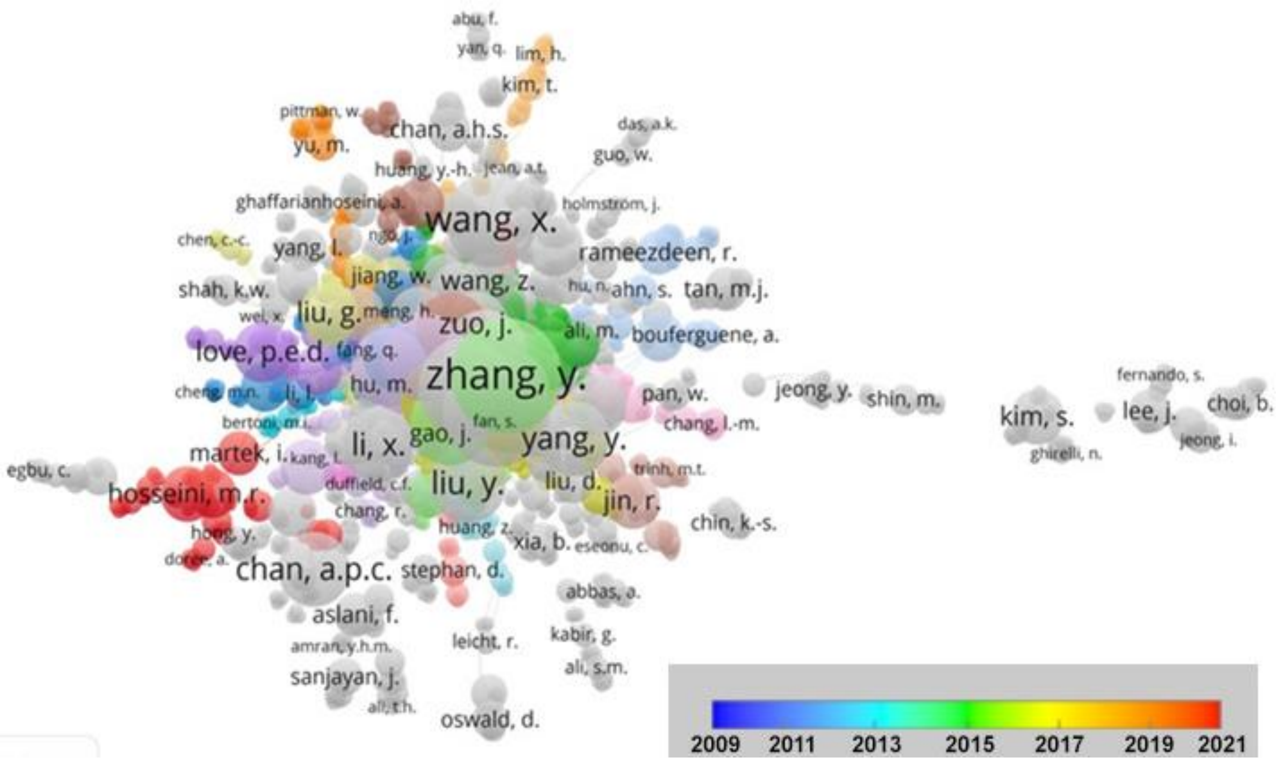

Figure 3.2: Research co-citation network for the ICT in Construction Industry: 2009–2021

The top ten researches were published from 2012 to 2021 and can be organised into four types, including literature review (Guo et al., 2017; Rezgui, 2001; Vidogah and Ndekugri, 1998; Zhou et al., 2013), information technology and ICT utilisation in the construction industry (Lu et al., 2014; Shen et al., 2010; Tam and Tam, 2006; Valero et al., 2015), barriers and strategy to technology application (Stewart et al., 2004; Yan and Demian, 2008) and technology and methods of innovation in the construction industry (Blayse and Manley, 2004). The highly citation of the review research is logically understanding as they present the trends based on systematic and comprehensive analysis assisting readers earn an in-depth understanding of the study field. Understanding the application and infrastructure of ICT in the construction industry is necessary for the productive management and improvement.

Therefore, researchers aim to evaluate the size of construction technology generation either at the project level (Porwal and Hewage, 2013), an organisation level (Berente et al., 2010) or at a regional level (Becerik-Gerber et al., 2011). Critical factors and barriers for ICT implementation in construction are analysed to help decision-makers to develop productive construction management strategies.

3.4.3 Keywords Co-releases Network

In general, keywords reflect the core of the main content in research and reflect the development of study themes. In regards, the keyword co-releases network for the identified literature is shown in Figure 3.3 which has 214 lines and 618 bubbles. The time range of the study data is 2009 to 2021 and based on the density of the data a time slice two years was generated and set by the software. In the previous network presentation (Figure 3.3), nodes present keywords that trend more than two times in the 376-research selected in this study. The connection between the bubbles or the edges reflects the number of times that keywords have been combined in different studies. The size of these edges or keywords bubble represents the number of times these keywords have been used. It has to be indicated that, “construction information and communication technology”, “construction organisation”, “construction industry”, and “construction technology application” are treated as stop-words. These stop word function as a filter for the search data after processing and refers to the most common keywords in the specific search processing (Merschbrock et al., 2016; Chang et al., 2020). As they are the fundamental concepts of ICT in the construction industry, and they do not add essential value to the current analysis. Alternatively, the recurrence of these keywords is more than other keywords, which will impact on the meaning of significant and topic core keywords in Figure 3.3 considering that the volume of the keyword bubble is relative to its recurrence.

The top repeated co-releases keywords are “Construction Industry”, “Information Technology”, ICT, and “Application” appearing 81, 64, and 59 times, respectively (Figure 3.3). “Application” is the third-top-ranking term, which is meet the study performed by many researchers such as Sanders et al. (Sanders and Premus, 2002), which predicted a raising number of research utilise these technologies (i.e., BIM, programme management tools and decision-support tools) to address complicated issues in the construction management, unlike other traditional research which focusing on statistical analysis methods.

The following high-frequent keywords "BIM" (frequency = 56), "impact" (53), "ICT" (49), “case study” (47), “management” (36), “use” (25), and “adoption” (19) represent the hot topics in construction associated with information and communication technologies research. These keywords also represent the following well-established areas of research in construction engineering and management: (a) Building information modelling in construction, (b) The impact of technology on construction, (c) Information and communication technology in construction, (d) implementation of technology in construction, (e) Construction Management, (f) The use of information technology and ICT in construction, and (g) ICT adoption in construction. As a widely accepted strategy for ICT in construction impact, adoption, management, and use are jointly included as one category.

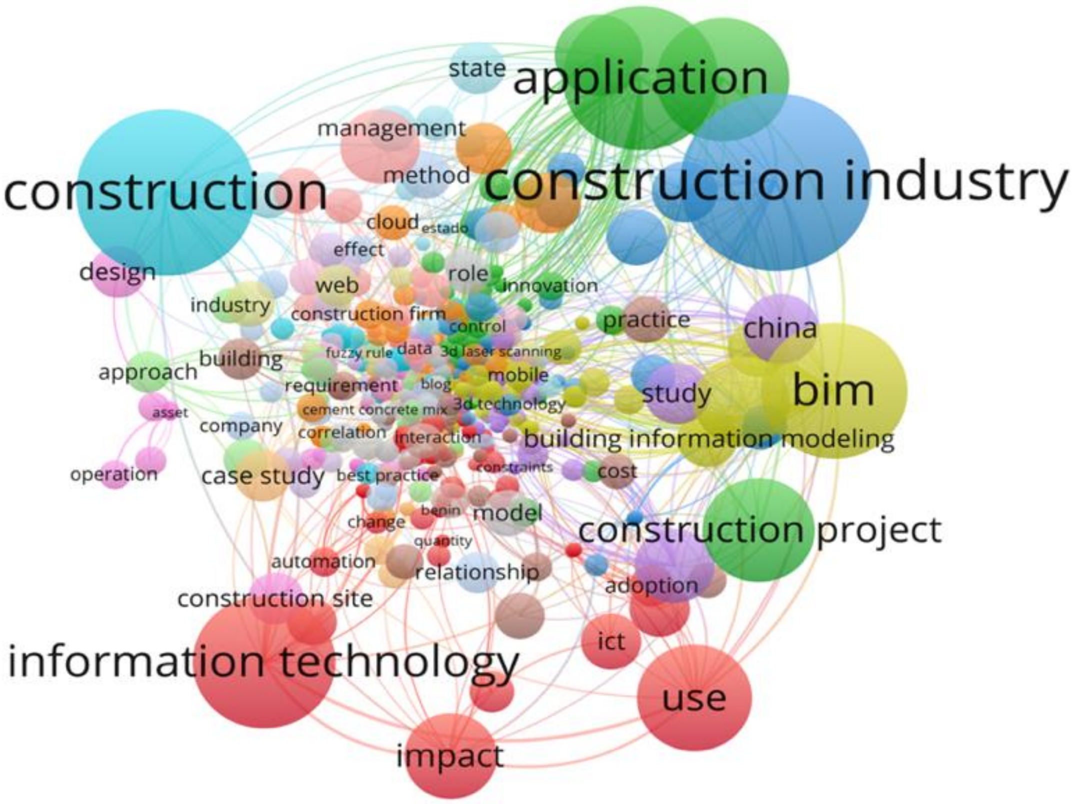

Figure 3.3: Keywords Co-occurrence Network in the ICT-in Construction

3.4.4 <u>Assemblage Analysis</u>

The co-releases analysis of the studies keywords has enabled us to understand the trending subjects in the field of information technology in construction research and specifically provide some insight on ICT application. However, word frequency alone is not enough in terms of the knowledge structure and the classification of the area of study. Assemblage analysis using VOSViewer tool employs a set of algorithms to translate the collected data into multiple structured assemblages (ZHANG, X., 2016; Chang et al., 2020). In this paper, cluster labels are generated automatically by VOSViewer, which picks the top-ranked keywords happening in each cluster and labels. Four clusters are identified based on research keywords, such as BIM, analysis, construction enterprise, application, case study, impact, building information modelling, and challenge as presented on the left side of Figure 3.4 and Figure 3.5. The modularity of the clusters is 0.4116 (modularity is greater than 0.3), and the silhouette is 0.6092 (silhouette is greater than 0.4), identifying the structure gained by clustering is important, and the result is credible and robust. Modularity in the clusters analysis compares the number of keywords or edges inside a specific cluster with the planned number of keywords or edges that one would find in the cluster (Gao and Yan, 2013; Gries and Stefanowitsch, 2010; Li-ming and Heng-heng, 2011; Ng et al., 2011).

Further detailed information of these four research clusters including the number of keywords inside each cluster and representative keywords is displayed in Figure 3.5 in rank order. Cluster ordered based on its size which identifies the number of research in each cluster from the total of 376 articles, and silhouette indicates the identity of a certain cluster. The value range of the silhouette is from number zero to number one which is the highest, thus the higher number of the silhouette represent higher the uniformity of clustering domains (Heidarinejad et al., 2014; Miriello et al., 2010; Ren et al., 2010).

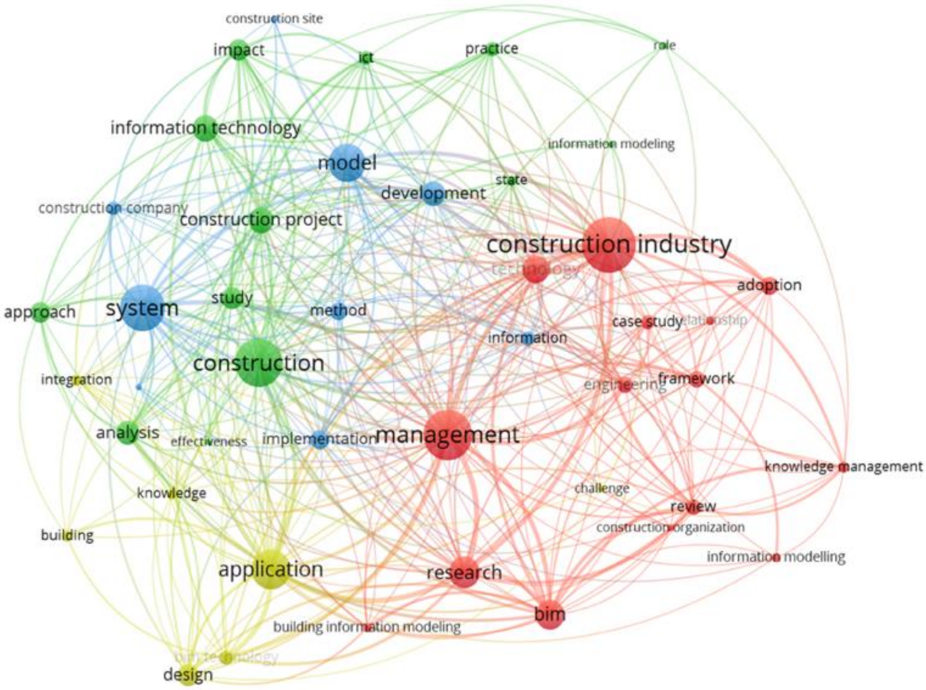

Figure 3.4: Cluster analysis network and density in the Construction ICT: 2009–2021

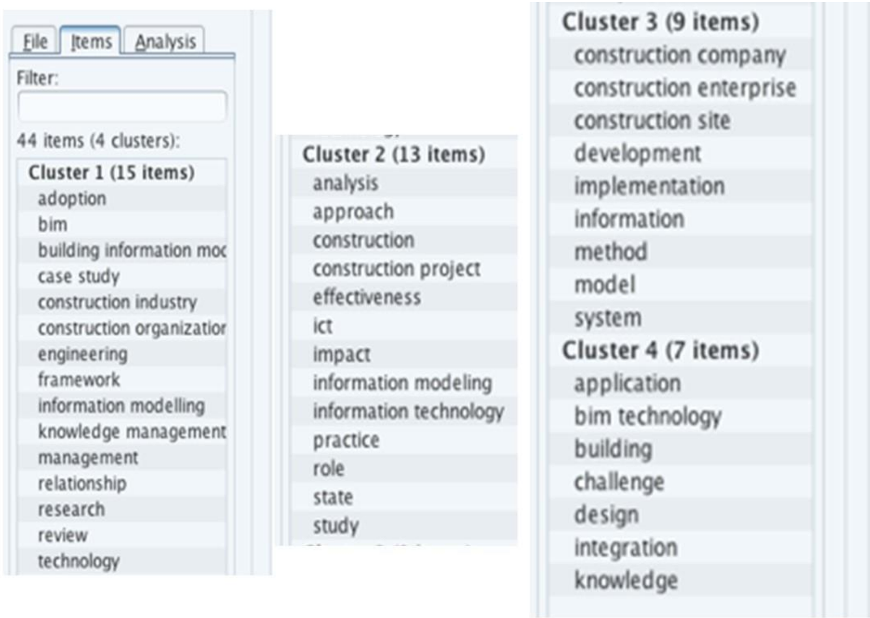

Figure 3.5: Cluster grouping analysis density in the Construction ICT: 2009–2021

The most significant cluster is cluster #1 which including keywords related to new technology adoption and implementation, including 15 keywords or topics inside (Figure 3.5). The publications inside this cluster refer to the ICT application and utilisation in the construction industry and organisation. Cluster #2 is related to the analysis of the impact of these technologies on construction project or industry. Cluster #3 talking more on the management of this technology and providing a system or model such as strategic alignment model which provide a method to assess the technology implementation in construction companies or enterprises. Cluster #4 which related more on the technology implementation and case study conclusion and the final thought regarding the integration of ICT in construction projects or organisations. In general, cluster #4 includes the issues of research methodology and practice in ICT utilisation.

An overlap between the results from the assemblage analysis and the co-releases analysis results cleared after comparing the subjects from this method of analysis such as building information modelling, adoption and case study. Moreover, differences between the two methods of analysis have been declared; for instance, assemblage analysis identifies some methods applied in the construction

ICT implementation and analysis, including approach, relationship, review, case study, whereas co-releases analysis presents the trending subjects, such as BIM in construction, and the impact of the ICT on construction industry. These results integrate in each other and benefit the understanding of the construction information technology and ICT implementation (Aier et al., 2011; Bennett and Cialone, 2014; Deb and Lee, 2018; Yi-ling, 2011).

3.4.5 Keywords Time Analysis

The keyword co-releases analysis as well as the assemblage assessment help us to define and better understand the domain of knowledge of the ICT application in the construction amongst the general trends of technology application. However, differences in keyword frequencies over time have not been presented. To discover the significance and frequency diversities of particular keywords in a limited range of time, Burst Detection tool has been used. A keyword can be considered as an effective sub-field, if there is a dramatic increase during a short time range in the recurrence of a keyword. VOSViewer has an option with a keyword burst tool that useful to identify significant swings over time in addition to high trends in a knowledge domain (Hosseini et al., 2018). Figure 3.6 presents the trending keywords with the most powerful citation bursts in the construction ICT field from 2009 to 2021 in time zone order.

Papers' keywords from 2009 to 2012 have a burst time of more than three years, which mean a considerable amount of data for these keywords presented during this period comparing with other periods and the typical keywords in this period are "system", "value", and "performance" (Figure 3.6). In this period, these studies focus on the value of using new technologies in construction (Goodrum et al., 2010), barriers or factors impact the technology utilisation in construction (Ametepey et al., 2015; Shi et al., 2013), the economic feasibility of using technology in construction

(Ganesan, 2019), system or model using in implementation of technology, and impact evaluation of using the technologies on construction performance (Ding et al., 2012).

The frequency of the term “information and communication technology” and "application" experienced a considerable ascension from 2013 to 2016, that is probably related to the application and the utilisation of the ICT, ICT in the construction and the strategy around that. After 2016, a varied group of subjects presented by authors and each subject lasted between 2 to 3 years. From 2014 to 2017, the ICT became a trending subject, especially through project management and construction performance. Likewise, quantify business performance and construction enterprises were also trending subjects from 2014 to 2017 (Agwu, 2012; L. Oyewobi et al., 2013; L. O. Oyewobi et al., 2016). On the other hand, the keywords related to BIM technology clarified in 2016 to 2021 with comparatively low recurrence if been compared to others. However, the BIM technology has been considered to be used as a reinforcing tool of the construction performance management with an integration of the information and communication tools in the construction, design, procurement, and commissioning phase (Panuwatwanich and Nguyen, 2017).

The keyword time analysis also provided some insight into the type of construction economy and the application of technological tools (Antuchevičiene et al., 2010; Brauers and Zavadskas, 2010). The analysis demonstrates that more recently; the projected attitude theory is utilised to investigate construction performance behaviour and the behaviour of the engineers, contractor employees' practitioners, designers, project managers and particularly contractors (Altheide, 2018; Li et al., 2018). As new technologies and innovations gained worldwide attention, building information modelling, 3D printing technology and ICT applications from gained more popularity from 2017 to 2021. Therefore, much research engaged in “business performance” and “strategy”, including simulation of the potential impact of new technologies on construction management approaches (i.e. BIM, information modelling, cloud computing and e-risk) (Takim et al., 2013; Wong et al., 2014).

In order to monitor the studies major trends of the last decade, a visual network view was developed to highlight the keywords co-releases from 2009 to 2021 (Figure 3.6). The integration of burst detection using VOSViewer and the network view can present the analysed trend of a study area (X. ZHANG, 2016).

The lines which connect the nodes refers to the co-release's connections between keywords. Moreover, the level of the colours of these lines are presenting the time zone relationship between the two keywords. The volume of node bubble (keywords) is symmetrical to the occurring frequency of keywords.

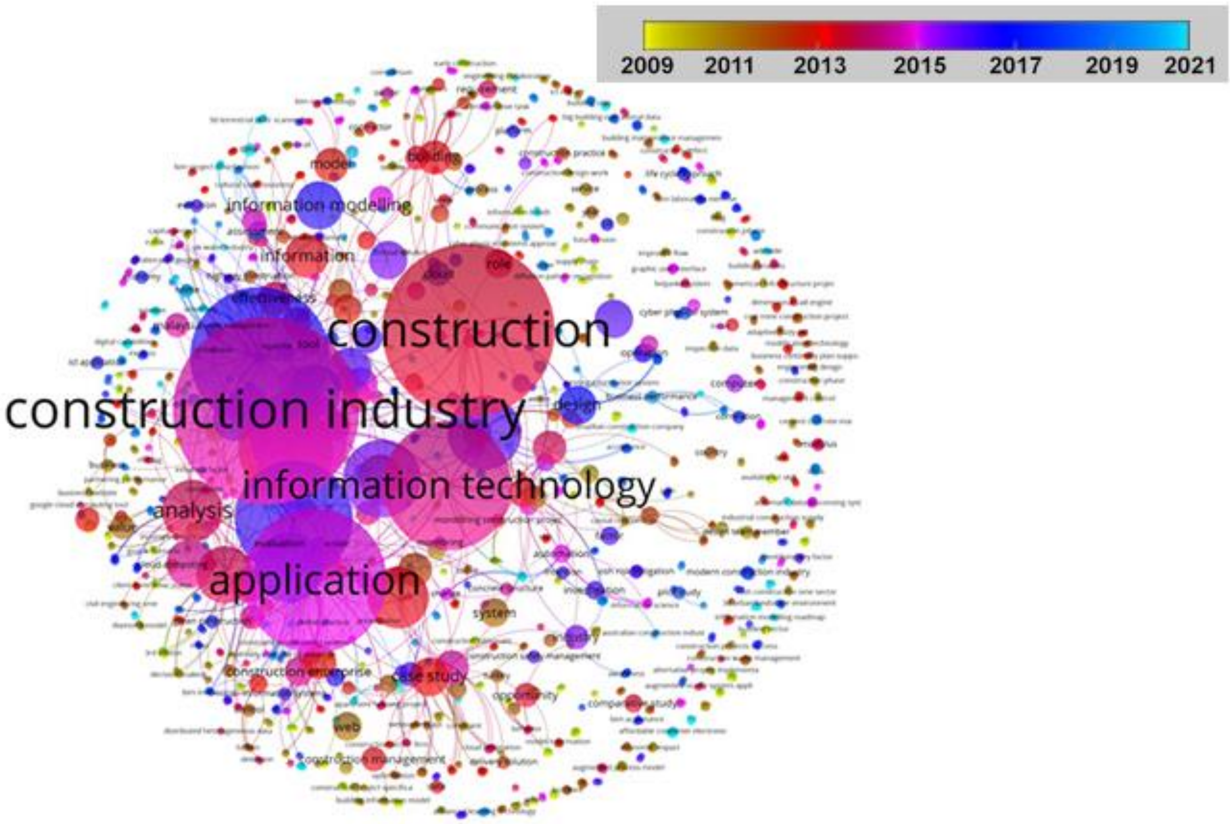

Figure 3.6: Top keywords with the strongest citation bursts from 2009 – 2021

3.4.6 Tools and Software Usage Analysis

The final analysis has been considered in this research was to identify and analyse the ICT tools usage in the previous technical research. Ezcan, V., Goulding, J. S., & Arif, M. (2020) have identified five main ICT applications groups which can cover most of the ICT products in construction as the following:

- Planning and Project Management: This group covers software or tools that allow managing complicated business processes with planning, organizing, and managing the various resource pools available (Li et al., 2018).
- Job Site Data Collection & Reporting: This group covers the most common usage of software or tools in any project size which involving the daily reporting support tools and can be used by non-professional construction teams (Pidgeon A et al., 2021).
- Computer-aided drafting (CAD): CAD systems provide drawing entities with powerful construction, editing, and database techniques to produce drawings and models of what buildings will look like when finished (Li et al., 2018).
- Cloud Storage, Sharing, and Web Conferencing: this group includes the communication technology tools which facilitate the organization or project communication and information sharing system (Li et al., 2018).
- Building information modelling (BIM): BIM software can directly and interactively present concepts of design in a form which represent physical and real images of the building to allow designers to identify clients' needs, and to promptly and effectively provide solutions to these needs (Chang et al., 2020).

Based on the above groups of ICT tools, a general search on The Web of Science (WoS) and Scopus has been conducted considering the ICT groups as search keywords and the timeframe from 2009 to 2021. Finally, the result data has been summarized in Table 3.2. The average citation score in Table 3.2 represents the mean citation score of the target research which have been selected to calculate the popularity of the ICT group. Based on this table, the Building Information Modelling ICT group are the most popular ICT research area considering the number of studies related to this ICT groups compared with the total number of the ICT studies. On the other hand, the studies related to the computer-aided drafting (CAD) ICT group have scored more citation popularity comparing with other ICT research areas.

Table 3.2: ICT applications groups' performance from 2009 to 2021

ICT Groups	**Application examples**	**%Age of usage in researches**	**Avg. Citation score**
Planning and Project Management	*Primavera, Microsoft Project, Syncro 4D Planning, Deltek Acumen, Planswift*	12%	41
Job Site Data Collection & Reporting	*Microsoft Office Package, NoteVault*	6%	14
Computer-aided drafting (CAD)	*AutoCad, Navisworks, Tekla*	31%	79
Cloud Storage, Sharing, and Web Conferencing	*Dropbox, Adobe Acrobat, Aconex, StoneX*	8%	12
Building information modeling (BIM)	*Navisworks, Tekla, Syncro 4D Planning*	43%	64

3.5 Discussion

The scientometric systematic analysis can provide the main components to draw an integrated framework for ICT in the construction industry (Darko et al., 2019; He et al., 2017; Zhong et al., 2019). The comprehensive framework in Figure 3.7 contains three main parts: the knowledge domains which is the top section, knowledge evolution which is the middle part and at the bottom the directions for future studies (Chen, 2017; Ivancheva, 2008). Based on the burst detection which has been described above, the knowledge development in ICT in the construction industry has been presented in the above "Keywords Time Analysis" section. In this section, the main identified knowledge domains for ICT in the construction research are discussed based on the outcomes of the keywords co-releases analysis and assemblage analysis.

3.5.1 Knowledge Domains

Considering the outcomes of keywords co-releases network and assemblage assessment, the domains of knowledge in ICT in the construction industry are declared and further illustrated in four columns within Figure 3.7. These knowledge areas are categorised as the following (Figure 3.7):

- Technologies and Methods
- Assessment and Comparison
- Composition and Quantification
- Factors and Challenges

The combination of high-frequency keywords from cluster #1, Cluster #3 and cluster #4 has been developed using SciMAT mapping analysis tool and create an indication of different knowledge domains. This is performed based on the trend of each keyword in research categories and the identified in the previously identified clusters.

Accordingly, the first column in Figure 3.7 demonstrates a knowledge domain involving the keywords related to the factors and barriers that disturb the management of ICT in the construction industry. Therefore, this column is critical for an effective implementation of ICT in construction by demonstrate the implementations challenges as well as the process to pass these utilisation barriers (Darko et al., 2019; Zhong et al., 2019; DG Azevêdo, 2020).

In the second domain, related keywords from cluster number one to cluster number four have been organised in this column which concern estimation and quantification of the construction industry, construction organisations and building research. Within this domain construction quantification methodology involves the classification of the study field, research scope, variables modelling method, and other particular methods (Oliveira and Martins, 2011; Pekericli et al., 2004).

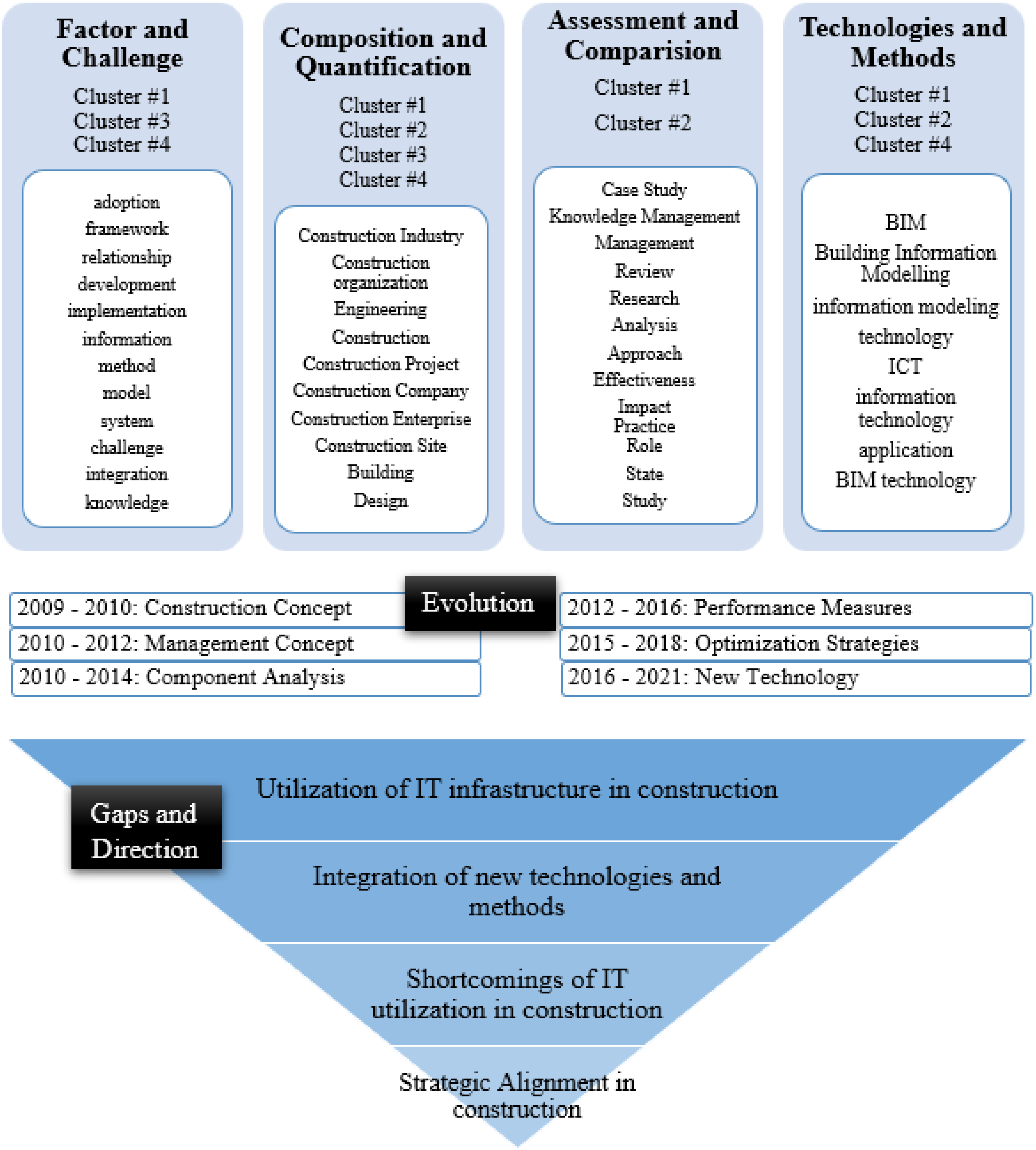

Figure 3.7: The comprehensive framework for ICT in Construction 2009 – 2021

The next domain categorised related to the ICT implementation assessment which can further characterised into two types starting with the feasibility analysis and process to the impact analysis for each utilisation simulations. This domain includes the related keywords from cluster #1 and cluster

#2. Finally, the fourth domain is technology and method; including correlative high-frequency keywords from Cluster #1, Cluster #2, and cluster #4 such as BIM, information modelling, cloud computing, big data, CAD and ICT.

The existing construction information technology ICT applications and tools have the problems related to insufficient data quality which is most researchers concentrated more on solving the issues related to it. However, there is a lack of studies related to the second problem which is the shortage to integrate with the various construction process (Orlikowski, 2000; Perkinson and Ahmad, 2006; Oliveira and Martins, 2011; Lu et al., 2014; Gunasekaran et al., 2017; Guo et al., 2017). The top keyword in this list is related to the building information modelling (BIM). This is one of the most effective areas of study in term of the integration of ICT in the construction industry and by integrating the data monitoring ICT with a visual related technology like BIM to improve project monitoring system, location-based management, and remote data collection (Abdirad and Dossick, 2016; Bui et al., 2016; Ghaffarianhoseini et al., 2017; Lee et al., 2013; Rogers et al., 2015).

3.5.2 Knowledge Evolution and ICT Application

Considering the keyword detection results using the time-range view which discussed during "Keywords Time Analysis" Section, the evolution of ICT research and knowledge in the construction industry can be tracked. Based on this keyword detection results, the trending research subjects from 2009 to 2010 were only related to primary concepts, for instance the topics related to "value", "construction", and "project management". Since 2011, the concepts have been changing from primary to advanced management such as the topics related to "performance" and "system". On the other hand, considering the research focus in the same range period, the concept itself has been diverted from the topics related to the basic ICT implementation challenges to more advanced and internal component analysis (i.e., productivity improvement). Research from 2013 to 2016 focused on construction "analysis", especially through "design" and "construction" measures (Amusan et al., 2018; Gunasekaran et al., 2017). From 2017 to 2018, "strategy" became the new concerns to improve performance and outcomes in both organisation size and project size (Altheide, 2018; Amusan et al., 2018; Zhong et al., 2019). From the time range of 2016 to 2021, new ICT and methods such as "big data" and "BIM" became trending topics. The evolutionary trend of ICT in the construction industry from 2009 to 2021 can be summarised as a transformation from traditional management concepts to an external and internal challenge analysis to innovative management practices and organisational strategy (Darko et al., 2019; Ganesan, 2019). Regarding the ICT application studies, building information modelling (BIM) applications have been identified as the most studied ICT construction application compared with other ICT application groups which can be because of the natural of BIM technology and how it is involving and can be integrated into other type of ICT group. On the other hand, the computer-aided drafting (CAD) application groups have scored the top citation rate which can be due to the history of the CAD applications and how it involves the integration with other ICT application groups.

3.5.3 ***Directions for Future Studies***

The directions for future studies section have also been captured in Figure 3.7. The first knowledge gap is to study the utilisation of ICT infrastructure in the construction industry. According to studies by researchers which have been considered in this investigation, it is necessary to analyse the connection between the information technology and ICT strategy and construction organisation or construction project strategy before the implementation of these technologies in the construction organisations (Amusan et al., 2018; Guo et al., 2017; Kanapeckiene et al., 2010; Lu et al., 2014; Mutesi and Kyakula, 2011; Oliveira and Martins, 2011; Son et al., 2015). However, most of the previous researchers concluded that the common problem of the construction organisations is the soft link between the organisation infrastructure and ICT infrastructure which affect the efficiency of information technology and ICT implementation (Jelodar et al., 2022; Amusan et al., 2018; Panuwatwanich and Nguyen, 2017; Rezgui, 2001).

The second research gap is to explore the utilisation of new ICT in the construction industry; analyse the results of this integration and also discuss methods of integration. Much research have investigated in the first research gap which is related to ICT utilisation in construction industry without discussing and analysing the strategy behind the utilisation methods (Ghaffarianhoseini et al., 2017; Oliveira and Martins, 2011). For instance, Zhang et al. proposed a BIM-based method that assists in construction safety management in an early construction stage (S. Zhang et al., 2015). Akinade et al. developed a comprehensive model based on BIM technology to determine the demolish capacity in the design stage of the project and before the construction stage start (Akinade et al., 2015). Accordingly, future studies can improve and expand the application of ICT from the early construction stage such as design, procurement and manufacturing stage to the stage of construction and commissioning and accordingly to the end of the project life stage (He et al., 2017; Wong et al., 2014; Zhong et al., 2019). Moreover, integrating further data processing technologies and data collection such as RFID and GIS into BIM is also becoming a necessity of modern construction practices (Darko et al., 2019; Hosseini et al., 2018; Panuwatwanich and Nguyen, 2017; Sun et al., 2017).

The third and fourth knowledge gaps are related to the shortcoming of ICT utilisation and having strategic alignment of resources in the construction sector. Based on reviewed research from 2009 to 2021, it is essential to conduct in-depth investigations of the relationship between ICT strategy and the existing business strategy (Henderson and Ruikar, 2010; Khosrowshahi and Arayici, 2012; Woo et al., 2016). It is still required to fill the gap of knowledge in strategic alignment of construction ICT and business and identify the issues behind the underperformance of ICT implementation in construction organisations. The mixed results across various studies appealed for more empirical research to investigate the link between strategic alignment and organisational performance (Eliwa et al., 2022; Eliwa et al., 2018; Acur et al., 2012; Johnson and Lederer, 2010; Morrison et al., 2011).

In addition, there is a lack of research and empirical evidence on the issue of the strategic alignment for information technologies and ICT in the construction organisations and the challenges in the adoption of these technologies. Thus, in-depth studies are required to present empirical evidence which can benefit the construction industry practice in the future and contribute to the body of knowledge (Budayan et al., 2015; Coltman et al., 2015; Doumi et al., 2013; Dutot et al., 2014; Morrison et al., 2011). The important of the ICT in construction industry has been highlighted out during the COVID-19 and post COVID period and how this type of study will benefit the construction organisation to implement to ICT in productive manner considering the strategic alignment between the business and ICT (MBIE-COVID-19, 2020; DG Azevêdo, 2020).

As new technologies and concepts are introduced this research can be replicated through similar methodology to further understand future trends. There is also a need for further in-depth research to understand ICT application and integration with major trending technologies and concepts in construction. This could include ICT integration with BIM; digital tools such virtual reality and augmented reality; application of sensor, Internet of Things and etc. Furthermore, the relationship of ICT with digital twins which is a high-fidelity representation of the real-world that connected and behaves like the real world, should be explored to improve understanding of the project life-cycle requirements and enhance decision making processes (Jones et al., 2020).

3.6 Conclusion

This study systematically reviewed publications related to ICT in the construction industry from 2009 to 2021 by using the scientometric analysis method. A total of 376 research selected for burst detection, co-citation analysis, cluster analysis, and keyword co-releases, in order to provide a comprehensive knowledge summary of the ICT application in the construction industry. Automation in Construction, Journal of Management in Engineering, Advanced Engineering Informatics, and Journal of Intelligent & Robotic Systems were identified as the four major journals associated with research on the ICT application in the construction industry. X Wang et al. (2013), Y Zhang et al. (2012), Albert P.C. Chan (2018), Y Yang et al. (2013), Peter E.D. Love et al. (2015) identified as the top five critical papers. By determining the high-frequent co-releases keywords, the trending research subjects in this area were identified as; "Building information modelling in construction", "The impact of technology on construction", "Information and communication technology in construction", "Case study on the implementation of technology in construction", "Construction Management", "The use of ICT in construction", and "ICT adoption in construction". Building information modelling (BIM) and the computer-aided drafting (CAD) group of application have been identified the most studied tools in the field of construction information technology.

Using the scientometric review analysis method, this study has presented a comprehensive framework for ICT application in the construction industry. The overall trends of ICT application in the construction industry from 2009 to 2021 were summarised as a transformation from traditional management concepts to an external and internal challenge analysis to innovative management practices and organisational strategy. The main knowledge domains of ICT application in the construction industry were identified and further classified into four columns (Figure 3.7) or domains and future studies directions were eventually discussed.

This study contributes to the construction industry body of knowledge by classifying the existing ICT related research, evolutionary trend, providing current status and lending to a comprehensive knowledge framework, and future directions. The research findings can provide hindsight; helping researchers and practitioners better understand the current research related to ICT applications in the construction sector. The evolutionary trend and knowledge domains can offer a clear and in-depth cognition of construction ICT research.

As mentioned above, the knowledge gap related to summarising and reviewing the depth and breadth of the technology application studies, especially the ICT applications and its effect on construction organisations has been identified. Also, a large amount of research has been devoted to the technology application in different industries ICT is still unclassified within the construction sector and organisational research. This identified knowledge gap provides specific needs and research directions for construction ICT research.

Finally, considering the research method, there are three limitations in this study. The first limitation is that the articles used for scientometric analysis collected only from the Scopus and WOS database only. Moreover, the study is mainly concentrated on the quantitative analysis in regard to the articles merging frequently in the ICT applications in the construction industry, which were used to indicate the hot topics. Finally, results may change at different with the updating databases.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 4
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

Eliwa, H., M.B. Jelodar, and M. Poshdar. Information technology and New Zealand construction industry: An empirical study towards strategic alignment of project and organisation. in Proceedings of the 18th International Conference on Construction Applications of Virtual Reality (CONVR2018), Auckland, New Zealand. 2018.

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

Chapter 4: Strategic Alignment effect on the construction organisations' ICT

The current chapter is based on the following article:

Eliwa, H., M.B. Jelodar, and M. Poshdar. Information technology and New Zealand construction industry: An empirical study towards strategic alignment of project and organisation. in Proceedings of the 18th International Conference on Construction Applications of Virtual Reality (CONVR2018), Auckland, New Zealand. 2018.

4.1 Introduction

The construction industry is one of the largest fields of investment in the world and it is one of the most influential sectors for New Zealand economic growth; ranking in the top five most contributing sectors (Liu et al., 2017; MBIE, 2015; Wilkinson, 2012). However, this industry faces significant challenges including low productivity, chronic delays, cost overruns, and quality issues (Mbachu & Taylor, 2014; Poshdar et al., 2014). The studies show that the use of advanced project management methods combined with the modern tools and systems such as information technology can deliver a 30% enhancement in total industry performance (Jia & Min, 2010). This situation calls for a reassessment of the state of the project management knowledge and the level of penetration of modern methods and technologies (Jelodar et al., 2016; Jia & Min, 2010; Onyegiri et al., 2011). Information technology (IT) supports processing, storing, sharing and producing information (Bjork, 1997). Initially, it was mainly depended on the data processing. However, given its wide-spread adoption today, IT can offer a higher level of cooperation, coordination and information integration to enhance the construction performance (Forcada Matheu, 2005). All the construction phases including the initial project planning, the execution stage, and the operational development can be benefited from the implementing IT. A review of the reports on the penetration of IT in construction shows that the adoption has started in projects (Weippert et al., 2003). However, a full establishment of IT in construction remains subject to the institutionalization of strategic alignment between IT application and the business strategies adopted by the firm (Acar et al., 2005; Gaith et al., 2009; Stewart & Mohamed, 2003).

The concept of strategic alignment is mainly based on the theory an IT correspondent to the firm's business strategy can shape an effective and competitive border and provide strong solutions to the firm's strategic problems (Luftman, 1996). The alignments have traditionally linked with two determinants. It has either been linked to the strategic fit that is the scope to which the infrastructure supports an organization's strategy; or the functional integration that is the scope to which IT approaches support the business plan (Izanec,1997). Effective implementation of the strategic alignment requires synchronization between the strategic fit and the functional integration (Henderson et al., 1996). This paper conducts an analysis of the existing connection between IT implementation strategy and the organisational and project strategies adopted by the construction industry in New Zealand. The following research questions have been considered: Do New Zealand construction firms have clear information technology strategy within the business initiative? How can the construction organisation in New Zealand achieve and manage the strategic alignment between information technologies, organizational infrastructure and business strategy? Answering these two questions will help in finding the routs to fit, align and integrate IT into the organisational and project business strategies of construction firms.

4.2 Literature Review

In the late 1960s, Japanese academia and industry emphasized on the concept of the information technology as a phase of economic development (Björk, 1999; Zhanglu & Wenwen, 2014). However, its application in engineering started in the 1970s as a computer-aided design (CAD) that facilitated engineering drawings (Forcada Matheu, 2005). However, this usage was restricted to large-size engineering projects. The development of personal computers (PC) in the 1980s increased the computational power and facilitated its implementation in the medium-size projects (Forcada Matheu, 2005; Peansupap & Walker, 2005).

The requirement for information transparency and perfection in a competitive business calls for effective tools that could enable business efficiency. The alignment of business efficiency with supporting technologies is the main concept of strategic alignment. Strategic alignment proposed to support the integration of information technology into business strategy and processes. (Luftman, 1996) defined it as a concept that aligns information frameworks with the business strategy to shape a powerful competitive border and produce strong solutions for field and organisation issues. The Strategic Alignment Model has established on the idea of "strategic fit" which is the vertical linkage between external and internal domains and explains the business requirement to make decisions. Another linkage can be established in the "functional integration" between firm and technology domains which relates to information technology and the alignment of the business (Henderson et al., 1996) (Figure 4.1). The concept of the strategic alignment model theorises the analytical scope of the firm strategy from the infrastructure and operation support (strategic fit) or business plans and information technology support (functional integration) (Izanec, 1997). On the other hand, Henderson (1996) concluded that the organisation should work on both strategic fit with functional integration for better results (Henderson et al., 1996).

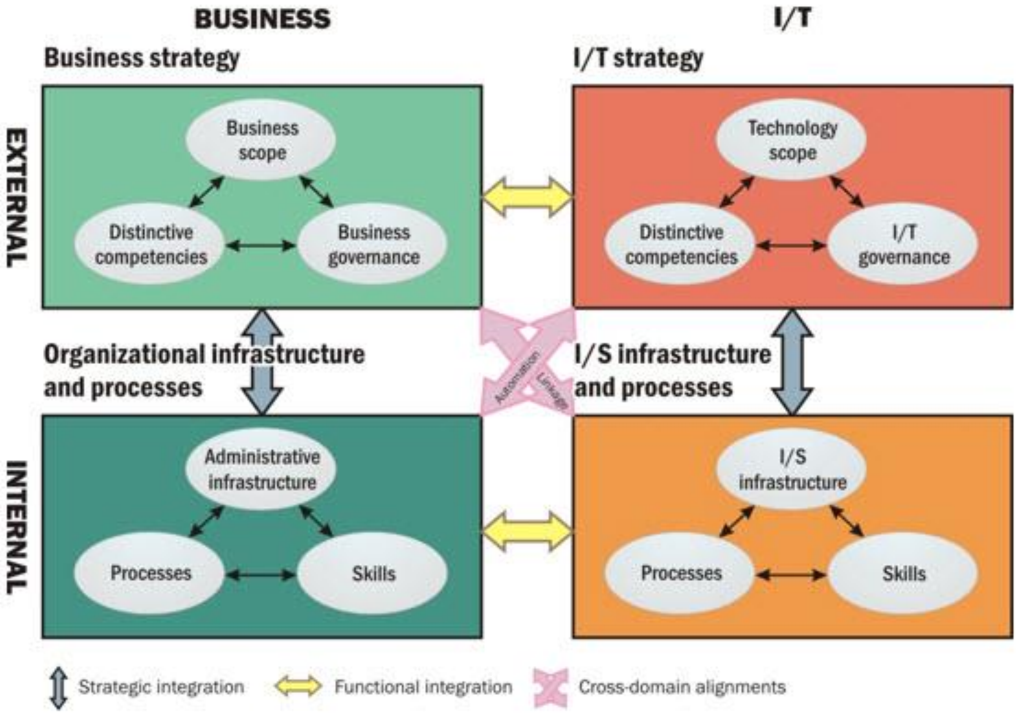

Figure 4.1: Strategic Alignment Model for Business. Source: Adapted from (Henderson & Venkatraman, 1989)

In 1999, Björk discussed the scope or the range of the study of the information technology applications in construction using an analysis technique based on a strong model of the information management in construction called IDEF0. The objective was to draw a clear border between the specific information technology research and other similar research in this area (Björk, 1999). The author found that in the previous studies about information technology in construction, there was a weakness in term of the information technology model identification (Björk, 1999). Other researchers have analysed the barriers that control the spread and the implementation of the information technology in construction organisations such as the nature of the application itself and considering the business strategy over information technology infrastructure (Henderson et al., 1996; Peansupap & Walker, 2005). Regarding the strategic alignment, they concluded that the business strategy, information technology strategy, firm infrastructure and information technology infrastructure should have a level of integration for best results (Figure 1) (Henderson & Venkatraman, 1989; Henderson et al., 1996; Peansupap & Walker, 2005).

As mentioned above, Henderson (1996) concluded that the organisation should work on both the infrastructure and operation support (strategic fit) with business plans and information technology support (functional integration) for better results and there are internal and external domains within each element (Henderson et al., 1996). The internal domain in the business strategy area described as "organizational infrastructure and processes", and it is mainly involved with options that determine the structure or restructure of pivotal business procedures, the executive structure and the development of resource skills. However, the external domain in this area described as "business strategy", and it is involved with governance decisions, business scope decisions and distinctive competency (Goh, 2006; Henderson et al., 1996). Correspondingly, the internal domain in the information technology strategy area described as "information technology infrastructure and processes", and it is involved with how to manage the information technology infrastructure in regard of its architecture, processes and skills. On the other side, the external domain in this area described as "information technology strategy", and it is involved with the organisation place in the information technology marketplace in regard of its technology scope, information technology governance and systemic competencies (Goh, 2006; Henderson et al., 1996). Various tools and techniques have been proposed to process the alignment issue using measurement methods or modelling techniques and one of the benefit models was the Strategic Alignment Model (Andres & Poler, 2017). The strategic alignment model works on developing the integration of the information technology domain and business domain at strategic scale - the relationship between information technology strategy and business strategy - and the operational scale - the relationship between organisational infrastructure and information technology infrastructure -. However, it required to consider one of the four dominant alignment perspective - which presented in Figure 4.2 - to operationalise the model (Goh, 2006; Henderson et al., 1996).

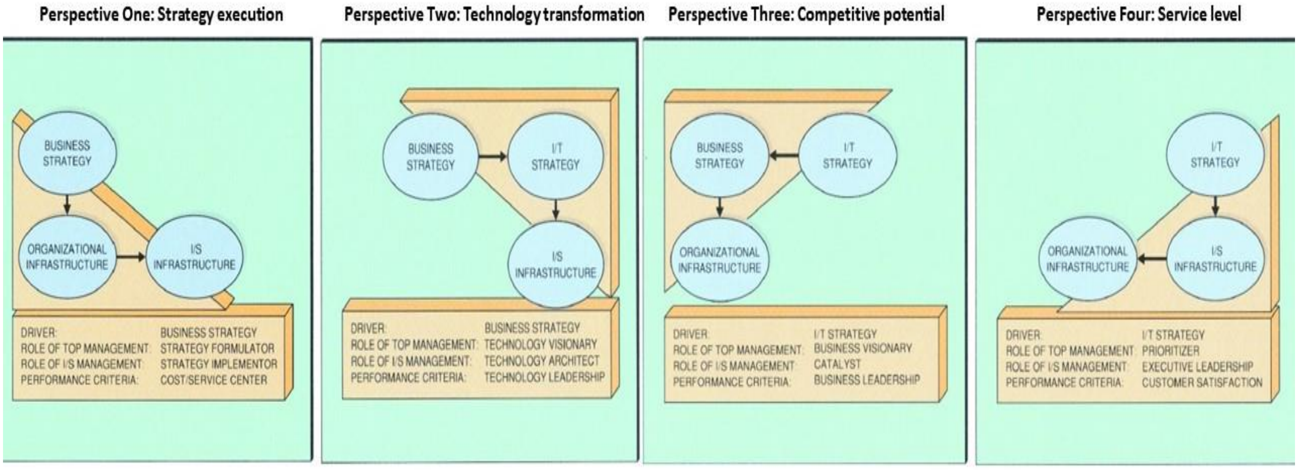

Figure 4.2: Four dominant alignment perspective of the strategic alignment model.

The latter argument confirmed by Tulenheimo (2015) who demonstrated that the project budget and management culture have significant shortcomings and inabilities in implementing new technologies in the construction industry which is proven to be difficult to penetrate (Tulenheimo, 2015). Moreover, the level of organisation was considered as an obstacle in term of information technology implementation; especially if the national use of the information technology as a project management tool is relatively late (Jia & Min, 2010). Zhanglu and Wenwen (2014) have suggested that the impact of the information and communication technology implementation on project performance and cost saving is dependent on the hosting country's growth and organisational culture towards the information technology (Zhanglu & Wenwen, 2014). Thus, the effective use of the information technology starts from the structure and the development of the construction firms as mentioned by Wilkinson (2012) who performed research to analyze the volume of information technology application; within construction project management of New Zealand during project phases and the acceptance of those organizations to invest in specialized information technology applications. It was found that the companies with a large number of employees are more likely to use the information technology application and considered it as strategic to their firm compared with the companies with fewer numbers of employees (Acar et al., 2005; Sarshar & Isikdag, 2004; Wilkinson, 2012; Poshdar et al., 2018).

Although there are obstacles and barriers to implementing the new information technology in the construction industry, there are direct and indirect relationships between the information technology implementation and project performance (Peansupap & Walker, 2005). Some researchers found that the information technology, in general, has a direct positive effect on the construction organisation performance by improving the efficiency of works and facilitating the project management. However, the positive impact of the information technology on the performance reflected a negative effect on the organisation workforce such as limiting the options for employment, the effect on work-life balance experienced by employees, the effect on workforce attitudes and create "technostree" which is stress results from working on technology for a long time. (Sun et al., 2008). According to Kang et al. (2013), there is a robust relationship between best practice or construction management and the project performance stronger than the relationship between the information technology implementation and the project performance or outcomes. However, the use of the information technology has a significant direct impact on the best practice or project management. In general, information technology implementation can directly affect the work progress without a direct relationship to the project performance (Kang et al., 2012). The latter argument was also supported by Onyegiri, Nwachukwu, and Jamike (2011) who found that the fast development of the information and communication technology has an indirect positive impact as it increases the communication efficiency, decreases data processing time, improves the decision-making and facilitates coordination works (Onyegiri et al., 2011). Thus, most researchers agree that implementing information technology has a positive impact on project performance and construction cost, but this still depends on and also restricted by the study location and the local culture (Jia & Min, 2010; Kang et al., 2012; Peansupap & Walker, 2005; Zhanglu & Wenwen, 2014).

In this regard, many researchers have chosen to analyse and study the impact of the information technology implementation using empirical studies in different countries and geographical locations with specific cultures as the level of results vary and depend on the position of the construction industry in this country (Tulenheimo, 2015). In the last ten years, many researchers studied the effect of organisation information technology on the construction projects in different countries. A researcher such as Zhou and Min (2010) who studied and tried to recognise the barriers that impact the implementation of the information technology in Chinese construction projects and analyse the possible ways to eliminate those barriers. The author studied the incorporation of the impact of sophisticated information technology on the management of the project and the obstacles in information technology implementation to analyse the value of coping strategies in the Chinese construction industry (Jia & Min, 2010). Other researchers studied the challenges of implementing new information technology in the construction industry using the local practical study to analyze the level of spreading this technology in the construction firms nationwide (Jia & Min, 2010; Tulenheimo, 2015).

Some authors consider the breadth of application and volume of information technology implementation of the on New Zealand construction industry without considering its effect on the project outcomes. For instance, Wilkinson (2012) studied the usage and volume of the information technology application corresponding to the project management in the New Zealand construction organisations during project phases and the organizational acceptance towards specialised investments in information technology applications. Based on a survey, the researchers found that 58% of the construction companies in Auckland used the information technology application which related to project management during planning and monitoring works; around 21% of those construction companies created their project management applications which reflect the company needs (Wilkinson, 2012). Thus, there is a definite acceptance of using the construction-related information technology applications in New Zealand construction industry. However, more in-depth analysis and empirical evidence through industry, organization, and project-based research are required to observe and identify the efficiency of using information technology tools and applications; in addition to determining the challenges around that (Liu et al., 2017).

4.3 Research Methodology

In order to analyze how information technology is integrated, fitted and aligned with the business strategies of construction firms in New Zealand, a two-phase methodology has been developed and implemented. In stage 1 the "Theoretical Review", an overall review of related literature from well-respected sources has been performed to recognize different characteristics and advantages of information technology implementation in the construction industry. For stage 2 known as "Practical Investigation", expert Semi-structured open-ended interviews selected as the most appropriate instrument for collecting the necessary data from large construction projects based in Auckland, New Zealand. The interviews conducted with the project managers, planning managers and senior engineers from each construction project. The semi-structured interview method provides an equilibrium between the elasticity of open-ended questions and the concentrate of a structured interview and the data during the semi-structured interviews can convert the study process from domains topics to more particular views (Harris & Brown, 2010). This type of qualitative study supplies key expert results which are in the same level of training and experience and can analyze multiple ways of problems management (Flick, 2009). Furthermore, using Expert Semi-structured interviews provides a foundation for the validation of other results from other research in the same field of study (Gubrium & Holstein, 2002; Jelodar et al., 2018).

Interview responses rate was based on the theoretical saturation principle which has been performed in similar research (Jelodar, 2016; Martin, 2011; Glaser, 2009). Accordingly, a total of thirteen expert interviews were conducted which are tabulated with complementary information in Table 4.1.

Table 4.1: Interviewees profile summary

	Role	Experience	Cur. Project	IT products/tools used	By-Product / Capabilities
Expert 01	Project Manager	21 years	Highway	BIM, Cloud, DSS, CAD	VR, AI
Expert 02	Project Manager	17 years	Airport	BIM, Cloud, DSS, CAD	VR, Wearable
Expert 03	Project Manager	31 years	Airport	BIM, Cloud, DSS, CAD	AR, AI
Expert 04	Project Manager	33 years	Infrastructure	BIM, Cloud, DSS, Sim, CAD	VR, Wearable
Expert 05	Senior Planning Engineer	12 years	Highway	BIM, Cloud, DSS, CAD	VR
Expert 06	Cost and Control Manager	30 years	Airport	BIM, Cloud, DSS, CAD	
Expert 07	Planning Manager	30 years	Airport	BIM, Cloud, DSS, CAD	
Expert 08	Planning Manager	16 years	Infrastructure	BIM, Cloud, DSS, Sim, CAD	VR, AR, AI
Expert 09	Senior Planning Engineer	13 years	Hotel	BIM, Cloud, DSS, CAD	VR, Wearable
Expert 10	Senior Civil Engineer	11 years	Highway	Cloud, DSS, CAD	VR
Expert 11	Senior Civil Engineer	10 years	Airport	Cloud, DSS, CAD	
Expert 12	Senior Civil Engineer	10 years	Airport	BIM, Cloud, DSS, CAD	Wearable
Expert 13	Senior Civil Engineer	23 years	Infrastructure	Cloud, DSS, CAD	VR, AR, Wearable

Experts were selected using the theoretical process as they are from different types of construction projects with purposive experience of using the information technology tools and systems in New Zealand construction work environments and projects. Therefore, the selection process considered that all the interviewees worked in four large size construction projects in Auckland New Zealand in the higher tier of management roles and used the information technology during their daily works. The sample population are holding high ranked positions in their organizations, making them well informed and experienced individuals. Therefore, the expectation that respondents must have a good understanding and demand of current practices and processes within their organizations and the wider construction industry is fulfilled. The expert face-to-face interviews structured with foundation questions related to the relationship between the information technology implementation strategy and construction organization strategy followed by complementary open-ended questions for better tangibility responses.

The answers from the foundation questions, the experts' comments and opinions have been categorised and classified using NVIVO software and then analysed - considering the software outputs - to be in the term of "agree" and "disagree". In this regard, the percentage of "agree" results has been calculated and distributed on the related domain considering the factors affecting the position of a specific domain in the organisation (Acar et al., 2005; Andres & Poler, 2017; Boddy et al., 2008). Thus, to achieve the main objective which is analysing the strategy of construction organisation to consider information technologies as strategic resources, the strategic alignment model has been selected as a framework for aligning the information technology with the business strategy. To apply the strategic alignment model on the collected data, it is required to analyse the data based on the main four elements or domains of strategic alignment which are business strategy, information technology strategy, organisational infrastructure and information technology infrastructure.

4.4 Findings

The findings of this study have been presented in two sections. In the first section, the collected data have been summarized and organized on the four strategic alignment domains based on their impact on each domain, and the goal is to append statistical result from the interview to each part of the four domains. Thus, to apply the structure of the strategic alignment model, each domain level has been analysed separately and presented as “Strong”, “Mid” or “Weak” to determine the power of each domain in term of considering the information technologies as strategic resources. The full process of the first section presented in Figures 4.3 and 4.4. Based on the collected data, the business strategy of the large-sized New Zealand construction organizations exists, and it is in an optimal good position. Moreover, the information technology strategy responds to the business strategy and the information technology organizational culture is strongly present (Figure 4.3).

On the other hand, the organizational infrastructure is the weakest area in New Zealand construction organizations which indirectly effect on the information technology infrastructure and process (Figure 4.4). Hence, for large-sized New Zealand construction enterprises, organizational infrastructure and information technology infrastructure are two areas identified as having the issue or opportunity that can be classified through the deployment of the information technology as a strategic resource.

Therefore, and from the figures above, the business strategy is the driver element with the strongest level compared with the other domains then the information technology domain follows it with an accepted healthy standard as well. The information technology strategy reacts to the business strategy, and the performance criteria based on financial parameters considering a cost pivot concentrate. Looking at the right-hand side chart (Figure 4.3) of the external domain, which is an information technology strategy, the information technology in New Zealand construction organisation mainly concentrates on performance efficiency by financial savings and increased the productivity and efficiency of the organisation work process. The strategy execution perspective considered as the typically dominant alignment for the New Zealand construction organisation based on Figure 4.4 as the organisation infrastructure is the weakest domain and lagging behind the development vision of the organisation due to a lack of investment on information technology facilities. Therefore, the information technology Infrastructure is impacted and need to be developed to support the firm or construction company infrastructure shortfalls.

However, the tested components have multiple effects with instances where they are reinforcing or balancing other potential components. For instance, creating more IT infrastructure will create requirements for more skilled professionals and if that may not be an option training facilities and workshops need to be included. These effects may disrupt cash flow issues or require more investment in other infrastructure which was totally unthought-of at the beginning of the process. These components and their collective interactions create systems and subsystems that are in the congregation with many different layers (Jelodar et al., 2015). The other observation made is the fact that a change in components makes the system unstable in a manner that different status changes are then experienced to reach more stability; however, this changing status is constantly happening especially with the fact the technology improvements and changes are rapidly taking place throughout the industry. On the other hand, the ultimate goal of IT systems and technology is to enhance quality and productivity which is a continuous process both at the project and industry level. On top of these complexities, a non-linear relationship exists leading to a range of dynamic variations in the system. Accordingly, a system dynamic model framework seems to fit into the findings of this study. The creation of the initial system dynamics model involved the problem statement, formulating a dynamic hypothesis, and formulating a simulation model (Jelodar et al., 2018). Based on this assessment a causal loop diagram is suggested to summarize and analyze the drives of information technology infrastructure based on the collective views of construction experts.

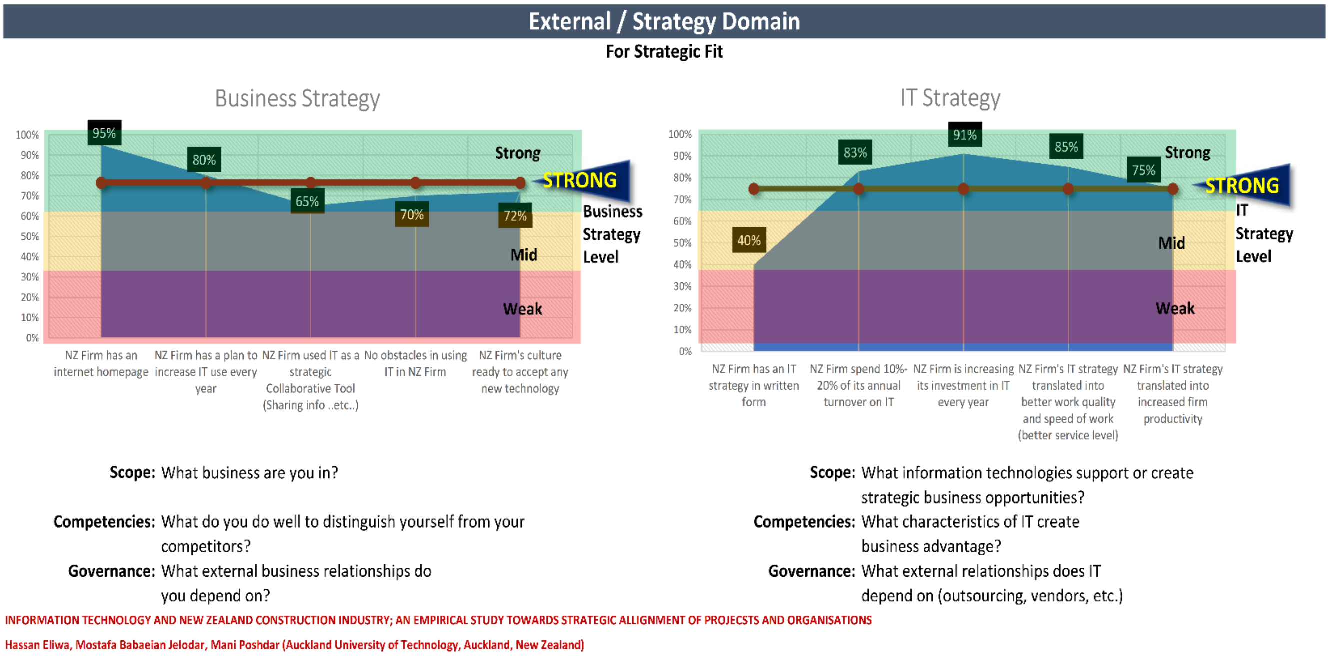

Figure 4.3: Results of analysis of New Zealand Organizations for Internal / Infrastructure Domains

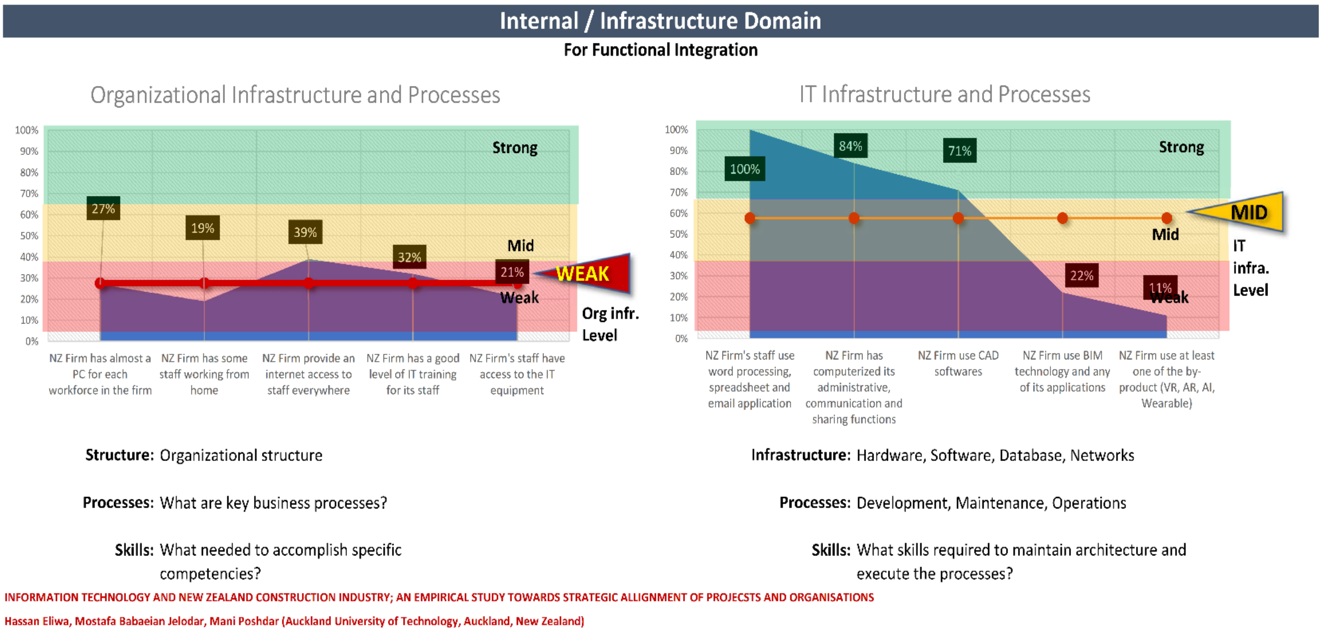

Figure 4.4: Results of analysis of New Zealand Organizations for External / Strategy Domains

This stage was performed via the application of a system dynamic Vensim PLE as a systems dynamic tool and presented in Figure 4.5. The method has been widely used in many interdisciplinary reassert area and similar complex construction-oriented issues such as innovation instruction (Jelodar et al., 2018). In addition, the diagram can isolate and identify the main factors to be considered as the weakest link or domain in the strategic alignment of technology and organizational infrastructure to the overall benefit of construction companies and opens up roots to further idea development for future investigation for more efficient problem solving in such issues (Nguyen & Ogunlana, 2005; Sterman, 2000; Walrave & Raven, 2016).

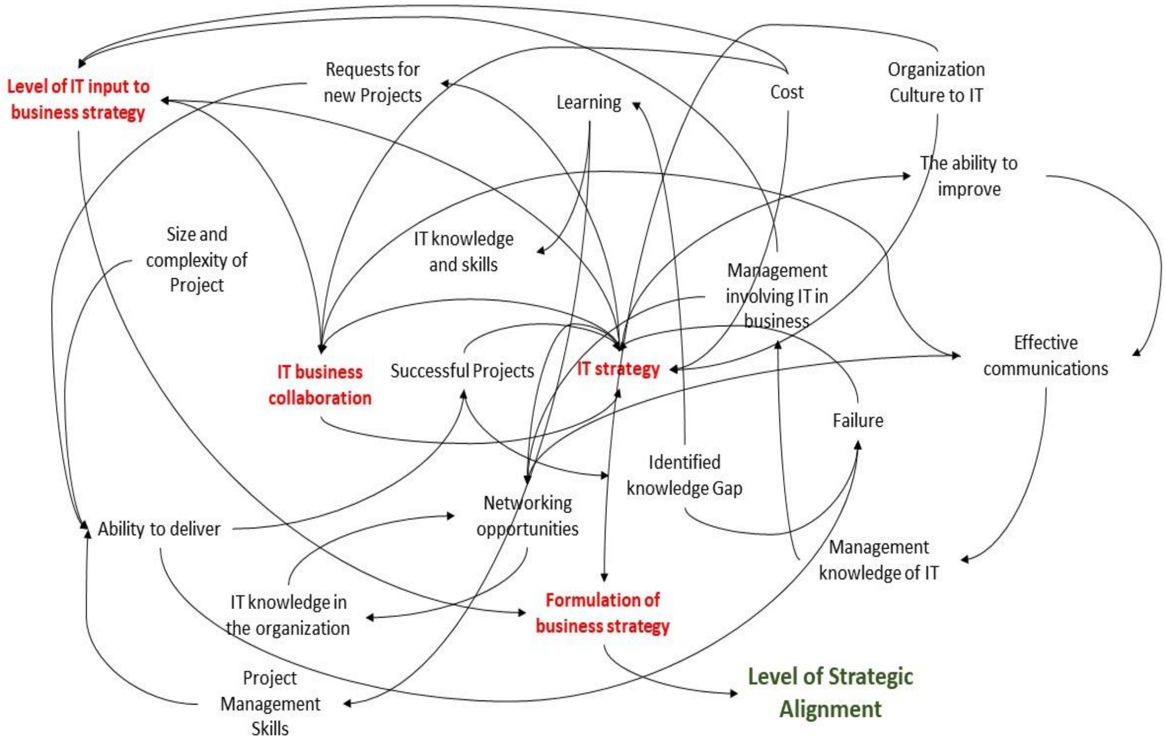

Figure 4.5: Causal loop diagram to summarize and analyse the drives of information technology Infrastructure

4.5 Conclusion

This research analysed the quality of the information technology usage by New Zealand construction organization. It studied the alignment of business and information technology strategies by applying the structure of the strategic alignment model. In New Zealand construction industry, firms have common requirements relating to building information technology capability, and at the policy level, it is important to address domain-specific concerns. Based on this study, organizational infrastructure and IT infrastructure are two areas identified as having an opportunity that can be addressed through the deployment of information technology as a strategic resource. The findings assist policy makers as well as construction project management to better understand the New Zealand construction sector firms' information technology and strategic management orientations.

This research identified possibilities for New Zealand construction organizations in focus to increase their strategic alignment level. As it has proposed actions, the organizations can take by identified the weak domains in the strategic alignment model as well as the performance criterion. This paper has considered the experts' and the literature suggestions and discussed possible actions to take to effectively align the use of information technology with organization business strategy. The overall action that needs to be taken in order to align information technology with the business strategy is transforming the overall perception of information technology as a costly department toward information technology as a provider of competitive advantage.

4.6 Research Limitation

The scope of this research limited to large construction projects within the Auckland region in New Zealand as Auckland region mostly covers national construction demand in New Zealand. Thus, the study provides insights into what the impact and challenges of implementing information technology tools, concepts and applications on New Zealand construction industry performance.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 5
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

◉ **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

Eliwa, H.K., M.B. Jelodar, and M. Poshdar, Information and Communication Technology (ICT) Utilization and Infrastructure Alignment in Construction Organizations. Buildings, 2022. 12(3): p. 281.

○ **The manuscript is currently under review for publication**

Please provide the name of the journal:

○ **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

Chapter 5: ICT infrastructure impact on the construction organisations' performance

The current chapter is based on the following article:

Eliwa, H.K., M.B. Jelodar, and M. Poshdar, Information and Communication Technology (ICT) Utilization and Infrastructure Alignment in Construction Organizations. Buildings, 2022. 12(3): p. 281.

5.1 Introduction

The construction sector can be considered as the biggest investing sector worldwide and, according to the New Zealand ministry of business report 2021, it is the topmost contributing and influential industry for New Zealand economic development (Adafin et al., 2021; Eliwa, Jelodar, & Poshdar, 2018; Harris, McCaffer, Baldwin, & Edum-Fotwe, 2021; The Ministry of Business, 2021). However, this sector faces considerable barriers and challenges such as low performance, frequent construction delays, quality issues and cost overruns (Harris et al., 2021). Therefore, finding solutions to improve construction projects performance and making the project management knowledge more efficient is the main challenge for organizations to achieve the client requirements (Alaloul, Liew, Zawawi, & Kennedy, 2020; Harris et al., 2021). One of these solutions is to apply new technologies and implement effective information and communication technology applications in construction projects (Adriaanse, Voordijk, & Dewulf, 2010; Harris et al., 2021).

Information and Communication Technology (ICT) can be described as technologies that are involved in the collection, transport, retrieval, retrieval, storage, access presentation and transformation of all forms of information (Hosseini, Chileshe, Zou, & Baroudi, 2012). ICT can also be defined as the application of Information and Communication Technologies tools, including software and computer hardware (Arayici, Aouad, & Ahmed, 2005; Peansupap & Walker, 2006). On the other hand, the information and communication technology (ICT) infrastructure can be defined as the necessary components to manage and operate enterprise IT environments (Serpell, Barai, & Oladapo, 2005; Yanting, 2018). An organization can deploy its IT infrastructure in a cloud computing environment or within their own computer facilities. These components include hardware and software as well as networking and operating systems (OS), which are all used to provide IT services and solutions (Yanting, 2018).

ICT utilization is crucial in the support of project operations and the organizational ICT infrastructure supports the performance of ICT implementation from the project level to the organization level (Di, Xiaorong, & Sha, 2014; Hanafizadeh, Saghaei, & Hanafizadeh, 2009). Moreover, many construction companies have turned to ICT utilization to quickly respond to changes in the environment and owners' demands (Eliwa, Jelodar, Poshdar, & Yi, 2020; Hanafizadeh et al., 2009). The creation of new and innovative processes for the projects is one major way ICT can add value to the organization performance. Also, if there is a strong ICT infrastructure within an organization, IT can enhance coordination, communication, cooperation, and collaboration among team members (Losurdo, Dileo, Siergiejczyk, Krzykowska, & Krzykowski, 2017). Although there was some research that suggested a positive correlation between ICT implementation and organizational performance, few empirical types of research have concentrated on the alignment between the ICT organizational infrastructure and the ICT utilization (Di et al., 2014; Losurdo et al., 2017). These studies focus on the impact of IT infrastructure on projects and capital facilities or infrastructure performance (Hanafizadeh et al., 2009; Losurdo et al., 2017). To date, there are only limited studies on the adoption of ICT by construction organizations and fewer studies regarding the effects of strong alignment of the ICT infrastructures and ICT utilization on organization performance considering the old age of the early studies long advocated computer-integrated construction (Campbell, Kay, & Avison, 2005).

Based on the available literature, there is a lack of information and evidence about the business value of ICT utilization in the construction industry. This scarcity of evidence could be why ICT usage, especially for project processes, seems limited (Babaeian Jelodar & Shu, 2021; Campbell et al., 2005). Therefore, it is important to study how this ICT usage impacts project team–owner relationships, general organization outcomes, and the success of construction projects. However, ICT utilization alone is not the perfect solution with a utilization strategy. Accordingly, the ICT infrastructure alignment is crucial to the overall organization's performance (Di et al., 2014; Eliwa et al., 2018; Ezcan, Goulding, & Arif, 2020).

Accordingly, this study aims to explain the relationship between the utilization of ICT, organizational ICT infrastructure, and construction project performance. The first re-search question is: How does the availability of ICT infrastructure in the construction organization support and improve the utilization of ICT? This may be one of the factors in improving the outcomes of the construction project; therefore, the second question is: How can the alignment between the ICT infrastructure and ICT utilization affect project performance? The main objective of this study is to investigate whether the effect of ICT utilization on project performance may be moderated and affected by the ICT infrastructure level in the organization. This study highlights the importance of an organizational ICT infrastructure for enhancing its usage. It also indirectly provides guidelines to improve capital construction organization and project performance.

5.2 Background: Construction ICT Utilization

A significant number of studies have been conducted on ICT adoption in the construction industry and its relation to construction project performance (Hou, Wu, Zhang, Tan, & Wang, 2021;

McNamara & Sepasgozar, 2021; Moshood, Nawanir, Sorooshian, Mahmud, & Adeleke, 2020; Schönbeck, Löfsjögård, & Ansell, 2020). These studies generally cover the utilization of ICT and factors that influence its implementation as a part of the construction management process. It also discusses the expected benefits of using ICT in project management and construction (Hou et al., 2021; Moshood et al., 2020; Schönbeck et al., 2020; H. Wu, Shen, Lin, Li, & Li, 2021). Considering the type of ICT usage; (Rahimian, Seyedzadeh, Oliver, Rodriguez, & Dawood, 2020) examined the scope to which ICT, in general, is being used in the execution of construction industry projects. On the other hand, (Elghaish & Abrishami, 2020) investigated the potential of a specific ICT which is the 4D BIM technology as a productive tool in project management. (Sharma et al., 2020) provided a valuation model that measures the utility of Electronic Networking Technologies as a type of ICT in construction project activities progress. (Alsafouri & Ayer, 2018) also addressed the crucial issue of how to best utilize ICT in construction industry organizations. (Ozumba & Shakantu, 2018) conducted a detailed case study to examine the role ICT transfer plays in innovation in medium to small size construction organizations.

Other authors are also active in the identification of the factors that influence the adoption and use of ICT (Alsafouri & Ayer, 2018; Chipidza & Leidner, 2019; Hasan, Elmualim, Rameezdeen, Baroudi, & Marshall, 2018). (J. Li et al., 2020) looked at the relationship between the construction equipment ICT and construction management progress. They ended up with three factors that mainly determine the impact of equipment ICT benefits which are ICT implementation control, ICT implementation acceptance and the project condition (J. Li et al., 2020). (Daniotti, Gianinetto, & Della Torre, 2020) suggested that a lack of information about ICT and its benefits and an unclear competitive advantage may have caused the construction management team to resent adopting new technologies. IT practices can improve customer relationship management by increasing efficiency and gathering performance information for management (Daniotti et al., 2020). (Osunsanmi, Aigbavboa, Oke, & Liphadzi, 2020) concluded that the ICT adoption process is mainly linked to client relationship management. According to (Adafin et al., 2021), New Zealand's construction sector has increasingly utilised ICT in design and the project operational phase; resulting in creation of unstructured and discrete utilisation strategies. Conversely, the construction management and onsite construction execution phases had the lowest ICT utilization levels in New Zealand's construction industry. Moreover, in the New Zealand construction industry, ICT utilization was most widespread in the second phase (design phase), and less spread during the fourth phase (project management phase) (Adafin et al., 2021; Allen, 2021; Sooriyamudalige, Domingo, Shahzad, & Childerhouse, 2020).

Many studies believe that ICT can provide significant benefits and is a contributing factor to construction projects performance, but it depends on the implementation methods (Daniotti et al., 2020; Eliwa et al., 2018; Saka & Chan, 2020; Wang, Lu, Hu, Gao, & Pishdad-Bozorgi, 2020). However, there is limited research on the construction industry that studied the impact of ICT on the performance of the construction organization, and existing focus on the project as dissenting to organization performance (Liu et al., 2021). (Adriaanse et al., 2010; Hosseini et al., 2012; Ozumba & Shakantu, 2018) are just a few examples of such studies. On the other hand, (Hong, Hammad, Sepasgozar, & Akbarnezhad, 2019; Peansupap & Walker, 2005) are two other examples of studies that examined the current state of ICT use at the organization level. (J. R. Henderson & Ruikar, 2010) was the most comprehensive of these studies as they evaluated ICT's utilization on an organization specified projects using the organization data. (J. R. Henderson & Ruikar, 2010) used their evaluation to determine the impact of ICT usage on a project cost and schedule success within organisational processes and context. (Boton, Kubicki, & Halin, 2015) carried out a case study in order to show the feasibility of using technologies such as 4D BIM on a construction project considering the organization information. To identify potential problems, the research team examined the master critical path schedule method CPSM (Boton et al., 2015). The authors found that depending the research results on the CPSM alone from the 4D planning results. So, they concluded the potential problems on the performance of the 4D planning technology (Boton et al., 2015). (Afzal & Shafiq, 2021) claim that their case study demonstrates the value of 4D models for visualizing and understanding construction methodology, schedule sequencing, communicating special constraints to a project and formalizing design information. They also argue that 4D models can be used to anticipate safety hazards, project resources assignment and allocation, and construction relative machinery to the worksite as well as the constructability reviews (Afzal & Shafiq, 2021). (Alaloul et al., 2020) found that this visualization allows stakeholders of the construction projects to better understand the construction schedule than traditional construction management tools.

(Howard & Björk, 2008) assessed the ICT usage across design and construction organizations using the ICT-barometer structured survey from Finland construction industry. It was found that majority of organizations used computers mainly for administrative and management internal tasks like archiving; while fewer organizations use ICT tools to manage construction projects during the delivery phase or documents sharing and clouding usage (Howard & Björk, 2008). (Lu, Pishdad-Bozorgi, Wang, Xue, & Tan, 2019) conducted an empirical study analysis on construction industry cases and found similar results. They also reported widespread usage of basic ICT tools such as spreadsheets, accounting, word processing, and emailing. While a small number of organizations used advanced tools like 3D and 4D technology, Lu et. al. says that larger organizations are using more of the most recent ICT tools compared with the medium to small size organizations (Lu et al., 2019; Mesároš, Behúnová, Mandičák, Behún, & Krajníková, 2021).

Based on the above statements, these studies were focusing on the specific types of ICT mostly at a project level. They do not consider the benefits that can be derived from adopting a wider range of ICT considering the organizational ICT infrastructure, organization innovation implementation strategy, and the organization ICT utilization experience. This research addresses this gap by investigating the impact of wide-range ICT utilization and organizational infrastructure alignment on the construction industry; both at organization and project level.

5.3 Project Performance and ICT Infrastructure of Strategic Alignment

Strategic alignment is based on the idea that ICT must be aligned with the business or organizational strategy to create a competitive advantage, a better solution to utilize ICT and solve organization and projects issues (W. Li, Liu, Belitski, Ghobadian, & O'Regan, 2016). According to (Avison, Jones, Powell, & Wilson, 2004), the strategic alignment's core premise is that analyses using the traditional way have tended to focus on the extent to way that alignment process and the organization infrastructure firm’s strategy (which is stated as strategic fit) or the extent to way that ICT utilization supports the business approaches (which is stated as functional integration). (J. C. Henderson & Venkatraman, 1999) state that organizations must take into account both strategic fit and functional integration in order to maximize their competitive advantage. Therefore, the strategic alignment concept is built on two basic building blocks: functional integration and strategic fit and within each of these blocks there are the internal and external domains, Figure 5.1 (J. C. Henderson & Venkatraman, 1999; J. C. Henderson & Venkatraman, 1994).

The external domain of ICT strategy is concerned with the positioning of the organization in the ICT market availability in terms of the ICT scope of the organization itself, ICT implementation efficiency and organization ICT implementation decision making, and this domain can be identified as an ICT strategy (Wetering, Mikalef, & Pateli, 2017). Moreover, the internal domain is concerned with the configuration and management of the ICT infrastructure, including its processes, skills, and system structure, this domain can be identified as an ICT infrastructure domain (Burn & Szeto, 2000; W. Li et al., 2016).

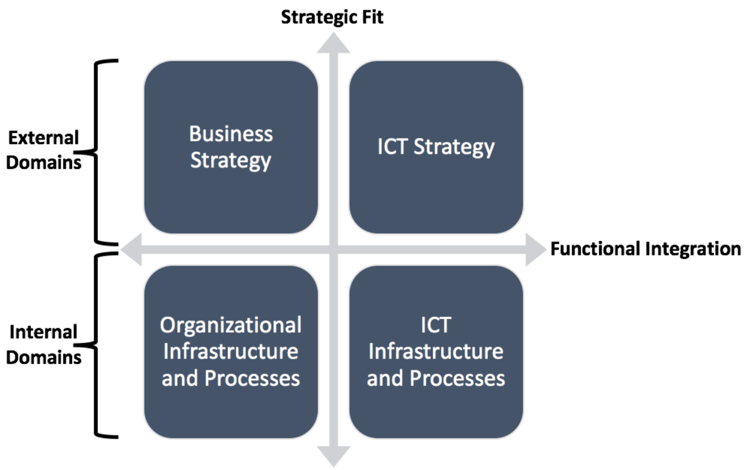

Figure 5.1: The strategic alignment model concept

In general, the strategic alignment term aims to integrate the ICT domains and the business domains at the strategic level which is based on the relationship between the organization ICT strategy and the organization business strategy. Also, at the operational level which is related to the level of the relationship between the ICT infrastructure and the infrastructure of the organization itself (J. C. Henderson & Venkatraman, 1999). To put the strategic alignment in place, we just need to consider one domain of these four domains which will be the driver of the alignment between the next two domains (Chi, Huang, & George, 2020). This perspective, which is the basis of our study, is the "Strategy Execution", where the business strategy drives both the organizational work process and ICT infrastructure (Chi et al., 2020; Eliwa et al., 2018).

(Isal, Pikarti, Hidayanto, & Putra, 2016) defined ICT infrastructure, as a part of the strategic alignment model, as any situation required for the implementation and utilization of various ICT by-products or services. Based on that, the term of ICT infrastructure can be the main factor that enables the organization to implement and establish effective ICT applications services (Bhattacharya, 2018). The ICT infrastructure component can be described into two parts, the first part is the hardware, which includes the tools, equipment and machinery that are essential to operate a specific type of ICT. The second part is the software or the operating system which provides the platform for operating the system hardware and includes all the applications and software that are necessary to run it (Beecroft, Osabuohien, Efobi, Olurinola, & Osabohien, 2020; Hinkelmann & Pasquini, 2014; Wetering et al., 2017). Moreover, human resources and policy issues are critical components in terms of ICT utilization, and this is why it is important to have an external supportive environment (Kurniawati, 2020).

The efforts of managing the organizational infrastructure are becoming more critical all over the globe and the form of system the required to effectively assess this management (Kurniawati, 2020; Nair, Pradhan, & Arvin, 2020). Considering project infrastructure as a child of the main organizational infrastructure, (S. P.-J. Wu, Straub, & Liang, 2015) has focused on the project infrastructure issues in terms of the evaluation of the organization performance. (S. P.-J. Wu et al., 2015) argue that the indicators of the project performance must be clearly defined as a part of the organization management and control strategy. (Kefi & Kalika, 2005) investigated the previous statement using an empirical study and highlighted the indicator system which has been used in the construction project key performance calculation. (Kefi & Kalika, 2005) noted that many of these indicators used in the case studies don't clearly describe the actual project performance as these indicators have been declined by the stakeholders as a system of the construction project performance measurements considering the conditions of the projects.

However, the organization management, project managers and project delivery teams have strongly believed in the importance of developing project performance metrics to help achieve project goals (Kurniawati, 2020; Nair et al., 2020). Considering that, construction management teams always want to be able to make informed decisions about the project performance indication, just like any other type of management (Wetering et al., 2017). Although there have been many studies on key performance frameworks for project measurements, there are not enough research studies to provide specific guidelines and there are no universally accepted principles for the performance measurements (Chi et al., 2020). The problem is exacerbated in the construction sector as there is limited studies on IT and ICT alignment models for construction organisations. Therefore, the current study focuses on alignment of ICT infrastructure for construction projects and respective organisations.

5.4 The Research Methodology:

The selection of appropriate research methodology for to satisfy the study objectives can depend on multiple factors such as: the shape and structure of the research questions which are the reasons for the research objectives, level of the researcher control on the data sources or the study condition, and the extent of the focus on historical rather than temporary events (Pandey & Pandey, 2021). Historical methods can be useful when the researcher does not control the data sources. Experiments are preferred if the researcher is directly, accurately, and systematically able to control the research behaviour (Noor, 2008; Pandey & Pandey, 2021). On the other hand, the use of the case study methodology is preferred if the research is about examining live or present events, but related behaviour of this event cannot be controlled or changed (Noor, 2008). In general, if our research questions are related to "why" and "how" and the researcher has limited control over the study cases, the case study methodology will be the best choice, which is the case in our research (Noor, 2008; Pandey & Pandey, 2021).

As described in the introduction section of this study, this research question was how the alignment between the ICT infrastructure and ICT utilization can influence performance. This case study method is widely used, especially in sociological examinations, and typically these studies are not sampling-based studies (Pandey & Pandey, 2021). However, it is important to select the right cases for the study in order to maximize the amount of information intake and learning within the limited timeframe of the study (Noor, 2008). In general, there are three case study methodology types: descriptive, exploratory, and explanatory (Pandey & Pandey, 2021). This research is using an exploratory in nature and based on the research question deals with an operational issues and events or links that require to be traced and examined. According to Snyder (2012) for the case study approach highlights the problems that are difficult to describe based only on the data collected empirically. However, it is possible to design a study based on the case study methodology in a specific framework so that both secondary data (organization and project-specific information) and primary data (ICT utilization and ICT infrastructure) are analysed (Pandey & Pandey, 2021; Snyder, 2012). To summarize the above statements, this study is developed and applied by a qualitative exploratory case study methodology which has been selected to gain a better investigation over the application of ICT infrastructure alignment system at the organization and project level (Pandey & Pandey, 2021; Snyder, 2012).

Considering all the above, the justification of the case study method for this research is based on three main points. The first point is that this methodology allows comparison between two or more empirical cases in multiple situations based on the study conditions, selecting specific results for this comparison (Snyder, 2012). The second point is that this methodology allows the collection of detailed data which support the study's discussion process towards a theoretical conclusion, which is our plan for this study (Johansson, 2007; Meyer, 2001; Snyder, 2012). Finally, this methodology allows the researcher to study the operational and strategic engagement of the study cases in a specific location or area (Snyder, 2012).

Accordingly, four construction projects within two different organizations in New Zealand were chosen. The selection of the cases and organizations were based on the following:

- The selected organizations have been considered from the top 10 major construction organizations in the infrastructure and building fields of New Zealand.

- Both organizations have declared ICT implementations strategies and have histories of ICT adoption. Moreover, both selected organizations have a department for ICT research and innovation.
- All four case study projects are considered large infrastructure or building projects in the Auckland area.
- All four case study projects have been completed and are currently at the operational phase. The final project data have been archived in the organization as the company's projects history.

A framework of multiple case study analysis has been developed and presented in Figure 5.2. The framework demonstrates the relationship between the organizations and project cases selected for this study in addition to the detailed level of exploration (Babaeian Jelodar & Shu, 2021).

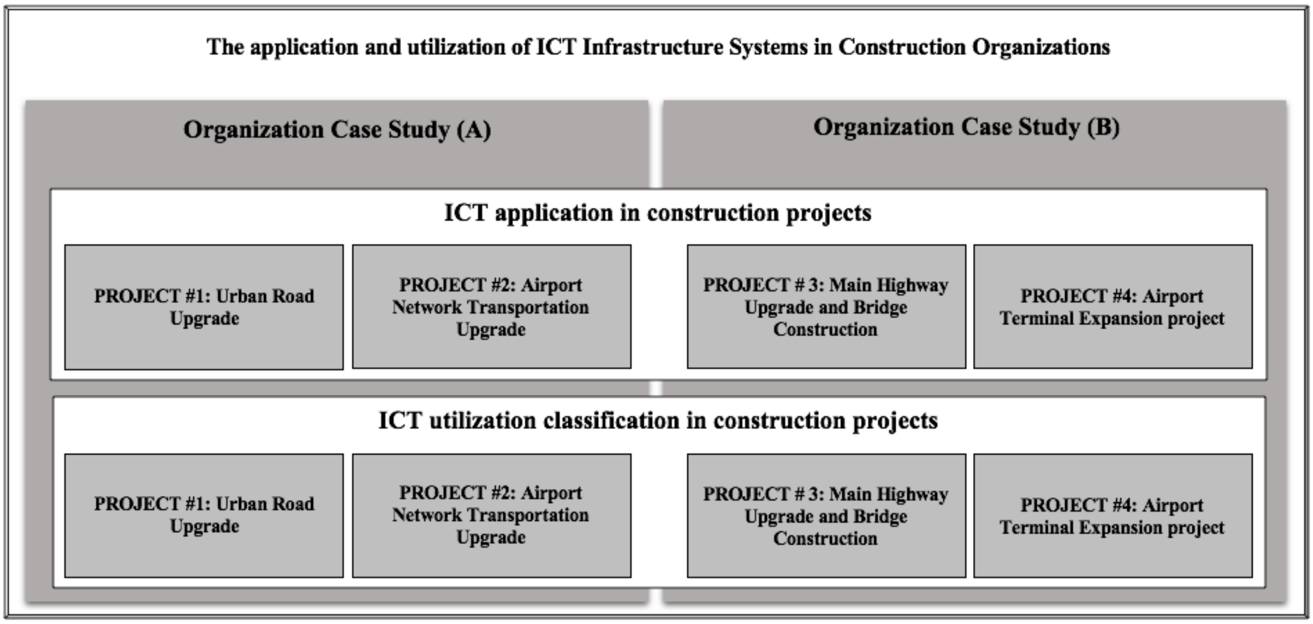

Figure 5.2: The case study methodology framework.

As mentioned above, all case study projects have been completed, which means the period of the investigations can be defined as the whole life cycle of the projects. The Auckland region, the major region in New Zealand, has been considered during the case studies' location selection. It covers most of the national construction demand (NCD) in New Zealand. Moreover, the governmental investment in construction in the Auckland region increased to $17 billion in 2021 compared with $12 billion in 2015, which is more than a 40% increase (The Ministry of Business, 2021).

5.5 Data Collection:

The ICT implementation and utilization journey in the selected case study projects were examined based on the research question and objectives. The ICT infrastructure and innovation ability in the organizations hosting the selected projects were extracted from the organizations' ICT strategic documentation and policies. Finally, project progress history and performance records evaluated each project's outcomes and performance. It included examining the as-built documents, such as the as-built schedule compared with the baseline schedule of the project life cycle. Initially, an overview description of each organization and project selected for case studies is provided in this section. This is followed by a detailed evaluation of ICT utilization and ICT infrastructure data as well as the projects' performance data.

5.5.1 Organization Case Study (A):

The first selected organization for this study was one of the largest construction companies in New Zealand. It can be considered the largest construction services provider in New Zealand. They have been providing and delivering construction and engineering services in New Zealand, and especially to the Public Works Department, for decades. The organization has over 10,000 employees working in 120 locations in New Zealand and over 60,000 employees globally. Organization A has three main construction sectors: transportation or infrastructure (the main and biggest sector), utility service provision, and facilities management. The operating income for this organization in New Zealand has been estimated at over NZD 13 billion (The Ministry of Business, 2021).

5.5.2 ***Organization Case Study (B):***

The second case study organization in this research started in New Zealand in 1909, using a different name with their first project, a two-story wooden villa in Otago. The company has a strong history in New Zealand with their special and landmark project. In 1940, this organization's current name was born, and it was listed on the share market. The organization has over 4000 employees working in various locations around New Zealand, and it has international branches. During their history, this organization has completed over 90 major infrastructure and building projects, in addition to small- and medium-sized projects, all over New Zealand. Moreover, it has been identified as the first overseas organization working on the modernization and development of the South Pacific. It has permanent locations in Samoa, Tonga, Fiji, Vanuatu, New Guinea, and the Solomon Islands (Goldsmith, 2009; Smith, 2009; The Ministry of Business, 2021).

5.5.3 ***Project Case Study (1):***

The first project case study in this research is a project completed by organization A, the "Urban Road Upgrade" project. The project is a 9 km long infrastructure upgrade to improve the highway, including construction of bridges in Auckland (Figure 5.3). The project's total cost is over NZD 130 million. The final project duration up to the operational phase was 43 months, from June 2016 to December 2019. The main project scope was the widening works on the main motorway, including constructing additional bridge lanes, replacing the over-bridges, stormwater upgrade, and modification and upgrading of the cycleway (NZTA, 2016b, 2019).

Figure 5.3: Urban Road Upgrade project plan (NZTA, 2019)

5.5.4 ***Project Case Study (2)***

The second project case study by organization A is “Airport Network Transportation Upgrade”. This project is focused on upgrading the airport core road networks, including the main highway and new roads (Figure 5.4). The total cost of the project is over NZD 100 million, and the main purpose is to increase the road capacity leading to the biggest airport in New Zealand to over 200,000 vehicles a day. The main project scope was to widen the main motorway to the airport, decrease the pressure on the motorway by building new roads, upgrade the shared pathway, and upgrade the utilities and the stormwater lines. The total project duration up to the operational phase was about 26 months, from August 2019 to September 2021 (AIAL, 2021; Stuff, 2019).

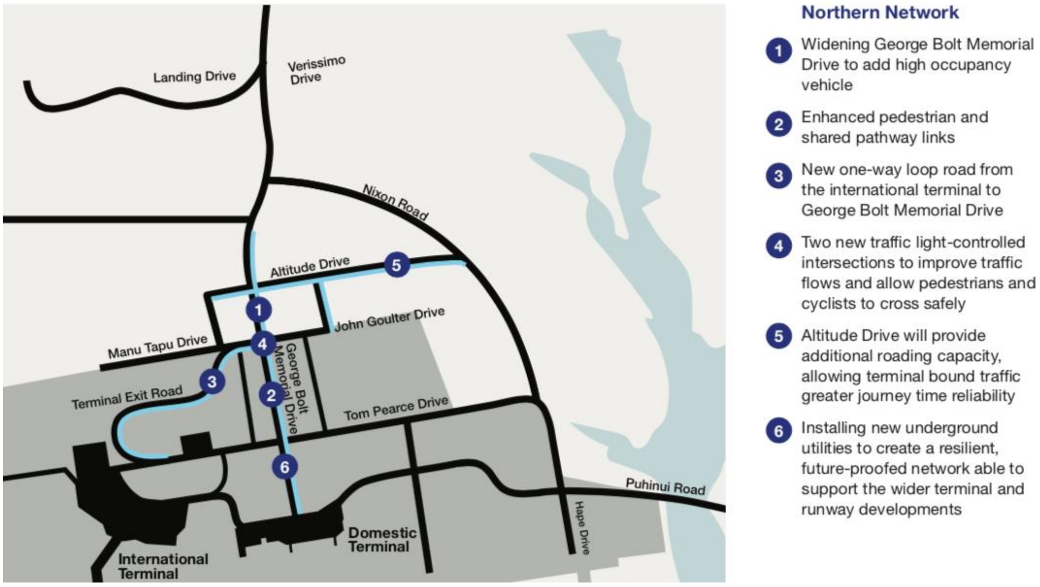

Figure 5.4: Airport Network Transportation Upgrade project (AIAL, 2021)

5.5.5 ***Project Case Study (3)***

The third project case study considered in this research is the "Main Highway Up-grade and Bridge Construction Project" by an alliance. A group of companies came together with the project client to deliver the project, sharing the project's profits and risks under the main contractor's management. Organization B was responsible for delivering the project extension from the south, related to the main tunnel construction, and from the north, related to the connection to the first project case study in this research, "Urban Road Upgrade". Organization B was also a supporter of the alliance in terms of providing IT infrastructure, provisional management consultation, and project coordination. The main project scope was to widen the main 5 km long motorway and construct two bridges and a cycleway (Figure 5.5). The total project cost was over NZD 220 million, and the total project duration was 36 months, from November 2013 to December 2016 (NZTA, 2013, 2016a).

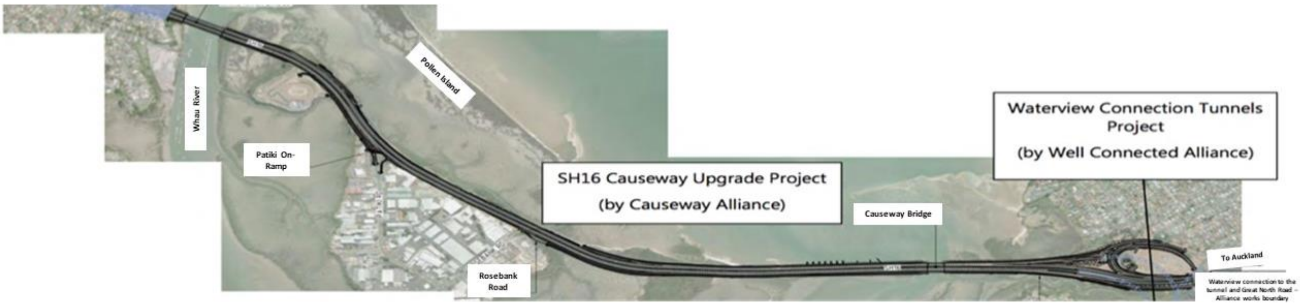

Figure 5.5: Main Highway Upgrade and Bridge Construction Project master plan (NZTA, 2016)

5.5.6 ***Project Case Study (4)***

The final case study in this research is the "Airport Terminal Expansion Project". Organization B was involved in this project, the biggest stage of the airport multistage development projects. It was focused on upgrading and developing the airport's international terminal building. The main project scope was constructing a new traveller pro-cessing hall, expanding the traveller lounge zone, reconfiguring the farewell zone, constructing a new security screening area, and major upgrading on the duty-free shopping spaces (Figure 5.6). The total project cost was NZD 220 million, and 32 months was the total duration of the project, from March 2016 to October 2018 (AIAL, 2020).

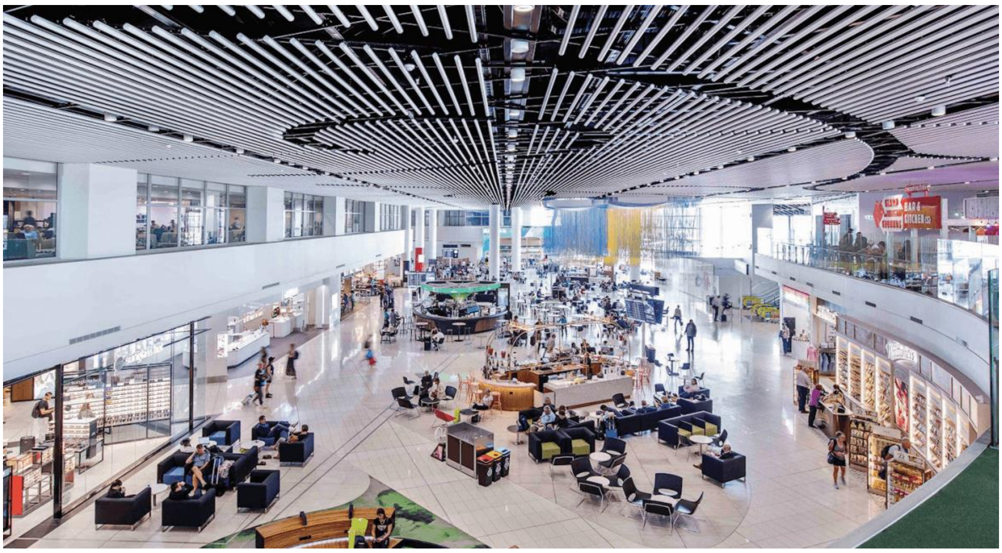

Figure 5.6: Airport Terminal Expansion Project - architectural elevation view (AIAL, 2020)

5.5.7 ***Data collection of the project's performances:***

As mentioned above, the performance data for each case study project have been collected from the internal project history document, including but not limited to the as-built project schedule, monthly project reports, and organization performance report. Then, the final performance data for each case study have been grouped, arranged, and summarized, as shown in Table 5.1.

Table 5.1: Projects case studies performance table.

Project Name	Actual Start Date	Actual Completion Date	Baseline Finish Date	Actual Duration	Baseline Duration	Variance Duration	Non-Compensable Delay	Compensable Delay	Percentage of Non-Compensable Delay from the Total Duration	Wet Weather Risk Counted	Reasons of Compensable Delays
Project 1: Urban Road Upgrade	06 June 2016	13 December 2019	31 May 2018	881	496	−385	−287	−98	33%	Yes	4 months approved time-cost variation due to change part of the retaining walls design
Project 2: Airport Network Transportation Upgrade	12 August 2019	24 September 2021	25 February 2021	531	386	−145	0	−145	0%	Yes	The first reason was due to the COVID-19 lockdown in 2020, and then the Airport reduced the scope of works for this project due to financial issues due to the lockdown. After that, the airport started to return the original scope back by stages
Project 3: Main Highway Upgrade and Bridge Construction	04 November 2013	15 December 2016	29 February 2016	779	580	−199	−51	−148	7%	Yes	Timber piles redesign requirement related to ground improvement requirement. Also, some of client change requests
Project 4: Airport Terminal Expansion project	07 March 2016	31 October 2018	16 February 2018	663	487	−176	−48	−128	8%	Not required	The client approved some variations due to design delay and damaged materials due to rainwater leaking through the under-construction roof. Also, some additional architectural features requirements by the client

From Table 5.1, the total duration, baseline duration, and delays have been calculated using working days timescale, considering the local approved working calendars. Compensable delay is the delay that the client has accepted as not being the contractor's responsibility, such as the client's change in scope or design change. Moreover, the compensable delays only included the client's approved time and cost variation. The non-compensable delays are any internal delays, such as production rate, poor management, change in the project management, material procurement, or subcontractor issues. The inclement weather contingency was also considered and calculated in the project's schedule for every external infrastructure project, including most of the earthworks, structures, and pavement works, through a special wet weather calendar assignment or as a risk on the construction activity. Considering the wet weather calculation in the schedule will decrease the project delay risk due to heavy raining days.

5.5.8 ICT Utilization and Organizational ICT Infrastructure:

As mentioned in the previous sections, the ICT infrastructure information has been exported from the organizations' internal documentation, especially from the innovation department in each organization. Table 5.2 summarizes the collected data regarding the level of ICT infrastructure from each of the organization case studies. From the table, the ICT infrastructure system has been classified. This classification considers the most critical factors that can affect the organizational ICT infrastructure level (Beecroft et al., 2020; Burn & Szeto, 2000; Bygstad & Aanby, 2010; Di et al., 2014; Kurniawati, 2020), and the following classes have been derived:

- IC01: Data centre infrastructure/hardware (including servers; storage subsystems; networking devices, such as switches, routers, and physical cabling; and dedicated network appliances, such as network firewalls)
- IC02: Internet infrastructure including fibre optic
- IC03: Cloud-based infrastructure
- IC04: Training systems
- IC05: ICT support systems
- IC06: Software upgrading systems

The rating system in Table 5.2 (High, Medium, and Low) has been developed to evaluate the level of application for each of the above-mentioned classes within the organization. Based on the rating system, if the organization is using the specific ICT class in all of its projects, the rating is considered as "High" for that specific class. If the organization is applying a specific class to more than 50% of its projects, the rating in this case has been considered as “Medium”. Finally, if the application of a specific class by the organization in less than 20% of the organization’s projects, the rating has been considered as “Low” in this case.

Table 5.2: The organizational ICT infrastructure availability for each case study

	Organization Size	Organization Type	Construction Services Type	Experience Level in the Field	Available ICT Infrastructure System in the Organization			Project Case Study per Organization
Organisation A	Large > 10,000 employees	Private / Contractor	Civil & Infrastructure	88 years' experience in the construction industry in New Zealand	IC01	High	All applied	Project1: Urban Road Upgrade Project 2: Airport Network Transportation Upgrade
					IC02	High	All applied	
					IC03	High	Applied and setup in all projects	
					IC04	Low	Technical training only and limited number of ICT training for limited number of Staff categories	
					IC05	Low	Very basic support system / support system for all ICT is outsourcing	
					IC06	Low	Very hard to get ICT software updated with a complicated approval process before getting it updated – Cost and budgeted issue	
Organisation B	Large > 4000 employees	Private / Contractor	Building Civil & Infrastructure Commercial Airport	112 years' experience in the construction industry	IC01	High	All applied	Project 3: Main Highway Upgrade and Bridge Construction Project Project 4: Airport Terminal Expansion project
					IC02	High	All applied	
					IC03	Mid	Applied in most of the projects	
					IC04	Mid	Technical training and ICT training available for popular systems and can be provided for special systems in request	
					IC05	Low	Very basic support system / support system for all ICT is outsourcing	
					IC06	High	The company policy urges the ICT support to provide the up to date version of all ICT tools available with a regular check every 6 months	

Table 5.3 presents the ICT utilization and implementation for each case study. The ICT applications have been grouped into five main ICT application classifications, which can classify most of the ICT products in the construction industry as the following (Adriaanse et al., 2010; Alsafouri & Ayer, 2018; Chipidza & Leidner, 2019; Ezcan et al., 2020; Hosseini et al., 2012):

- Sharing tools, cloud storage, and web conferencing: this collection includes the communication technology tools which facilitate the organization or project communication and information sharing system.

- Job-site data collection and reporting: this collection covers the most common usage of software or tools in any project size, which involves the daily reporting support tools and can be used by non-professional construction teams.
- Computer-aided drafting (CAD): CAD systems provide drawing entities with powerful construction, editing, and database techniques to produce drawings and models of what buildings will look like when finished.
- Planning and project management: this collection covers software or tools that allow the managing of complicated business processes by planning, organizing, and managing the various resource pools available.
- Building information modeling (BIM): BIM software can directly and interactively present design concepts in a form that represents physical and real images of the building to allow designers to identify clients' needs and provide solutions to these needs promptly and effectively.

Table 5.3: List of ICT applications and categories implemented in each project case study

Project Name	List of By-Products Used in This Project	List of Application Categories Used in this Project
Project1: Urban Road Upgrade	Dropbox, Adobe Acrobat, Aconex Microsoft Office Package, NoteVault AutoCad, Navisworks, Tekla Primavera, Microsoft Project, Syncro 4D Planning Deltek Vision	Cloud Storage, Sharing, and Web Conferencing Job Site Data Collection & Reporting BIM and CAD Planning and Project Management Accounting
Project 2: Airport Network Transportation Upgrade	Adobe Acrobat, Aconex Microsoft Office Package AutoCad Primavera, Microsoft Project, Deltek Acumen Deltek Vision	Cloud Storage, Sharing, and Web Conferencing Job Site Data Collection & Reporting BIM and CAD Planning and Project Management Accounting
Project 3: Main Highway Upgrade and Bridge Construction Project	Adobe Acrobat, StoneX Microsoft Office Package AutoCad Primavera, Microsoft Project, Deltek Acumen Planswift, Trimble Accubid CMiC	Cloud Storage, Sharing, and Web Conferencing Job Site Data Collection & Reporting BIM and CAD Planning and Project Management Estimating and Take-off Software Accounting
Project 4: Airport Terminal Expansion project	Adobe Acrobat, Aconex Microsoft Office Package AutoCad, Navisworks Primavera, Microsoft Project, Syncro 4D Planning, Deltek Acumen Planswift, Trimble Accubid CMiC, Jonas Software CYPE INGENIEROS	Cloud Storage, Sharing, and Web Conferencing Job Site Data Collection & Reporting BIM and CAD Planning and Project Management Estimating and Take-off Software Accounting Building Engineering Application

5.6 Discussion:

By analysing the data collected in the previous sections and empirically assessing project performance of the case studies, it is observed that the "Airport Network Transportation Upgrade" (Project 2) had the best performance. For this project, the full delay period has been compensated, and according to the client, none of the delay reasons are the contractor's issue. However, according to Table 5.3, this project has utilized fewer categories of ICT.

Accordingly, the "Main Highway Upgrade and Bridge Construction" (project 3) has been identified as having the lowest project performance compared with the other cases in this study. Moreover, this case had the same structure of ICT utilization compared with project 2, "Airport Network Transportation Upgrade", which is also the lowest compared with the other cases in this study. A numerical illustration of the combined case studies' information has been created and presented in a bubble chart format (Figure 5.7).

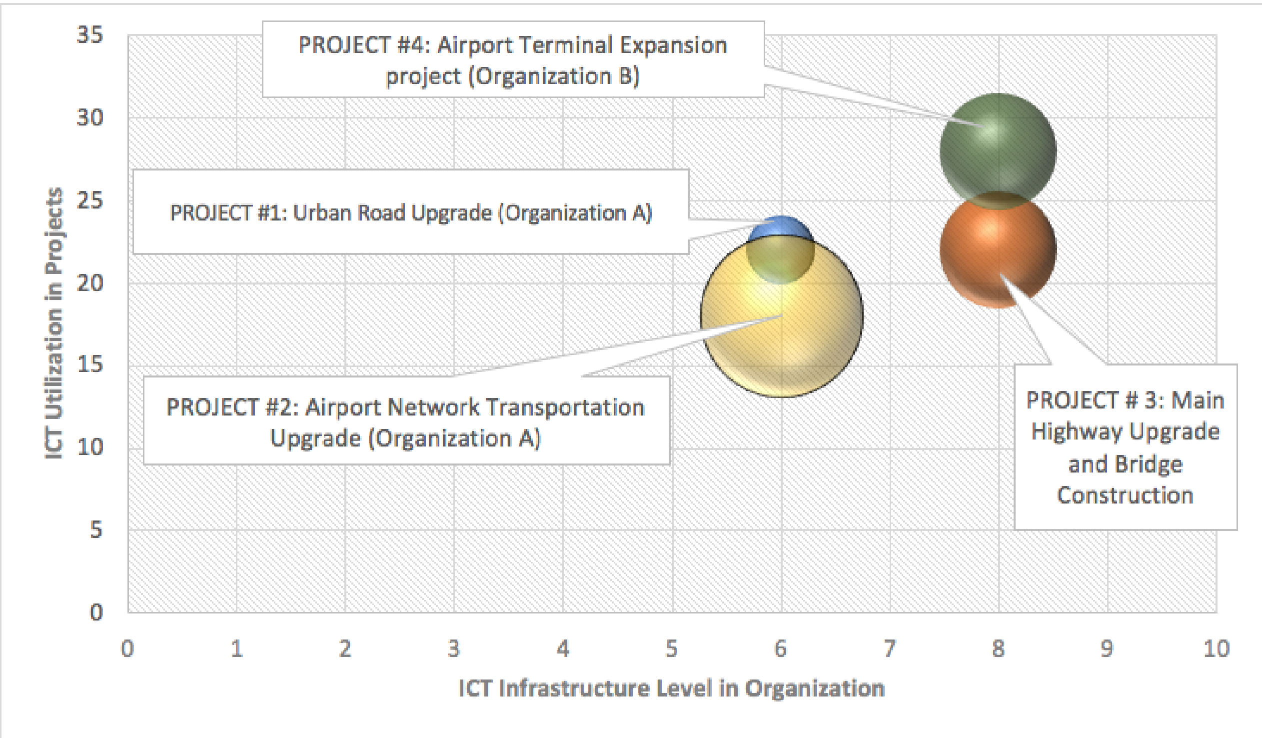

Figure 5.7: ICT infrastructure, ICT utilization, and project performance relationships

This was to understand the alignment level between the ICT infrastructure for each project and the corresponding organizations, the ICT utilization in the projects, and the final project performance. It was done by considering the ICT infrastructure level in each organization, the ICT level of utilization in each project, and the final project performance and outcomes.

Although the data collected from the case studies were in various forms and have been analysed separately, the numerical conversion of this data was also very insightful. This is especially the case if the range of collected data is wide, and these data need to be studied together for a single result (Johansson, 2007; Meyer, 2001; Noor, 2008; Pandey & Pandey, 2021). Hence, a scale was developed for ICT infrastructure classification from each organization and used in generating the bubble chart in Figure 5.7. Two points were assigned if the ICT infrastructure level in the organization is high, one point if this level is in the medium stage, and no points if the classification is low or does not exist; then, the total number of these points have been calculated from each organization and added to each project's case study depending on its organization.

The same concept has been applied to the ICT utilization in projects (Figure 7) to calculate the level of ICT implementation. However, both ICT categories and ICT products have been considered during the calculation process. Therefore, each ICT category implemented in the project will have three points, in addition to one more point for each additional ICT product in this category. Finally, the project performance value has been indicated with volume-based bubbles. The bubble that is largest in volume refers to the project highest in performance compared with the other case study projects.

Based on Figure 5.7, two cases in the study, project 4 (Airport Terminal Expansion Project) and project 3 (Main Highway Upgrade and Bridge Construction), have an acceptable alignment between their organization ICT infrastructure and the project ICT utilization, and at the same time, they have achieved an acceptable performance result. On the other hand, one of the cases in the study, project 2 (Airport Network Transportation Upgrade), has better performance outcomes than the previous cases in the study. However, it has been delivered using less alignment of ICT infrastructure and ICT utilization. By studying in detail, the project conditions of these three cases based on the projects' history data, project 2 was delivered with 145 working days of delay. However, all the delay has been accepted by the client as a "compensable delay" due to the COVID-19 lockdown (the first lockdown period in New Zealand was from 25 March 2020 to 28 April 2020), which was only about 21 working days, and also due to an extension of the total work period re-quested by the client to redeliver the decreased scope of the project (the scope was de-creased due to COVID-19's financial effect on the airport projects).

Looking at this project condition from the contractor's point of view, the project team received an extension of time exceeding the previous work period to deliver both the original scope and reduced scope of works compared with the tender phase's approved construction duration. Based on this, we cannot consider the non-compensable delays in this particular project as constituting a good project performance. The construction work productivity was not the main reason for these positive non-compensable delay outcomes. Conversely, the other two cases with good performance outcomes, project 4 (Airport Terminal Expansion Project) and project 3 (Main Highway Upgrade and Bridge Construction), had all the compensable delays purely as a result of a client design issue, work change request, additional works request, or client delay in response to a request for information.

Based on the findings, the good level of the strategic alignment between the organization's ICT infrastructure and the project's ICT utilization, as well as the level of the ICT implementation, could be one of the important factors that can facilitate project delivery and improve the project outcomes. However, as stated above, the performance of the project depends on many other factors, such as construction teams' experience, resource availability, subcontracting management, changes in management, project management level, project type, working conditions, and material availability. It cannot be assumed that the ICT strategic alignment level is the main reason for the high-performance or low-performance results. For instance, although the ICT utilization in project 3 (Main Highway Upgrade and Bridge Construction) is higher than in project 2 (Airport Network Transportation Upgrade), there was a huge non-compensable delay outcome in the construction phase of this project. By studying this project in detail, it has been found that de-lays were caused by issues such as a change in the organization structure or organization transfer, as the project was initially awarded to another organization and then reassigned. Moreover, the results from this study can be a reference for organizations' human resource management, considering more ICT positions in the project supporting the projects' de-livery team. Accordingly, the application of decision support systems is on the rise within the construction sector. These systems rely heavily on ICT application and require specialized trained personnel (Jelodar et al., 2014).

Consequently, more empirical research is required on the alignment of organization ICT infrastructure and project ICT utilization, and their effects on construction performance. Finally, this research can analyze the effect of efficient ICT utilization on project performance in the construction industry, which leads to optimal strategic utilization. Construction organizations can use these empirical study results to deliver their products more efficiently, cheaper, and faster, and maintain stakeholders' satisfaction.

5.7 Conclusion

In this research, case studies have been diagnostically analysed to investigate the effect of the strategic alignment between the organization's ICT infrastructure and the project's ICT utilization on the project performance. Four project cases have been selected in two large-sized organizations in Auckland, New Zealand, and historical data related to the project performance, project ICT implementation, and ICT infrastructure level from each organization have been collected. Thus, all the collected data have been organized into a bubble analysis histogram to compare and investigate the results related to the ICT and to the performance outcomes.

The findings have been analysed and presented based on a multiple case study framework, which included review of project records and historical data. The strategic alignment between ICT infrastructure and ICT utilization can be one of the factors that can improve the final project performance, considering the best-case scenario in terms of the project conditions. Moreover, it has been recommended that more empirical research in the same field of study is required to obtain more accurate results answering the main re-search questions of this study.

In terms of the practical implications of this study, this research can be used to analyse the effect of efficient ICT utilization on project performance in the construction industry, which leads to optimal strategic utilization. Based on the approaches discussed, construction organizations can enhance strategic alignments between organizational infra-structure and actual ICT utilization. This enables organizations to better understand the functions of ICT tools and infrastructure in enhancing project performance. Conversely, the feedback from the case studies allows for the identification of less effective ICT infra-structure and can cater for more objective and project-based outcomes.

In addition, the issues of strategic ICT alignment have been investigated in construction for the first time. This adds to the body of knowledge on new technology applications and utilizations in construction. A method of evaluating and identifying ICT utilization and infrastructure has been proposed. This can be further explored in construction re-search using different research methodologies or the application of expansive empirical studies with different settings and study conditions.

For future research and education recommendations, an in-depth exploration of how ICT alignment with organization infrastructure can improve the outcomes of a project would be very helpful. Further research might compare, for instance, traditional management projects with modern or ICT-based management projects. Moreover, additional methodological work is needed on how ICT alignment with organizational infrastructure can impact the outcomes of projects. Other methodologies could include structured interviews or focus group gatherings with construction management experts. Although methodologically challenging, it would be very useful to conduct some longer-term studies, seeking to quantify the impact of ICT implementation on different types of construction projects and organizations at different size levels.

Finally, considering the research method, the scope of this study is limited to advanced large construction projects managed by large-sized construction organizations within New Zealand. The selection of the study cases in this research was based on organizations with ICT usage history and ability to provide strong ICT infrastructure.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.	
Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 6
What percentage of the manuscript/published work was contributed by the student?	90
Describe the contribution that the student has made to the manuscript/published work: Lead author, conducted study and wrote the text	
Please select one of the following three options:	
◯	**The manuscript/published work is published or in press** Please provide the full reference of the research output:
◉	**The manuscript is currently under review for publication** Please provide the name of the journal: Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. Organizational Infrastructure and Information and Communication Technology (ICT) Infrastructure Alignment in Construction Organizations. Submitted to ASCE - Journal of Construction Engineering and Management
◯	**It is intended that the manuscript will be published, but it has not yet been submitted to a journal**
Student's signature: [signature]	Main supervisor's signature: [signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

Chapter 6: The impact of functional integration on the construction organisations performance

The current chapter is based on the following article:

Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. Organizational Infrastructure and Information and Communication Technology (ICT) Infrastructure Alignment in Construction Organizations.

Submitted to ASCE - Journal of Construction Engineering and Management

6.1 Introduction

In terms of investment, the construction industry is often regarded as one of the world's most important contributors to economic growth (A. Adriaanse & Voordijk, 2005; Rimmimgton, Dickens, & Pasqire, 2015). There are significant obstacles and hurdles in this industry, such as poor performance and frequent building delays, as well as quality concerns and overruns in costs (Adwan & Al-Soufi, 2016; Babaeian Jelodar & Shu, 2021; Rimmimgton et al., 2015). As a result, the key difficulty businesses have in meeting customer expectations is identifying ways to enhance construction project performance and increase the efficiency of project management expertise (Adwan & Al-Soufi, 2016; Alsafouri & Ayer, 2018). Using new technologies and effective ICT applications in building projects is one of these solutions (A. Adriaanse & Voordijk, 2005; Adwan & Al-Soufi, 2016).

Any technology used to gather, transfer, retrieve, store, access, display, or alter information is considered an ICT (Redwood, Thelning, Elmualim, & Pullen, 2017; Rimmimgton et al., 2015;

Zavvari, Sutrisna, & Jelodar, 2022). The application of software and computer hardware, as well as other aspects of ICT, is another way to describe the term (Kasim, 2011). ICT infrastructure, on the other hand, may be described as the components required to manage and operate corporate ICT environments (Alsafouri & Ayer, 2018; Jacobsson & Linderoth, 2010). An enterprise may install its ICT infrastructure in computer facilities or in a cloud computing environment (Turk, 2021). ICT services and solutions rely on a wide range of components, including hardware, software, networking, and operating systems (OS) (Peansupap & Walker, 2006).

ICT may significantly improve an organization's performance by enabling the development of new and creative methods for projects (A. M. Adriaanse et al., 2004). In addition, application of ICT improves collaboration, cooperation, communication, and coordination among team members if a business has a robust ICT infrastructure (H. K. Eliwa et al., 2022). Research has shown a favourable association between ICT and organizational performance, but the alignment between the ICT organizational infrastructure and ICT consumption has received little empirical attention (Brewer et al., 2005). There has only been little research on construction companies' use of ICT, and even fewer studies have looked at the impact of closely aligning ICT infrastructures and ICT use on the efficiency of construction firms (J. R. Henderson & Ruikar, 2010). Since computer integration has been promoted in building literature for a reasonably long time, this is not surprising (A. Adriaanse & Voordijk, 2005; A. M. Adriaanse et al., 2004; Redwood et al., 2017; Turk, 2021).

The lack of knowledge and proof concerning ICT's commercial value in the construction sector is based on literature accessible to us. This lack of evidence may explain why ICT use seems restricted, particularly in project management (Hasan, Ahn, Rameezdeen, & Baroudi, 2019). Accordingly, this research aims to evaluate the impact of functional integration of the internal domains in the strategic alignment model, which relates to the alignment between the ICT infrastructure and the organizational infrastructure on the construction organizations' performance and outcomes.

6.2 Background: Construction ICT Utilization

Much research has been undertaken in the construction business on how ICT adoption affects project performance (Fischer & Kunz, 2004; FLANAGAN & MARSH, 2000; Poshdar, González, Raftery, & Orozco, 2014). These studies often focus on the use of ICT in the construction management process and the variables that impact its adoption (FLANAGAN & MARSH, 2000). The use of ICT in construction and project management is also discussed (Fischer & Kunz, 2004). (Amusan Lekan et al., 2018) investigated the degree to which ICT is generally employed in the execution of building projects, considering the kind of ICT use. Regarding project management in particular, (Park & Park, 2020) examined specific ICT potential as an effective tool. E-networking technologies, a form of ICT, were evaluated by (Somu, MR, & Ramamritham, 2020) to determine their value in the advancement of building project operations. It was also addressed by (Oraee et al., 2019), who looked at how construction firms may make better use of information and communications technology. To find out how ICT transfer affects innovation in medium- to small-sized construction firms, (AboAbdo, Aldhoiena, & Al-Amrib, 2019) conducted research.

The increasing use of ICT by New Zealand's construction industry has led to unstructured and discontinuous ICT use techniques (H. Eliwa et al., 2018b). On the other hand, construction management and on-site construction execution used the least amount of ICT in New Zealand (H. Eliwa et al., 2018b). ICT use was most prevalent in the second phase (design phase) in the New Zealand construction sector and less prevalent in the fourth phase (project management phase) (Chowdhury, Adafin, & Wilkinson, 2019; Wilkinson, 2001). In general, research on the influence of information and communications technology on the construction performance of organizations is few, and much of the current research focuses on project performance rather than organization performance (M. El-Mashaleh et al., 2006; FLANAGAN & MARSH, 2000; Moon, Kim, & Kwon, 2007). One example is the research done by (Whyte, Bouchlaghem, & Thorpe, 2002) and (Y. Chen, Yin, Browne, & Li, 2019) that looked at the present situation of ICT usage at the organizational level. They used data from the organization to assess how ICT was used on certain projects (Y. Chen et al., 2019; Whyte et al., 2002). As a case study, (Chang, Yu, & Cheng, 2017) looked at how 4D BIM may be used in a building project while considering the organization's data. The study team investigated the master critical path scheduling method (CPSM) to discover possible issues (Chang et al., 2017).

Fewer businesses, on the other hand, use ICT technologies to oversee the execution of building projects, share documents, and utilize the cloud. Empirical research by (Bello et al., 2021) on construction sector examples also came up with similar outcomes. Basic ICT applications, including spreadsheets, bookkeeping, word processing, and emailing, were also widely used, according to the study's findings (Bello et al., 2021). On the other hand, (Besklubova, Skibniewski, & Zhang, 2021) found that big firms were more likely to adopt the most modern ICT technologies, such as 3D and 4D printing, than smaller organizations.

These studies focused on a specific ICT category at a project level. Moreover, these studies have not considered the importance of utilizing a wider range of ICT considering the alignment of the ICT infrastructure and organizational infrastructure and the organization's ICT utilization experience. Therefore, this study addresses this gap by investigating the impact of the alignment between the ICT infrastructure and the organizational infrastructure on the construction organizations' performance on a wider range of ICT utilization.

6.3 The Strategic Alignment: Functional Integration

Traditional company strategy development processes have failed to fully harness information and communication technology (ICT) (Amusan Lekan et al., 2018; Dallasega et al., 2020; Peansupap & Walker, 2006). As a result, ICT was often regarded as a cost centre or an expense rather than a source of company value (Peansupap & Walker, 2006). Strategic alignment throws fresh light on ICT and its significance in formulating company strategies by considering the right balance between strategy and infrastructure and the functional integration of business and ICT (Coleman & Papp, 2006). Strategic alignment covers strategy and infrastructure challenges to establish alignment among these four areas by concentrating on business and ICT (Coleman & Papp, 2006). The correct utilization of ICT in integrating and developing company strategies and corporate goals is referred to as strategic alignment (H. K. Eliwa et al., 2022). It is still one of the top concerns of company leaders, and its significance has been extensively recognized and recorded since the late 1980s (J. C. Henderson & Venkatraman, 1999).

The Strategic Alignment Model (SAM) is a methodology for successfully implementing business, technology, and infrastructure. It recognizes that the convergence of business strategy, IT strategy, organizational infrastructure and processes, and ICT infrastructure and procedures are required for business success (Hua, 2007). SAM is divided into four domains: business strategy, information technology strategy, organizational infrastructure and processes, and information technology infrastructure and operations, as presented in Figure 1 (J. C. Henderson & Venkatraman, 1999). Each has its fundamental components: scope, competencies, and governance on the outside, and infrastructure, skills, and processes on the inside. It has been constantly refined since its inception (J. C. Henderson & Venkatraman, 1999). The SAM model may kick off the business alignment and IT methodologies (J. C. Henderson & Venkatraman, 1999). While useful in understanding the components that create alignment, this model does not give a method or directions for achieving alignment (Hua, 2007).

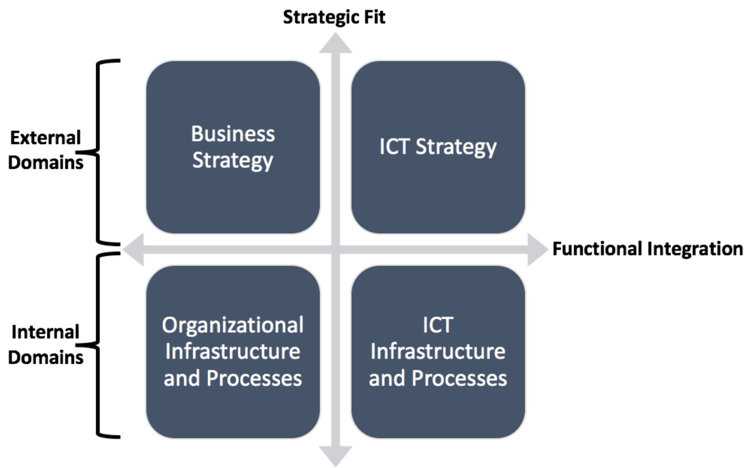

Figure 6.1: The strategic alignment model concept (H. K. Eliwa et al., 2022)

The approach is defined by two essential strategic management attributes: strategic fit (the interaction between external and internal domains) and functional integration (the integration of business and technological domains) (J. C. Henderson & Venkatraman, 1999). In addition, (J. C. Henderson & Venkatraman, 1999) includes cross-domain viewpoints, stating that neither strategic nor operational integration is necessary to align an organization properly.

Based on Figure 6.1, the initial connection in the SAM is the strategic fit which presents the model's vertical linkage (J. C. Henderson & Venkatraman, 1999). This connection explains the need for the company to make decisions that will determine its market position (J. C. Henderson & Venkatraman, 1999). Functional integration is the second connection. It offers the most direct relationship between information technology and business alignment (J. C. Henderson & Venkatraman, 1999; Papp, 2001). This relationship indicates the company's capacity to successfully situate itself in the marketplace via ICT (Papp, 2001; Y.-Y. Chen & Huang, 2010). The fundamental focus of the strategic alignment approach is the connectivity or "fit" between these functional areas. ICT alignment happens when all domains achieve the right level of standardization at the same time, according to this fit strategy (Y.-Y. Chen & Huang, 2010). True strategic alignment necessitates "constant and simultaneous attention to all four areas." This connection can provide a competitive edge and optimize the impact of information technology (Hua, 2007).

The infrastructure of ICT strategy, like the infrastructure of ICT and organization, consists of three major components (H. K. Eliwa et al., 2022). The first component is the ICT architecture, which includes: Computing (which is the data processing equipment and its corresponding operating system software); Communication (which is the telecommunications channels and their associated mechanisms for interlinking and interworking); Data (which would be the organization's data resources and the provisions for use, access, control, and storage); and Applications (which would be the main application). The second section is Processes, which deals with the work processes that are fundamental to the functioning of ICT strategic infrastructures, such as systems development, maintenance, and monitoring and control systems. Lastly, the Skills section concerns the knowledge and talents necessary to properly manage the company's ICT strategic infrastructure (Chung, Rainer Jr, & Lewis, 2003; H. K. Eliwa et al., 2022; Tallon, 2015).

6.4 Research methodology

A two-stage research design was constructed. The first stage of the study included a 3-parts self-administered quantitative expert survey questionnaire. Principal component factor analysis has been conducted; this used to identify the underlaying factors and reduction of variables. PCFA is based on bundling highly correlated items or variables as one group or factor (Pallant, 2010). Finally, multiple regression analysis methods have been used to develop a relationship model between the dependent and independent variables. The second stage of the research was verifying the analysed data using qualitative research method through semi structured interviews from the New Zealand construction industry (H. Eliwa et al., 2018b; Maxwell, 2008).

6.4.1 ***Stage one: The Structured Survey Questionnaire***

As mentioned above, the structured questionnaire survey has been designed into three main parts. The first part contained questions regarding the participants' judgment, which was required to filter the quality results out of the total responses. The second part of the survey involved the ICT category selection based on the survey's users' experience in the ICT application in the construction industry. in this section, the users have the opportunity to rate the involvement of each ICT category in the construction field. This categorization of the ICT considers the most critical factors that can affect the organization and ICT infrastructure level, and the following classes have been derived (H. K. Eliwa et al., 2022; Ezcan, Goulding, & Arif, 2020):

- Building Engineering Application: Such as ATEAN (Carrier), CARGASW (Climasoft), CALCULUX, CYPE INGENIEROS, COSMOS and DUCTSIZE applications
- Accounting: such as Sage, Viewpoint, Quickbooks, CMiC, Jonas Software and Deltek Vision applications
- Bidding and Tendering: such as CMiC, iSqFt, Procore, SmartBidNet, Textura, Viewpoint, eBid Exchange and Pipeline Suite applications
- Estimating and Take-off Software: such as On-Screen Takeoff, HeavyBid, Bluebeam Revu, Planswift, B2W Estimate, Trimble Accubid, ProEst, Sage Estimating and WinEst applications
- Planning and Project Management: such as Primavera, Microsoft Project, Power Project, Agile, JobMaster, Prolog, PlanGrid, Constructware, and CMiC applications
- Building Information Modeling (BIM) and Computer-aided Design (CAD): such as AutoCad, Revit (Autodesk), Navisworks (Autodesk), Sketchup (Trimble), Tekla (Trimble), QTO (Autodesk), AutoVue, ArchiCad and Assemble Systems applications
- Job Site Data Collection & Reporting: such as Microsoft Office Package, Autodesk's BIM360, B2W, HCSS, PlanGrid, and NoteVault applications

- Customer Relationship Management (CRM): such as Cosential and FollowUp Power applications
- Cloud Storage, Sharing, and Web Conferencing: such as DropBox, Adobe Acrobat, Aconex, and Microsoft Team applications

The final part of the survey developed with questions that can estimate the strength of the functional integration domains for each ICT category considering the users' selection of the ICT applications as presented in the previous part. The questionnaire development structure and the selection criteria considered that all the participants worked at a professional level within the construction industry with at least five years of experience in the construction field and any ICT usage experience. The survey population has considered the position of the participants in their organizations; therefore, the results accuracy can be discussed based on the percentage of the participants' position (Grassini & Laumann, 2020).

Based on the survey condition, each participant has answered the same number of questions multiple times based on his/her ICT classification selection. This type of question structure has increased the number of results for each question as each participant can equivalent to a maximum of nine participants if he/she selected that he/she has an experience in all the ICT classifications mentioned above during the survey collection. Based on the survey development, 14 independent variables have been considered to determine the strength of the organizational and ICT infrastructure domains. On the other hand, the dependent variable has been identified as the organizational performance and outcomes, and it was concluded through seven structured questions during the survey.

The first step of the analysis was using the principal component factor analysis method for the variables' selection. The analysis was conducted using the IBM SPSS Statistics tool version 28, and the idea was to select the optimal question for the dependent variable and three of the most ranked questions for each independent variable. The factor analysis method allows the researcher to investigate the relationship between a large number of variables which in our case are in the form of questions from the survey, and then to check whether these variables can be grouped, classified and summarised using a smaller number of factors or potential variables (Jelodar, Yiu, & Wilkinson, 2015; Joliffe & Morgan, 1992). These potential variables are covered underneath the survey result data and are not measured directly. The key concept for this type of factor analysis is that the sets of these variables can be related to each other due to the case that is all related to the same implicating factor (Joliffe & Morgan, 1992; Suhr, 2005). In this study, the variables have been identified already from the survey questions based on the literature (Bhattacharya, 2018; Brewer et al., 2005; Y.-Y. Chen & Huang, 2010; Chung et al., 2003; H. Eliwa et al., 2018; H. K. Eliwa et al., 2022; Wetering et al., 2017) and the main function for this analysis is to identify the optimal selection for the multiple regression analysis (Herve Abdi, Williams, & Valentin, 2013; Suhr, 2005).

Finally, the stepwise multiple regression analysis using the IBM SPSS Statistics tool version 28 was used to evaluate the relationship between the construction organizations' performance and the improvement of the functional integration for both strategic alignment model domains, which are organization infrastructure and ICT infrastructure. Stepwise multiple regression, compared with the other multivariate techniques, has the advantage that the number of prospect subset models tested or checked before the model for each subset is decided. Thus, there is a better chance of selecting the best subsets in the initial data when there are a large number of potentially relevant regressor variables (Armstrong & Hilton, 2010; Jelodar et al., 2015; Whittingham, Stephens, Bradbury, & Freckleton, 2006; Yasar, Bilgili, & Simsek, 2012). A framework identifying the relationships between the independent and dependent variables and the analysis phase stages of the study results has been developed and presented in Figure 6.2.

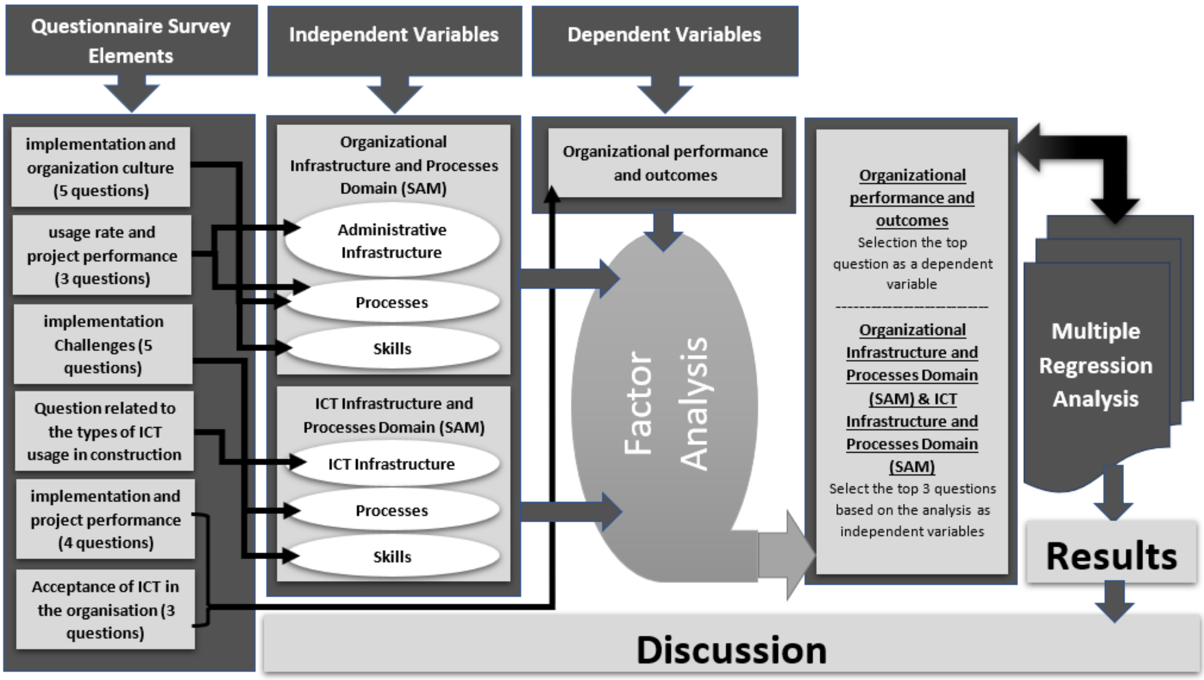

Figure 6.2: Quantitative expert survey questionnaire framework

6.4.2 Stage two: The qualitative expert Semi-structured open-ended interview

In stage two a qualitative approach through expert interviews is adopted as an explanatory measure. This allows for an in-depth analysis of ICT alignment with organisational infrastructure and also provides means of validation for the findings in the previous structured survey questionnaire stage. Data verification is related to the performance of a check on the existing data exported from other research methodology to ensure that it is consistent, accurate, and reflects its proposed purpose (Donalek, 2005; Mills & Birks, 2014). The verification performance is having critical role when the study data is exported from two different sources and one of these sources was having the data results based on an empirical study which is the same condition we have in this study (Donalek, 2005; Mills & Birks, 2014; Skinner, 2007).

Semi-structured open-ended interview selected as the most suitable qualitative method by collecting the substantial data from experts in large construction organizations based in Auckland, New Zealand (Dearnley, 2005; H. Eliwa et al., 2018b). The semi-structured interview method of study supplies a balance between the flexibility of open-ended questions and the condense of a structured interview and the data during the semi-structured interviews can convert the study process from domains topics to more particular views (Dearnley, 2005; Schmidt, 2004). This type of qualitative study provides key expert results which are in the same level of training and experience and can analyse multiple ways of problems management (Newcomer, Hatry, & Wholey, 2015). Moreover, using Expert Semi-structured interviews provides a base for the validation of other results from other research in the same field of study (Newcomer et al., 2015; Schmidt, 2004). The approach is developed as a mean of in-depth exploration (Amirtash, Parchami Jalal, & Jelodar, 2021; Creswell & Creswell, 2017); which in this case was to identify and verify the effect ICT alignment and level of this alignment on organizational performance. Purposeful sampling methods using snowballing techniques was adopted to target expert information rich interviewees (Creswell & Creswell, 2017). The interviewees were selected from senior management level construction industry experts and professionals including project managers, control managers, senior engineers and team leaders.

Content analysis and specifically analysis of identified themes within the responses is conducted. Content analysis and thematic analysis are data analysis methods used to analyse the qualitative and descriptive data gathered from different collection methodologies (Neuendorf, 2018). This type of analysis allows the researcher to identify significant data from a data frame, categorize data into different sections and analyse the content present in each data item (Neuendorf, 2018). In general, the content analysis and thematic analysis can identify frequencies of data and provide a logical structure to the research (Neuendorf, 2018; Vaismoradi, Jones, Turunen, & Snelgrove, 2016).

6.5 Data Collection

6.5.1 Stage one: The Structured Survey Questionnaire

A total of one hundred and sixteen valid responses have been collected in several stages and follow-up calls for the survey. The targeted participants were the construction managers, project managers and experienced project engineers. A response rate of 45% was acceptable for a questionnaire survey focusing on obtaining responses from industry practitioners (Ahuja, Yang, & Shankar, 2009; Sarshar & Isikdag, 2004; Serpell, Barai, & Oladapo, 2005; Wong & Sloan, 2004).

Figure 6.3: Respondents' classifications data

Figure 6.3 shows a breakdown of the respondents in terms of their work position, work experience, the classification of the construction sector they worked in and experience in the construction field. Based on the survey population data, about half of the participants had a project management position description at the management decision level. In general, more than 90% of the survey participants are on the professional level in the construction industry. Regarding the participants' experience level, from Figure 3, most survey participants had adequate years of experience in the construction field, including using the ICT in their construction projects. The selection criteria considered that all the participants worked at a professional level within the construction industry with at least five years of experience in the construction field and any ICT usage experience. However, as the percentage of the participants with less than five years of experience is less than 5 percent, the study filter can be waived, and the four percent of the participants with experience of up to four years can be considered (Martin, 2006; Roopa & Rani, 2012).

The second set of survey questions asked the participant to select one or more ICT classifications based on his/her experience from the list discussed in the previous chapter. The next questions were dependent on the participant's selections on the ICT classifications question. Participant were required to answer the same set of questions multiple times based on the number of the ICT classifications selected in the last part of the survey questionnaire. This type of survey structure has increased the result data for each question related to the ICT classifications and lines of data have increased from 116 results from each question to 350 results.

6.5.2 Stage two: The qualitative expert Semi-structured open-ended interview

A total of thirteen interviews were conducted with experts and professional participants from New Zealand construction industry and theoretical saturation was achieved (A. M. Adriaanse et al., 2004; H. Eliwa et al., 2018b; Tallon, 2015). Professionals were selected from different types of construction projects, in the higher tier of management roles and with beneficial experience of using the information and communication technologies during their experiences in New Zealand construction industry (Donalek, 2005; H. Eliwa et al., 2018b; Skinner, 2007). The sample population are occupying important ranked positions in their organizations which making them having good understanding of the current practices and processes within their organizations and the wider construction industry is fulfilled (Donalek, 2005). Table 1 summarises expert interviewee details.

These face-to-face interviews have been structured with base questions related to the relationship between the information and communication technologies implementation strategy and construction organization strategy followed by integral open-ended questions for preferable tangibility responses. The main general question of this interview was to determine the reason of the underperformance of the ICT in the construction organization field. This interview methodology had been presented by this study authors in a conference in 2018 as the main qualitative methodology to determine the relationship between the alignment of all strategic alignment model domains and the construction organization performance and outcomes (H. Eliwa et al., 2018b).

Table 6.1: Expert Interviewee details

Expert Interviewees	Position/role	Experience
R1	Project Manager	21 years
R2	Project Manager	17 years
R3	Project Manager	31 years
R4	Project Manager	33 years
R5	Senior Planning Engineer	12 years
R6	Cost and Control Manager	30 years
R7	Planning Manager	30 years
R8	Planning Manager	16 years
R9	Senior Planning Engineer	13 years
R10	Senior Civil Engineer	11 years
R11	Senior Civil Engineer	10 years
R12	Senior Civil Engineer	10 years
R13	Senior Civil Engineer	23 years

The answers from the main based questions, the participants' comments and ideas have been classified and categorised using NVIVO tool, then the outputs and results from NVIVO analysed in the term of "agree" and "disagree" structure (Donalek, 2005; Schmidt, 2004). Therefore, the percentage of the results with "agree" term has then been calculated and dispensed on its related strategic alignment model domain considering the factors that categorize the strength of this specific domain in the organisation (A. M. Adriaanse et al., 2004; Donalek, 2005; H. Eliwa et al., 2018b; Hua, 2007; Schmidt, 2004).

6.6 The Results

6.6.1 The Principal Component Factor Analysis:

As explained, the principal component factor analysis has been used initially for the optimal variable selection for each of the concluded variables (Herve Abdi et al., 2013; Suhr, 2005). In general, The Principal Component Factor Analysis aims to reduce a group of variables in the shape of questions into smaller numbers, more significant sets of factors by research for clusters of the target variables that have relationship evidence (Herve Abdi et al., 2013; Suhr, 2005). In other words, the main purpose of using the principal component factor analysis is to reduce available data by investigating the most important variables in the formation of the incident or the system (Hervé Abdi & Williams, 2010). IBM SPSS Statistics software version 28 has been used to perform the principal component factor analysis on 21 variables under three main categories: the organizational performance and outcomes set of questions as the dependent variables; the organizational Infrastructure and Processes set of questions as the first independent variables; and the ICT infrastructure and processes set of questions as the second independent variables, and the factor weight matrix was gained using the data and the main principal component factor.

The selections of the question variables related to each dependent and the independent category were based on the literature considering the main factors that determine the strength of the functional integration domains in the strategic alignment model (Baier, Hartmann, & Moser, 2008;

Budayan, Dikmen, & Birgonul, 2015; Choe, 2016; H. Eliwa et al., 2018b; Hua, 2007; Jouirou & Kalika, 2004). Consequently, survey questions related to these factors have been developed in the following category of variables:

- Organizational performance and outcomes (the main category for the dependent variable)
- The strength of the "Organizational Infrastructure and Processes" domain in the strategic alignment model (the first category for the independent variables)
- The strength of the "ICT Infrastructure and Processes" domain in the strategic alignment model which related to the ICT utilization level (the first category for the independent variables)

The developed questionnaire had 21 questions (variables), and answers were given on a scale of one to five, where the "strongly agree" answer represents number five, and the "strongly disagree" answer represents number one. Principal Component Factor Analysis (PCFA) has been used to select the optimal question for the organizational performance and outcomes category as the selective dependent variable and three optimal questions from the first and the second independent variables Considering the above factors. As mentioned, 350 lines of answers have been imported to the SPSS Statistics software considering the scale as the type of measure and the Coefficients option for the Correlation Matrix. It is significant to have a large sample size to make the PCFA meaningful and secure accurate correlations between the variables included in the analysis (Hervé Abdi & Williams, 2010; Herve Abdi et al., 2013). One of the factors that can be used to test the data sampling adequacy is the Kaiser-Meyer-Olkin (KMO). This factor tests the data sample size and guides whether or not it is sufficient (Herve Abdi et al., 2013; Joliffe & Morgan, 1992). A value of less than 0.5 indicates that the survey data sample is extremely small, but ideally, the value of the KMO is required to be around 0.7 (Hervé Abdi & Williams, 2010; Joliffe & Morgan, 1992). Based on the analysis, the Kaiser-

Meyer-Olkin (KMO) Measure of Sampling Adequacy in this study was 0.798, which indicates that the study sample size is sufficient.

The other important factor that needs to be considered during the principal component factor analysis is "Bartlett's Test of Sphericity". This factor tests the correlation level between the particular variables and whether or not it is suitable (Hervé Abdi & Williams, 2010; Joliffe & Morgan, 1992). In our study and from the SPSS analysis result, the "Bartlett's Test of Sphericity" value is $P < 0.001$, which can be considered a significant value and has enough correlations as it is less than the alpha level ($P < 0.05$) (Joliffe & Morgan, 1992).

PCFA is done through a Varimax Rotated Component Matrix in Table 6.2, Table 6.3, and Table 6.4. The Rotated Component Matrix rotates the imported data and then shows how each variable distribute onto each of the factors and to what range. The results from the Rotated Component Matrix allow the researcher to decide the classifications of the variables based on the results range, considering that the factor analysis in general only mathematically groups the variables, and the final decision related to the results and discussion is totally according to the researchers' point of view (Joliffe & Morgan, 1992; Suhr, 2005; Tipping & Bishop, 1999; Wold, Esbensen, & Geladi, 1987).

Table 6.2 demonstrates results of Rotated Component Matrix for the questions under the dependent variable group this study which mainly focuses on items related to organization's performance and outcomes. Accordingly, two factors have been identified based on the component or factor optimal value. Based on the items loading to these factors; these clusters of items were renamed as newly identified factors of “Workforce related performance” and “Project management performance” (Table 6.2). The two factors combined also provided an measure for the overall organization's performance and outcomes.

Thus, the Rotated Component Matrix for the questions under the independent variables’ groups have been demonstrated in Table 6.3 and Table 6.4.

Table 6.2: RCM results for the dependent variables under the organization's performance and outcomes

	Component / Factors		New Factor Names
	1	2	
The use of this ICT Increases project achievement	***0.802***	0.296	**Workforce related performance**
The use of this ICT makes project management easy	***0.771***	0.184	
The use of this ICT is not costly regarding resources, time and effort	***0.711***	0.374	
The use of this ICT could reduce the number of staff employed	0.291	***0.655***	**Project management performance**
The use of this ICT is an effective tool for staff of all abilities	0.277	***0.681***	
The use of this ICT eases the pressure on organization staff	0.385	***0.737***	
The use of this ICT motivates staff to get more involved in project activities	0.306	***0.697***	

Table 6.3: RCM results for the independent variables under the "Organizational Infrastructure"

	Component / Factors			New Factor Names
	1	2	3	
The organization's staff received in-service training on using this ICT	***0.731***	0.341	0.268	**Organization provides support for ICT implementation**
The organization has good and effective technical support related to this ICT	***0.719***	0.380	0.249	
The organization's staff have acquired the ability to use a broad spectrum of this ICT competently	***0.588***	0.317	0.217	
The organization has a strong planning methodology which incorporates this ICT, and all business unit heads	0.271	***0.686***	0.152	**Organization has strategy for ICT implementation**
The cost of using this ICT is acceptable and does not affect the budget	0.382	***0.627***	0.274	
The organization's staff is gaining a sense of self-confidence in using this ICT for specific tasks	0.261	***0.604***	0.208	
The diversity of this ICT increases project achievement	0.186	0.411	***0.802***	**ICT acceptance culture in the organization**
Using this ICT to solve a problem or report is more productive	0.293	0.227	***0.749***	

Table 6.4: RCM results for the independent variables under the "ICT Infrastructure and Processes"

	Component / Factors			New Factor Names
	1	2	3	
The use of this ICT does not require software-skills training	***0.861***	0.204	0.174	**The availability of the organization ICT training resources**
Available this ICT resources for training and support	***0.819***	0.219	0.108	
Easy transforming and re-configuring business process to suit this ICT	0.311	***0.616***	0.153	**ICT align with the organization process**
Easy alignment between business strategy and this ICT	0.361	***0.508***	-0.027	
Easy upgrading this ICT to a new version with acceptable costs	0.392	0.308	***0.727***	**Wide range of the ICT implementation in the organization**
ICT Usage level	0.337	0.371	***0.519***	

Table 6.3 reflects the independent variables under the "Organizational Infrastructure and Processes" and three clusters have been identified based on the component or factor optimal value. Consequently, the independent variables under the "ICT Infrastructure and Processes" presented in Table 6.4 and three clusters have been identified as well based on the component or factor optimal value. Finally, the identified clusters from the Rotated Component Matrix for the dependent and independent variables have been summarised and illustrated in Figure 6.4. Based on the Rotated Component Matrix (RCM) and factor optimal values, the dependent variables and the independent variables in this study are presented in Table 6.2, Table 6.3 and Table 6.4.

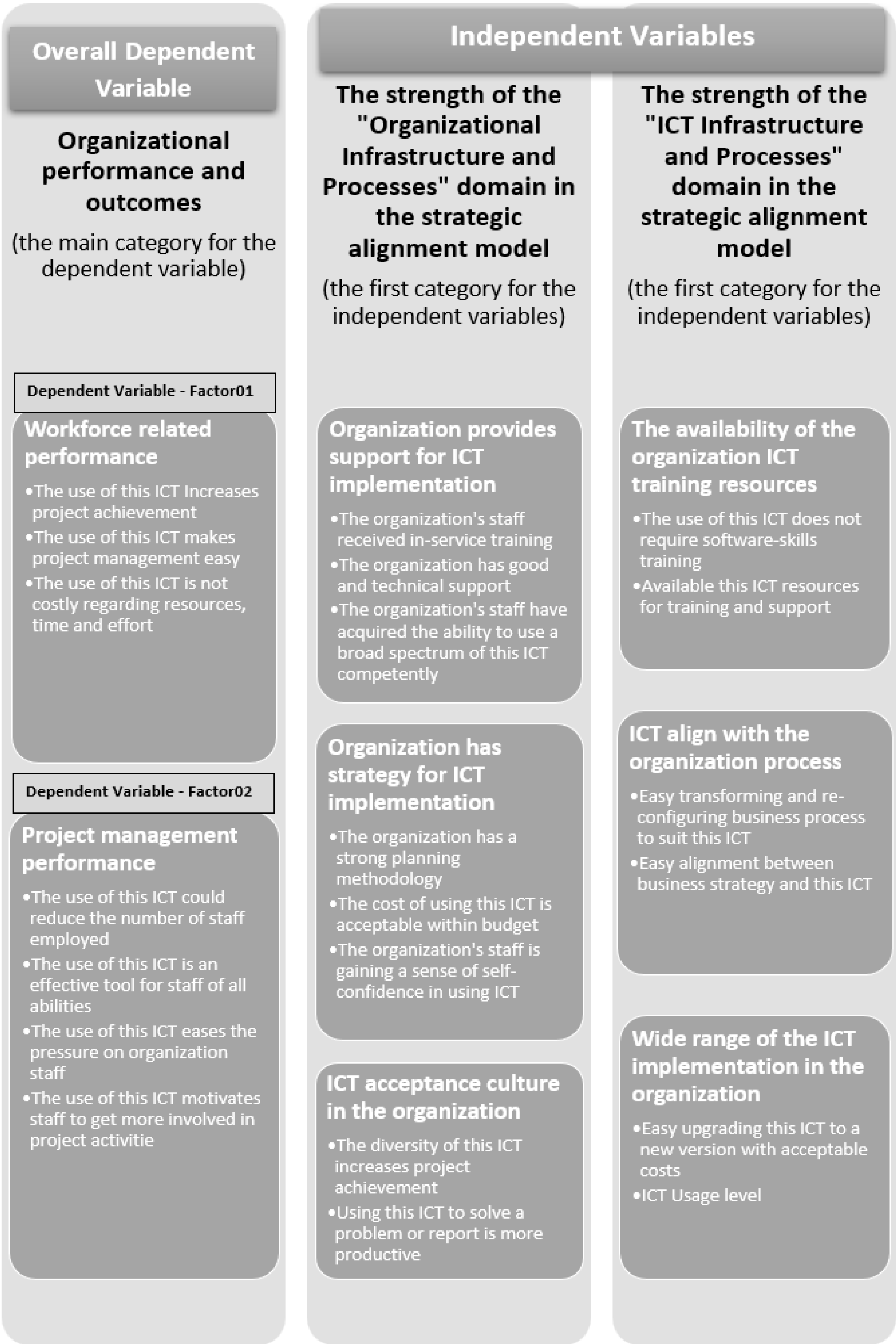

Figure 6.4: The clustering structure of the dependent and independent variables based on the Principal Component Factor Analysis

6.6.2 ***Multiple Regression Analysis:***

The multiple regression analysis is an expansion of the simple linear regression analysis, which is required when the study aims to project the value of the dependent variable based on the value of more than one independent variable (Berry, Feldman, & Stanley Feldman, 1985; Roediger, Watson, McDermott, & Gallo, 2001; Trunfio, Scala, Vecchia, Marra, & Borrelli, 2020). The multiple regression analysis allows the researchers to calculate and investigate the overall fit of the resulting model and the value of the contribution for each of the independent variables to develop an equation for the dependent variable prediction (Berry et al., 1985; Roediger et al., 2001; Trunfio et al., 2020; Uyanık & Güler, 2013). The first process in the multiple regression analysis is to check the quality of the result data which is in this study from the results of the survey questionnaire by passing seven hypotheses which are required to be implemented to get accurate and valid results from the multiple regression analysis (Aiken, West, & Pitts, 2003; Berry et al., 1985; Roediger et al., 2001; Uyanık & Güler, 2013). The seven hypotheses can be summarized as the following:

Hypothesis (A): The study dependent variables - which summarized in the Figure 4 under the organizational performance and outcomes - can be measured based on a continuous scale rather than an ordinal scale (Aiken et al., 2003; Berry et al., 1985). In this study, the dependent variables are related to the organizational or project performance level, which can be calculated in a percentage level and considered a continuous scale variable.

Hypothesis (B): The independent variables - which are the "Organizational Infrastructure and Processes" and the "ICT Infrastructure and Processes" - should be two variables or more and can be either on an ordinal, nominal, or continuous measurement (Berry et al., 1985; Roediger et al., 2001). In this study, we have a total of six variables – after the factor analysis selection - as independent variables and all of these are measured on an ordinal scale.

Hypothesis (C): The independence of residuals or the independence of observations case should be applied in the study, which can be measured using the Durbin-Watson statistic option in the IBM SPSS Statistics tool (Aiken et al., 2003; Roediger et al., 2001; Trunfio et al., 2020). The optimal value of the Durbin-Watson statistic should be 1.5 to 2.5 to ensure that the data observations are independent (Aiken et al., 2003; Roediger et al., 2001; Trunfio et al., 2020). Table 5 summarizes using the Durbin-Watson statistic option in this study data. Based on Table 5, the Durbin-Watson statistic is equal to 1.749 and 1.703 for the first model, 1.811 and 1.792 for the second model, and 1.681 and 1.694 for the last model, which is between the range of 1.5 and 2.5; therefore, the data are not autocorrelated.

Hypothesis (D): Considering the relationship between the dependent variable and each of your independent variables are linear relationships, the relationship between the dependent variable and the independent variables collectively is linear as well (Berry et al., 1985; Uyanık & Güler, 2013). That relationship can be visually inspected using the partial regression plots and the scatterplots using the IBM SPSS Statistics tool (Uyanık & Güler, 2013). In this study, the partial regression plots have been applied to the dependent variables with each independent variable, proving that the data in this study is linear. The study data's linearity means that the regression's independent variables have a linear straight-line relationship with the dependent variable (Uyanık & Güler, 2013). The other visually observation required to be performed is that the residuals are normally distributed and was checked using the linear regression histogram option in the SPSS Statistics tool with a superimposed normal curve (Aiken et al., 2003; Roediger et al., 2001).

Hypothesis (E): the homogeneity characteristic has to be shown between these data to get optimal results from the study data (Aiken et al., 2003; Berry et al., 1985; Trunfio et al., 2020). This homogeneity between the data can be measured in the IBM SPSS Statistics tool by plotting the independent variables' values and the dependent variable's value on a scatterplot (Trunfio et al., 2020). The research data is homogeneous if it looks like a shotgun explosion of randomly distributed data

(Aiken et al., 2003; Trunfio et al., 2020; Uyanık & Güler, 2013). The opposite of homogeneity is heteroscedasticity, where the data's shape on a scatterplot is comparatively like a fan or cone shape (Aiken et al., 2003; Trunfio et al., 2020; Uyanık & Güler, 2013). For this study, the scatterplot of both categories of the independent variables against the dependent variables using the IBM SPSS Statistics tool has been produced and the data distribution of this study was clearly observed as the shape of a shotgun explosion, which means that this data has the homogeneity characteristic.

Table 6.5: Model Summary - the Durbin-Watson statistic and level of prediction

Model (dependent variable with independent variables)		R	R Square	Adjusted R Square	Std. The error in the Estimate	Durbin - Watson
Dependent Variable	**Independent variables**					
Workforce related performance	"Organizational infrastructure and process" category of the independent variables	0.551	0.509	0.502	0.726	1.749
	"ICT Infrastructure and Processes" category of the independent variables	0.582	0.536	0.514	0.791	1.703
Project management performance	"Organizational infrastructure and process" category of the independent variables	0.597	0.531	0.518	0.763	1.811
	"ICT Infrastructure and Processes" category of the independent variables	0.594	0.518	0.507	0.839	1.792
Overall Organization Performance	"Organizational infrastructure and process" category of the independent variables	0.618	0.582	0.561	0.743	1.681
	"ICT Infrastructure and Processes" category of the independent variables	0.669	0.573	0.548	0.772	1.694

Table 6.6: The correlation matrix for the dependent variable Workforce related performance.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**	**Tolerance**	**VIF**
1	**(Constant)**	1.722	.136		9.881	<.001	1.317	2.008		
	[IV1.1]	.622	.061	.681	8.037	<.001	.481	.811	.831	**1.074**
	[IV1.2]	.191	.041	.228	4.331	<.001	.109	.274	.669	**1.811**
	[IV1.3]	.488	.039	.514	11.166	<.001	.411	.565	.610	**1.622**
2	**(Constant)**	1.768	.161		10.031	<.001	1.451	2.085		
	[IV2.1]	.376	.030	.396	8.603	<.001	.317	.435	.671	**1.727**
	[IV2.2]	.097	.008	.102	2.219	<.001	.082	.112	.531	**1.937**
	[IV2.3]	.196	.016	.206	4.485	<.001	.165	.227	.639	**1.342**

Hypothesis (F): The data of the study should not have multicollinearity in the results, which happens in the case of more than two independent variables having a high level of correlation between each other that can affect the accuracy of the final model in the results (Aiken et al., 2003; Roediger et al., 2001; Trunfio et al., 2020). The absence of the multicollinearity can be checked using the SPSS Statistics with the variance inflation factor (VIF) values in which the value of the VIF should be below 10.00 for each of the independent variables, and in the optimum case, this value is required to be below 5.00 (Aiken et al., 2003; Roediger et al., 2001; Trunfio et al., 2020). Table 6, Table 7 and Table 8 present the correlation matrix of the study data with the VIF values on the last column for each independent variable in both categories. Based on this table, this research data does not show multicollinearity as all VIF values are less than 5.00.

Hypothesis (G): During the data observations, there must be no significant leverage points, outliers' points or influential points which are impacting the performance or the implementation of the multiple regression analysis and can result in a high negative effect on the regression model (Astivia & Zumbo, 2019; Roediger et al., 2001; Uyanık & Güler, 2013). The observation of these three points can be determined by the level of the "model fits" option and "statistical significance" using the IBM SPSS Statistics tool (Astivia & Zumbo, 2019; Uyanık & Güler, 2013). The "model fits" summary is presented in Table 6.5, where the "R" value - which measures the quality of the independent variables - represents the multiple correlation coefficient values and is recommended to be too low in the percentage.

Table 6.7: The correlation matrix for the dependent variable Project management performance

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**		**Collinearity Statistics**	
		B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**	**Tolerance**	**VIF**
1	**(Constant)**	1.964	.178		11.146	<.001	1.613	2.317		
	[IV1.1]	0.022	0.002	0.023	0.503	<.001	0.019	0.025	.706	**2.179**
	[IV1.2]	0.274	0.022	0.289	6.269	<.001	0.231	0.317	.792	**2.199**
	[IV1.3]	0.491	0.040	0.517	11.235	<.001	0.414	0.568	.857	**1.205**
2	**(Constant)**	1.416	.128		8.037	<.001	1.163	1.670		
	[IV2.1]	.081	0.007	0.085	1.853	<.001	0.068	0.094	.813	**1.311**
	[IV2.2]	.724	0.058	0.762	16.566	<.001	0.610	0.838	.595	**2.075**
	[IV2.3]	.318	0.026	0.335	7.276	<.001	0.268	0.368	.534	**1.431**

Table 6.8: The correlation matrix for the dependent variable overall organization's performance

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**		**Collinearity Statistics**	
		B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**	**Tolerance**	**VIF**
1	**(Constant)**	1.858	.169		10.543	<.001	1.525	2.191		
	[IV1.1]	.527	0.042	0.555	12.058	<.001	0.444	0.610	.641	**2.194**
	[IV1.2]	.374	0.030	0.394	8.557	<.001	0.315	0.433	.859	**1.224**
	[IV1.3]	.319	0.026	0.336	7.299	<.001	0.269	0.369	.447	**1.749**
2	**(Constant)**	1.887	.171		10.707	<.001	1.549	2.225		
	[IV2.1]	.509	0.041	0.536	11.646	<.001	0.429	0.589	.759	**1.476**
	[IV2.2]	.174	0.014	0.183	3.981	<.001	0.147	0.201	.700	**2.008**
	[IV2.3]	.169	0.014	0.178	3.867	<.001	0.142	0.196	.846	**1.891**

Thus, the "R Square" value represents the value of the coefficient of determination, or, on the other hand, the variation percentage demonstrated by the regression line through the total variation. Based on table 6.5, the "R" value in this study is from 0.5 to 0.6, and the "R Square" value means the independent variables explain around 50% to 60% of the variability of the research dependent variable.

Based on the above, all study data has met the seven hypotheses which are required for the accuracy and validity of the multiple regression analysis results, and the estimated model coefficients can be produced (Aiken et al., 2003; Berry et al., 1985; Roediger et al., 2001; Trunfio et al., 2020; Uyanık & Güler, 2013). Based on Table 6.6, Table 6.7 and Table 6.8 the general form of the equations models to predict the dependent variables from the independent variables under the strength of "Organizational Infrastructure and Processes" and "ICT Infrastructure and Processes" categories are:

predicted "Workforce related performance" = 1.722 + (0.622 x IV1.1) + (0.191 x IV1.2) + (0.488 x IV1.3) = 1.768 + (0.376 x IV2.1) + (0.097 x IV2.2) + (0.196 x IV2.3) (Eq.6.1)

predicted "Project management performance" = 1.964 + (0.022 x IV1.1) + (0.274 x IV1.2) + (0.491 x IV1.3) = 1.416 + (0.081 x IV2.1) + (0.724 x IV2.2) + (0.318 x IV2.3) (Eq.6.1)

predicted "overall organization's performance and outcomes" = 1.858 + (0.527 x IV1.1) + (0.374 x IV1.2) + (0.319 x IV1.3) = 1.887 + (0.509 x IV2.1) + (0.174 x IV2.2) + (0.169 x IV2.3) (Eq.6.1)

6.6.3 <u>The qualitative expert Semi-structured open-ended interview</u>

As the main purpose of the interview questions was to investigate the underperformance of the information and communication technology in the construction industry, the weakness of the strategic alignment model domains can be as an indication of the positive affect of the strategic alignment on the organization performance (A. M. Adriaanse et al., 2004; H. Eliwa et al., 2018b; H.

K. Eliwa et al., 2022). Consequently, the collected data from the interview questions have been classified and organized based on the domains of the strategic alignment model and also to investigate the functional integration between business and ICT related domains as demonstrated in Figure 1. As mentioned in the Data Collection section of this research, based on the answers provided to the main questions interview responses have been classified and categorised using NVIVO tool, and the outputs were analysed in the term of degree level of "agree" and "disagree" structure. Based on that, the percentage of the results with the "agree" term has then been calculated and dispensed on its related strategic alignment model domain considering the factors that categorize the strength of this specific domain in the organisation. The strength and weakness levels of each domain have been calculated based on previous studies in the same field (Acur, Kandemir, & Boer, 2012; A. M. Adriaanse et al., 2004; Donalek, 2005; H. Eliwa, Jelodar, & Poshdar, 2018a; Hua, 2007; Schmidt, 2004). Therefore, to determine the strength of each strategic alignment model domain, each question from the interview results has been calculated as mentioned in the data collection section, and the final domain strength has been presented in terms of “Strong”, “Mid” or “Weak” considering the information technologies as strategic resources.

The results from the above process have been presented in Figure 5. Accordingly, the organizational infrastructure and process domain has been identified as the weakest strategic alignment domain within New Zealand construction organizations, and it can be concluded from the figure that it indirectly effects the strength of the information and communication technology infrastructure and process domain. The charts of Figure 6.5 demonstrate that the alignment of the organizational infrastructure and information and communication technology infrastructure are the two areas which identified as having the issue or opportunity that can be categorized through the deployment of the information and communication technology as a strategic resource. Having the organisation infrastructure as the weakest domain in this study, the strategy execution perspective can be considered as the typically dominant alignment for the New Zealand construction organisation taking into account the structure and the limitation of this study methodology (A. M. Adriaanse et al., 2004).

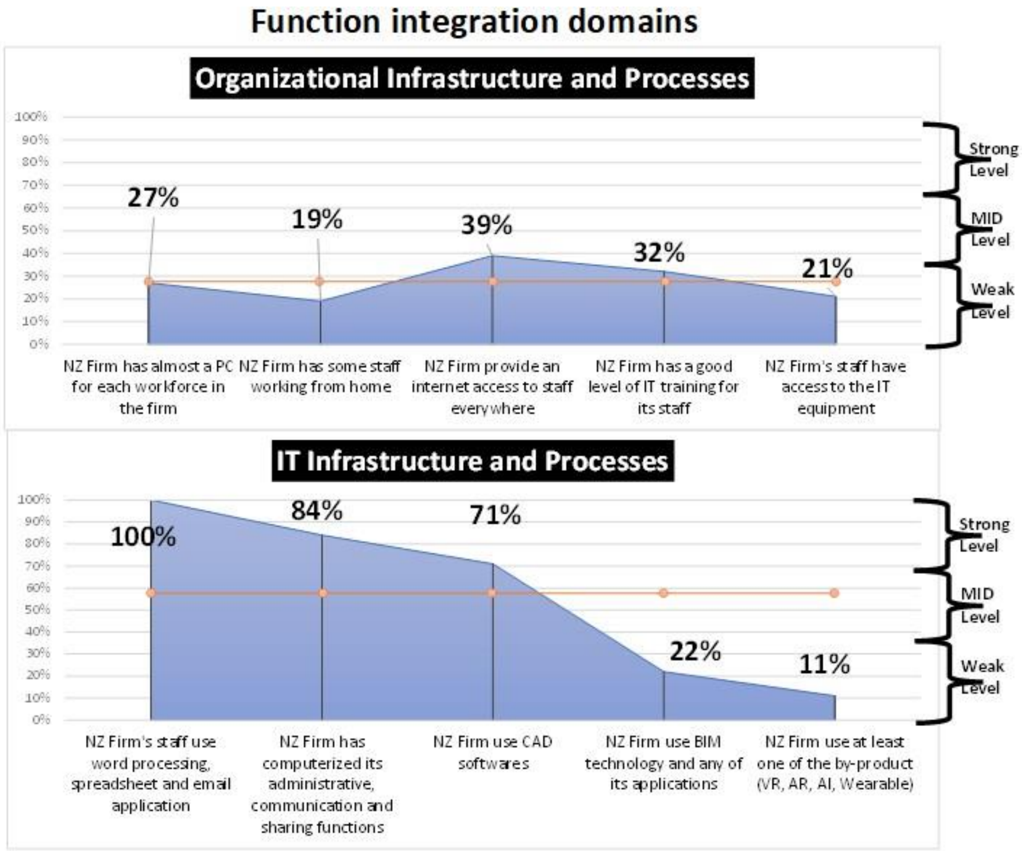

Figure 6.5: the qualitative expert Semi-structured open-ended interview analysis results

The weakness of the organisational infrastructure can be an indirect reason of the weakness of the construction organizations development vision due to a lack of investment on information technology facilities (H. Eliwa et al., 2018b; Hua, 2007). Therefore, the information and communication technology Infrastructure is impacted and require to be developed to support the construction organizations infrastructure shortfalls (H. Eliwa et al., 2018b; Hua, 2007). The same concept can apply to the IT infrastructure which is at an overall level of medium from demonstrated in Figure 6.5 it's the further development of this domain requires further resources and investment, which may disrupt cash flow and also investment in other infrastructure which was totally unthought-of at the beginning of the process (H. Eliwa et al., 2018b; Hua, 2007).

6.7 The Discussion

After analysing the data collected by the survey questionnaire method using the factor analysis and then multiple regression analysis, and after verifying these results using a qualitative expert Semi-structured open-ended interview methodology, it is observed that the alignment of the function integration can positively affect the construction organization's performance and outcomes. Through multiple regression analysis equation models have been created from the values of the unstandardized coefficients, which in general determine the variation of the dependent variables with the independent variables considering all other independent variables are set on a constant value (Aiken et al., 2003; Trunfio et al., 2020; Uyanık & Güler, 2013).

Considering the above statement and the first equation model (Eq.6.1), the effect of the ICT support level "IV1.1" – B value of the unstandardized coefficient - is equal to +0.622 of the workforces related performance - the dependent variable - according to the coefficients table which can be described as that the level of the ICT support level in the organization can positively affect the workforce related performance for this organization. This positive effect on the organization's performance can be described as a positive relationship between the strength of the organizational infrastructure and the organization's performance as the strength of the organizational infrastructure is affected by the ICT support and training (Budayan et al., 2015; Y.-Y. Chen & Huang, 2010). From the same equation model, the existing of the ICT strategy in the organization "IV1.2" and the Wide range of the ICT implementation in the organization "IV2.3" can both improve the workforce related performance by about 19%, the acceptance of the ICT in the organization "IV1.3" and the ICT training resources in the organization "IV2.1" can positively affect the workforce related performance by about 37% to 48%. However, there is a small amount of effect of the ICT align with the organization process "IV2.2" on the workforce related performance as the percentage of the value is about 9%. The same concept can be applied to the remaining equation models considering all six independent variables under the "Organizational Infrastructure and Processes" and "ICT Infrastructure and Processes" categories, and a positive impact on the dependent variables can be concluded for all.

As mentioned, multiple regression analysis allows researchers to calculate and investigate the overall fit of the resulting model and the value of the contribution for each of the independent variables to develop an equation for the dependent variable prediction (Aiken et al., 2003; Berry et al., 1985; Roediger et al., 2001; Uyanık & Güler, 2013). Based on this statement, the researchers can conclude the relationships between the dependent and independent variables based on the study case conditions (Aiken et al., 2003; Berry et al., 1985; Roediger et al., 2001; Uyanık & Güler, 2013). Each of the independent variables in Table 6.6, Table 6.7 and Table 6.8 can be considered statistically significantly predict the organizational performance as the value of the coefficients is almost equal to zero in the population, which can be observed from the sig. Column in these tables (Aiken et al., 2003).

Thus, from all of the three equation models, the enhancement of all independent variables under the "Organizational Infrastructure and Processes" and "ICT Infrastructure and Processes" categories, which have been identified as ICT support level in the organization, the organization ICT strategy, the ICT acceptance in organization, the ICT training resources, the ICT align with the organization process, and the ICT applications in the organization can result in a positive impact on the main dependent variable which is the organization performance.

As a verification of this study's results, expert Semi-structured open-ended interviews have been conducted by the author which presents that the main reason of ICT underperformance in the construction organizations could be due to the weakness of the function integration alignment (H. Eliwa et al., 2018b). Moreover, (H. K. Eliwa et al., 2022) have evaluated and analysed the importance of the organizational ICT infrastructure domain in the strategic alignment model to improve the ICT utilization using New Zealand cases in the construction industry which can be another qualitative verification of this study results. Based on (H. K. Eliwa et al., 2022) study, the strategic alignment between the ICT infrastructure and the ICT implementation can be one of the factors that can improve the organization's performance.

6.8 The Conclusion

In this research, a two-stage research design was constructed to investigate whether the construction organizations' performance may be restricted and affected by the strength of the alignment between the ICT infrastructure and the organizational infrastructure domains. In the first stage, a 3-parts self-administered quantitative expert survey questionnaire has been developed and distributed to a targeted group of construction industry professionals. The survey results were then organized and analysed using the principal component factor analysis method for selecting variables. Then the multiple regression analysis was used to evaluate the impact of the functional integration of the internal domains in the strategic alignment model on the construction organizations' performance and outcomes. The final part of the multiple regression analysis in this study is to produce the equation models, which can be a guide to investigating whether the construction organization's performance may be restricted and affected by the strength of the alignment between the ICT infrastructure and the organizational infrastructure domains. It has been found that, the improvement in all of the selected independent variables under the "Organizational Infrastructure and Processes" and "ICT Infrastructure and Processes" categories, which have been identified as ICT support level in the organization, the organization ICT strategy, the ICT acceptance in organization, the ICT training resources, the ICT align with the organization process, and the ICT applications in the organization can result in a positive impact on the main dependent variable which is the organization performance. Based on that research results, the functional integration of the strategic alignment in the construction organization could optimize the organizations' performance and outcomes. Subsequently and based on the resulting equation models, it is observed that the alignment of the function integration can positively affect the construction organization's performance and outcomes. The research results were verified using expert Semi-structured open-ended interviews and using (H. K. Eliwa et al., 2022) case study framework research which resulted that the strategic alignment between the ICT infrastructure and the ICT implementation can be one of the factors that can improve the organization's performance. Hence, this study proposes the incorporation of the ICT and organization infrastructure alignment into the construction organizations' work process and frameworks to reach better performance and outcomes for the organizations' projects as a theoretical contribution. As a practical contribution, the analysed data from the selected cases in this study can act as a decision-making tool in construction organization management as a case study.

Moreover, and in terms of the practical implications of this study, a decision support system or tool can be developed based on this research model that provides recommendations and guidance to construction organizations in terms of effective ICT implementations. Also, this research can analyse the effect of efficient function integration in the strategic alignment model on the organization's performance in the construction industry, which leads to optimal strategic utilization. A method of investigating and evaluating the ICT infrastructure and the organization infrastructure alignment on the organization's performance has been proposed. It can be further explored in the construction industry and ICT research using different methodologies.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 7
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

○ **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

◉ **The manuscript is currently under review for publication**

Please provide the name of the journal:

Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. A qualitative study on the effect of the functional integration of the strategic alignment model domains on the construction organisations' performance. Submitted to International Journal of Project Management

○ **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

1

Doctoral Research Committee July 2022

Chapter 7: A qualitative investigation of the importance of the functional integration

The current chapter is based on the following article:

Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. Information and Communication Technology Capability for Construction Organisations; Effect of Strategic Alignment on Performance.

Submitted to ASCE - Journal of Construction Engineering and Management

7.1 Introduction

The construction sector is often recognized as one of the most significant global contributors to economic development (FLANAGAN and MARSH 2000, Brewer, Gajendran et al. 2005, Oladinrin, Ogunsemi et al. 2012). This sector has considerable challenges, including cost overruns, issues with quality, construction delays, and poor performance (Oladinrin, Ogunsemi et al. 2012, Babaeian Jelodar and Shu 2021). Consequently, finding strategies for improving construction project performance and boosting project management skills is the leading challenge enterprises face in meeting consumer expectations (FLANAGAN and MARSH 2000, Poshdar, González et al. 2014). One of these ideas is to use cutting-edge ICT applications in construction projects (FLANAGAN and MARSH 2000, Whyte, Bouchlaghem et al. 2002, Chung, Rainer Jr et al. 2003).

An ICT is any device that collects, transmits, retrieves, stores, accesses, displays, or modifies data. Another definition of the phrase is using computer hardware, software, and other ICT components (Whyte, Bouchlaghem et al. 2002, Fischer and Kunz 2004). On the other hand, the elements needed to administer and run corporate IT environments might be referred to as ICT infrastructure (Chung, Rainer Jr et al. 2003). An organization may set up its ICT infrastructure in computer facilities or a cloud computing environment. IT solutions and services employ a variety of components, such as operating systems, networking, software, and hardware (Chung, Rainer Jr et al. 2003, Tallon 2015, Eliwa, Jelodar et al. 2022).

The organizational ICT infrastructure supports ICT implementation performance at all levels, from projects to organizations (Brewer, Gajendran et al. 2005, Yang and Huang 2016). ICT is essential to assist project operations (Redwood, Thelning et al. 2017). Many construction companies also quickly use ICT to respond to customer needs and environmental changes (Brewer, Gajendran et al. 2005). By allowing the creation of innovative and creative project management techniques, ICT may dramatically enhance an organization's performance (Whyte, Bouchlaghem et al. 2002, Fischer and Kunz 2004, Brewer, Gajendran et al. 2005). Additionally, if a company has a robust ICT infrastructure, ICT may enhance team member participation, cooperation, communication, and coordination (Chung, Rainer Jr et al. 2003, Eliwa, Jelodar et al. 2022). The relationship between ICT organizational infrastructure and ICT consumption has been largely neglected and unexplored. Despite the positive link between ICT and organizational performance, there is little research and empirical evidence on how these resources should be aligned and integrated (Pour, Matin et al. 2019, Turk 2021, Eliwa, Jelodar et al. 2022). Few studies have examined the effects of closely coordinating ICT infrastructures and ICT usage on the effectiveness of construction enterprises, and even fewer have examined the use of ICT by construction organizations (Peansupap and Walker 2006, Eliwa, Babaeian Jelodar et al. 2020, Eliwa, Jelodar et al. 2022). Since the incorporation of computers has been advocated for in building literature for some time, this is to be anticipated (Rimmimgton, Dickens et al. 2015, Eliwa, Babaeian Jelodar et al. 2020).

According to the literature, there is a lack of knowledge and proof about ICT's economic value in the construction industry (Babaeian Jelodar and Shu 2021). This lack of data may explain the apparent limitations of ICT usage, especially in project management (Babaeian Jelodar and Shu

2021). Researching the effects of ICT on project team-owner relations, organizational results, and the completion of a construction project is paramount (Amusan Lekan, Oloniju Leke et al. 2018, Yu, Peng et al. 2018). However, in the context of a consumption strategy, depending just on ICT use is inadequate (Amusan Lekan, Oloniju Leke et al. 2018). Therefore, a firm's total performance depends on having an ICT infrastructure that is well-aligned (Amusan Lekan, Oloniju Leke et al. 2018, Chen, Yin et al. 2019).

Consequently, this research aims to study the impact of functional integration within internal domains in the strategic alignment model. The study investigates the effect of alignment between the ICT infrastructure and the organizational infrastructure on construction organizations' performance and outcomes (Jouirou and Kalika 2004, Coleman and Papp 2006). The research question is; how can the organization's performance and outcomes be impacted by the alignment of ICT and organizational infrastructure? This study contribute to the performance enhancement within construction firms and highlights the significance of functional integration as a strategic alliance between the ICT and organizational infrastructure for increasing utilization. Additionally, it also offers recommendations for strengthening capital-building project management and organization.

7.2 Background

In the construction industry, much investigation has been into how ICT adoption impacts project performance (Whyte, Bouchlaghem et al. 2002, Park and Park 2020). The ICT use in the construction management process and the factors influencing its acceptance are often the subjects of most of these studies (Park and Park 2020). ICT's application to project management and construction is also covered (Park and Park 2020). Amusan et al. (2018) looked at the overall level of ICT usage in the execution of construction projects, considering the ICT use itself (Amusan Lekan, Oloniju Leke et al. 2018). Park et al. (2020) looked at the exceptional ICT potential as a valuable tool for project management (Park and Park 2020). Somu et al. (2020) assessed e-networking technologies, a kind of ICT, to establish their utility in improving construction project operations (Somu, MR et al. 2020).

Other studies are putting a lot of effort into determining what factors affect people's decisions to use or not use ICT (Eliwa, Babaeian Jelodar et al. 2020, Huang, Shi et al. 2020). Yu et al. (2018) investigated the link between better construction management and information and communication technology use in heavy machinery project status, the ICT implementation's acceptability, and the ICT implementation's management are the three most important aspects influencing the equipment ICT advantages (Yu, Peng et al. 2018). A construction management team may have resisted using new technology because they were ignorant of its benefits and uncertain competitive advantage (Yu, Peng et al. 2018). The construction sector in New Zealand is using ICT increasingly, which has resulted in ways of using ICT that are ad hoc and discontinuous (Wilkinson 2001, Chowdhury, Adafin et al. 2019). The least ICT was used in New Zealand for construction administration and on-site execution (Eliwa, Babaeian Jelodar et al. 2020). The New Zealand construction industry's use of information and communication technologies peaked during the second phase (the design phase). It declined during the fourth phase (the project management phase) (Wilkinson 2001, Eliwa, Jelodar et al. 2018).

Studies have shown that information technology may considerably benefit building operations (Rimmimgton, Dickens et al. 2015). However, this depends on the implementation method (Rimmimgton, Dickens et al. 2015). There are few studies on how information and communications technology affect thriving construction organizations' functioning (Alsafouri and Ayer 2018). What little there is tends to be more concerned with project performance than organization performance (Dallasega, Revolti et al. 2020). The study by Whyte et al. (2002) and Chen et al. (2010) is one such. Two studies examining the prevalence of IT in different types of businesses are presented (Whyte, Bouchlaghem et al. 2002, Chen and Huang 2010). They used data from the organization to evaluate how ICT was used on specific projects. The usage of ICT in an organization's processes and procedures impacts project costs and timeliness, according to research by Lhee et al. (2014) (Lhee, Flood et al. 2014). Chang et al. (2017) utilized a construction project as a case study to see how 4D BIM may be used while considering the organization's data (Chang, Yu et al. 2017). The researchers looked at the master critical path scheduling method (CPSM) to identify potential problems (Chang, Yu et al. 2017).

To calculate the ICT use in design and construction firms, Adejimi et al. (2010) employed the ICT barometer structured surveys from the Nigerian construction sector (Adejimi, Oyediran et al. 2010). Computers were mainly employed for archiving internal administrative and management duties (Yu, Peng et al. 2018). ICT tools are, however, used by fewer firms to manage the execution of construction projects, exchange information, and make use of the cloud (Bello, Oyedele et al. 2021). Similar findings emerged from Bello et al. (2021) empirical study, which used instances from the construction industry (Bello, Oyedele et al. 2021). The study's results show that common usage of elementary ICT applications, such as accounting, spreadsheets, word processing, and emailing, was also seen (Bello, Oyedele et al. 2021). However, Besklubova et al. (2021) discovered that large businesses were more likely than smaller businesses to implement the most cutting-edge ICT innovations, including 3D and 4D printing (Besklubova, Skibniewski et al. 2021).

These studies narrowed the attention to a particular ICT project type (Adejimi, Oyediran et al. 2010, AboAbdo, Aldhoiena et al. 2019, Chen, Yin et al. 2019, Bello, Oyedele et al. 2021, Besklubova, Skibniewski et al. 2021). The necessity of employing a variety of ICT tools through considering the alignment of the ICT infrastructure and organizational infrastructure, as well as the organization's expertise with ICT consumption, has not been considered in these studies (Eliwa, Babaeian Jelodar et al. 2020, Eliwa, Jelodar et al. 2022). The current research fills the gap by examining the effects of organizational infrastructure and ICT infrastructure alignment on the performance of construction companies over a larger spectrum of ICT consumption. Yet, very few studies have been conducted to explore the critical effect of function integration as the main factor involving ICT implementation on construction organizations' performance. Considering their unique work characteristics and environment, this study set out to fill this research gap by exploring the impact of the organization and ICT infrastructure on the performance of construction organizations.

7.3 The Strategic Alignment: Functional Integration

Information and communication technology (ICT) has not been appropriately incorporated into traditional business strategy development procedures (Park and Park 2020, Radman, Babaeian Jelodar et al. 2021, Eliwa, Jelodar et al. 2022). Therefore, ICT was often seen as a cost centre or expenditure rather than a source of corporate value (Choe 2016, Radman, Babaeian Jelodar et al. 2021). Strategic alignment throws fresh light on ICT and its function in formulating corporate strategies by considering the appropriate balance between infrastructure and strategy as well as the functional integration of ICT and business (Henderson and Venkatraman 1999, Papp 2001). Strategic alignment tackles infrastructure and strategy issues to create alignment across these four domains by concentrating on business and ICT (Chung, Rainer Jr et al. 2003). Strategic alignment effectively integrates information and communication technology (ICT) in developing company strategy and corporate goals (Adriaanse, Voordijk et al. 2004, Jouirou and Kalika 2004). It continues to be a top worry for business executives, and since the late 1980s, its importance has been widely acknowledged and documented (Henderson and Venkatraman 1999, Papp 2001). It's not always evident how an organization may align business and IT or the effects of misalignment (Jouirou and Kalika 2004).

As shown in Figure 1, the strategic alignment model (SAM) consists of four domains: information technology infrastructure and operations, organizational infrastructure and processes, information technology strategy, and business strategy (Henderson and Venkatraman 1999, Papp 2001). Each has its own core components: infrastructure, skills, and procedures on the inside, scope, competencies, and governance on the outside (Coleman and Papp 2006). Most subsequent alignment models and consulting techniques depart from this underlying concept (Coleman and Papp 2006). They do not provide empirical evidence or a road map for analyzing and enhancing alignment; competitive advantage results from the efficient use of IT as a facilitator of business strategy (Jouirou and Kalika 2004). The SAM model may initiate the alignment of the business and IT approaches (Papp 2001, Jouirou and Kalika 2004). While this model is valuable for understanding alignment components, it does not provide a technique or instructions for establishing alignment (Coleman and Papp 2006).

A vital component of the idea of strategic alignment is the relationships that already exist (Jouirou and Kalika 2004). Because each quadrant and component must work together, these linkages are necessary (Jouirou and Kalika 2004). The first connection is the strategic fit which displays the vertical connectivity of the model (Papp 2001). This connection explains the need for the business or the organization to make decisions that will determine its market position (Coleman and Papp 2006). Strategic fit refers to using strategy to determine a corporation's organizational infrastructure (Henderson and Venkatraman 1999, Papp 2001, Coleman and Papp 2006). The second relationship is functional integration (Henderson and Venkatraman 1999, Papp 2001). It provides the closest connection between business alignment and information and communication technology ICT (Papp 2001, Wetering, Mikalef et al. 2017). Technology must also change along with the business to keep up with the company's operations (Papp 2001). This relationship indicates the business or the organization's capacity to successfully situate itself in the marketplace via information and communication technology ICT (Chung, Rainer Jr et al. 2003). The connectedness or "fit" between these functional domains is the primary emphasis of the strategic alignment strategy (Papp 2001, Choe 2016). According to this fit technique, ICT alignment occurs when all domains simultaneously reach the proper degree of standardization (Papp 2001, Choe 2016). To achieve true strategic alignment, constant and simultaneous attention to all four areas is needed, and this link may give you a competitive advantage and maximize the effects of technology (Papp 2001, Choe 2016, Eliwa, Jelodar et al. 2018).

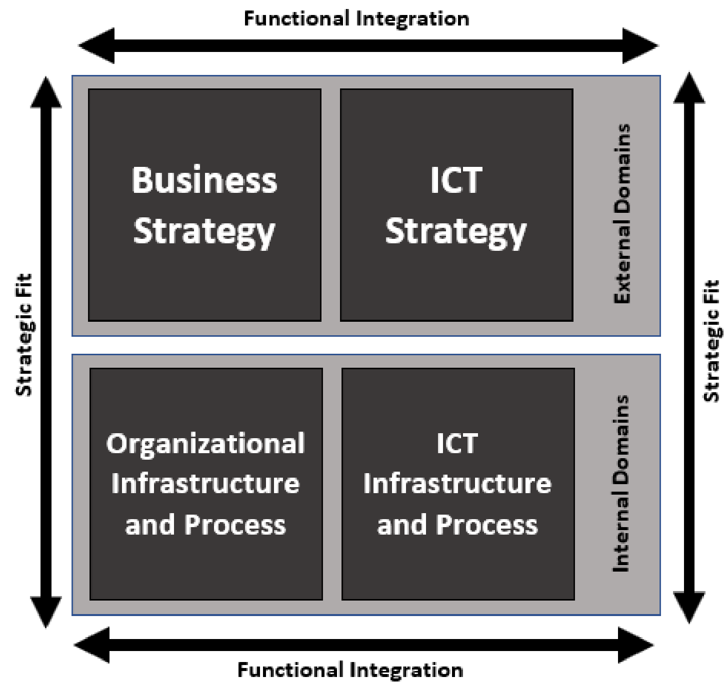

Figure 7.1: The strategic alignment model concept

There are two types of business and information and communication technology ICT integration: ICT's strategic potential is determined by strategic fit, which is the fusion of business and ICT strategies (Henderson and Venkatraman 1999, Papp 2001). The second type is functional integration which forms the relationship between organizational infrastructure or operations and ICT infrastructure or processes (Figure 1) (Henderson and Venkatraman 1999, Papp 2001, Choe 2016). Similar to the ICT infrastructure and organizations, the ICT strategy infrastructure comprises three main components (Choe 2016). The first component of the system is the ICT architecture, which consists of the following elements: Applications (which would be the primary application); Data (which would be the organization's data resources and the provisions for access, use, storage control); Communication, communication channels and the interworking and interlinking systems that go along with them); and Computing (data processing equipment and its corresponding operating system software) (Chung, Rainer Jr et al. 2003, Choe 2016, Wetering, Mikalef et al. 2017, Bhattacharya 2018). Processes, the second component, covers the activities essential to implementing ICT strategic infrastructures, including control systems, monitoring and maintenance, and system development. Lastly, the Skills section discusses the skills and expertise required to effectively manage the business's strategic ICT infrastructure (Tallon 2015, Choe 2016, Pour, Matin et al. 2019, Eliwa, Jelodar et al. 2022).

7.4 The Research Methodology

The structure of the research questions and objectives, the degree of the researcher's control over the data sources or study conditions, and the degree to which the focus is on historical rather than current events are just a few of the variables that must be considered while selecting an appropriate research methodology to meet the study objectives (Pandey and Pandey 2021). Historical approaches might be helpful when the researcher has little control over the data sources. However, experiments are favoured if the researcher can directly, precisely, and consistently regulate the research behaviour (Noor 2008, Pandey and Pandey 2021). On the other hand, the case study technique is chosen when the research involves analyzing current or ongoing occurrences, and the connected behaviour of these events cannot be controlled or altered (Noor 2008). In general, the case study approach will be the ideal option if the research questions are connected to "why" and "how" and the researcher has little influence over the study cases, which is the situation in our research (Noor 2008, Pandey and Pandey 2021).

This study is a qualitative investigation into the effect of the alignment of the organizational infrastructure and ICT infrastructure on the construction organizations' performance. The research methodology involves multiple case studies. To optimize the quantity of knowledge absorbed and learned, it is crucial to choose the appropriate case studies with different situations and characteristics

(Noor 2008). Generally, three kinds of case study methodology are explanatory, exploratory, and descriptive (Pandey and Pandey 2021). This exploratory study is motivated by inquiries about operational problems and things that need to be tracked down and looked at Snyder et al. (2012) claim that the case study technique brings to light the issues that are difficult to define only from experimental data (Snyder 2012). However, it is feasible to plan research based on the case study approach in a particular framework that analyses secondary data (information related to the organization and project) and primary data (organizational infrastructure and ICT infrastructure) (Snyder 2012, Pandey and Pandey 2021). To better understand the use of the functional integration alignment system at the organization level, this research was created and implemented as a qualitative exploratory case study approach, as stated above (Snyder 2012, Pandey and Pandey 2021).

Based on the considerations mentioned earlier, there are three key reasons why this study's case study methodology was chosen. The first is that, depending on the research circumstances, this approach enables comparison between two or more empirical examples in various contexts, determining specific outcomes for this comparison (Snyder 2012). Secondly, this study method must allow data collection suitable for supporting the debate process and lead to a theoretical conclusion (Meyer 2001, Johansson 2007, Snyder 2012). In this type of methodology, the researcher should also explore results associated with a particular place or region; this adds to the generalisability power of the results (Snyder 2012).

As a result, nine construction projects from three distinct New Zealand organizations were chosen. The following criteria guided the selection of the organizations and cases:

- The selected organizations in this study are from the top 10 major construction organizations in the infrastructure and building sector of New Zealand.

- All organizations in this study have stated their plans to integrate ICT and have a history of doing so. Furthermore, each chosen organization has an ICT research and innovation department or similar at any level.
- All selected project cases in this study are considered large infrastructure or building projects in the Auckland area.
- All selected project cases in this study are completed projects and are currently at the operational stage. The as-built project data for all selected cases have been archived in the organization's project history.

Figure 7.2 shows the framework established and developed for analyzing the research case studies.

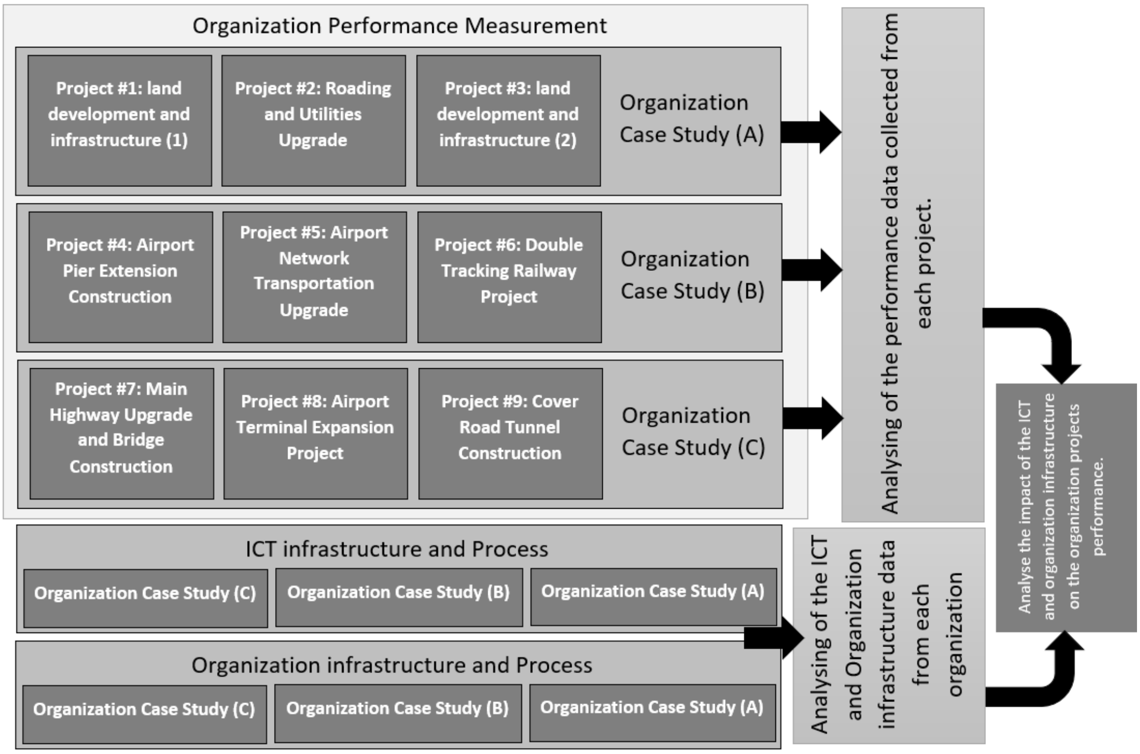

Figure 7.2: The case study methodology framework

Along with the degree of depth of inquiry, the framework shows the connection between the organizations and project instances chosen for this study (Babaeian Jelodar and Shu 2021). As was already indicated, all case study projects have been completed. Therefore, the research period may include the whole project life cycle. When choosing the locations for the case studies, the Auckland area - the largest region in New Zealand - was considered. Most of New Zealand's national construction demand (NCD) is from the Auckland area; government spending on buildings has only climbed by more than 40% from $12 billion in 2015 to $17 billion in 2021 (The Ministry of Business 2021).

7.5 Data Collection

The research topic and goals were used to analyze the ICT deployment and use process in the chosen case study projects. The organizations hosting the selected projects' ICT strategy papers and policies were used to extrapolate the organizations' ICT infrastructure and innovation capacity. Finally, each project's results and performance were assessed using its progress history and performance data. Examining the as-built documentation was part of it, as was comparing the as-built timetable to the project life cycle baseline schedule. In the beginning, this part gives a general description of each organization and project chosen for case studies. This is followed by thorough data analysis on ICT infrastructure, organizational infrastructure, and project performance.

7.5.1 Organization Case Study (A)

The first selected organization in this research is an alliance of organizations established for the construction of build-ready land across various areas in Auckland, New Zealand. It specialises in land development and getting government-owned land ready to build new homes. The alliance also specialises in designing and constructing new or upgraded infrastructure, parks, and public spaces. The alliance's responsibilities include detailed civil works design, the removal of existing houses, existing houses land remediation, arranging planning and engineering consents related to civil and infrastructure works, road construction and park construction. The alliance has over 1,000 employees working over multiple locations in Auckland, New Zealand and manages over NZD 500 million size projects (Paul et al., 2020; Rohani et al., 2019).

7.5.2 Organization Case Study (B)

The second organization selected in this study is considered one of the largest construction organizations in New Zealand. This organization has been providing engineering services in all types of construction, including building and infrastructure, over New Zealand and Australia for decades. This organization works in over 120 locations in New Zealand with over 10 thousand full-time employees, and its operating income has been estimated at over NZD 13 billion. Globally, the organization manages projects in Australia and South Pacific with over 60 thousand employees and over USD 50 billion operating income (The Ministry of Business, 2021).

7.5.3 Organization Case Study (C)

The last organization used as a case in this study was a construction firm started in New Zealand in 1909 with a two-story wooden building in Otago as its first project. This organization has a strong history in New Zealand with their special and landmark projects. This organization was operating under a different name until it changed to its current name in 1940 and was listed on the share market. The organization has over 4000 employees working in various locations across New Zealand. During their history, this organization has practically completed over 90 major infrastructure and building projects, in addition to small- and medium-sized projects, all over New Zealand. Moreover, it has been identified as the first overseas organization working on the modernization and development of the South Pacific (Baker, 2002; The Ministry of Business, 2021; Zealand, 2018).

7.5.4 ***Project Case Study (1)***

The first project case study selected in this research was managed and completed by the organization (A). The project is a land development and infrastructure project with a total cost of over NZD 100 million. The entire project duration to the practical completion, including development, design, construction, and final handover, was 25 months, from February 2020 to August 2022. The main scope of this project was to design and develop a residential area, including demolition of existing houses, remediation of the house area, new utilities and services installation, stormwater network improvement, public park construction, roading, footpath construction and landscaping works (Piritahi, 2022a).

7.5.5 ***Project Case Study (2)***

Another project managed by the organization (A), this project was completed in 16 months, from April 2021 to the end of July 2022, costing over NZD 70 million. This project's scope was to design and construct the utility infrastructure of the developing area, including installing and connecting 30 stages of watermain networks in 10 different roads. The project scope also involves installing over 900m of stormwater lines, electric services, communication networks, roading reinstatement, footpath construction and berm and landscaping finishing (Oranga, 2021).

7.5.6 ***Project Case Study (3)***

The third case study in this research, also managed and completed by organization (A); has the same construction scope as the first project study but in a different neighbourhood in the Auckland region. The project is also related to land development and infrastructure, but it is smaller in scope than the first project in this study, with a total cost of over NZD 60 million. The total project duration, including the design and construction, was 13 months from early August 2021 to the end of August 2022. As the first project case study, this project involved the design and the construction of the infrastructure work in a new developing neighbourhood area in south Auckland and all related works regarding that, including service utility installation, construction of a new stormwater line, roading construction, walkways construction and landscaping works (Toomey et al., 2021) (Piritahi, 2022b).

*7.5.7 **Project Case Study (4)***

This project case study is the first case study in this research that has been managed and completed by the organization (B). The main scope of this case was constructing a 350m airport pier extension at the Auckland international airport that connect two stands to the international terminal with two new gates, four new airbridges, associated boarding facilities and a multi-aircraft ramp system capability. The primary purpose of this project is to allow two flights to land simultaneously on one stand. It was a crucial development in meeting the solid demands of increasing the passengers and flight capacity. The project also involves extending the existing airport fuel system, expanding the existing building to improve the passengers' seating area and providing access from the newly constructed area to the other airport floors. This project was completed in about 24 months, from February 2016 to mid-February 2018, costing over NZD 90 million (Philp, 2018).

*7.5.8 **Project Case Study (5)***

The second project case study selected in this research by organization (B) is “Airport Network Transportation Upgrade”. The main project scope was the upgrading of the airport substance road networks, including the widening of the main motorway leading to the international airport, upgrading the shared pathway, upgrading the utility services, constructing new stormwater lines, and decreasing the pressure on the highway by the construction of new service roading network. The total cost of this project was about NZD 100 million, and the overall project duration to the practical completion was about 26 months, from August 2019 to September 2021. The primary purpose of this project was to increase the road capacity leading to the largest international airport in New Zealand to over 200,000 vehicles per day (AIAL, 2021; Weeks, 2019).

7.5.9 Project Case Study (6)

The last case study selected from organization (B) is a double-tracking railway project. This project case is one of the most significant projects delivered by the New Zealand governmental rail network firm, and it involved the construction of about 3 kilometres of double-tracking railway between two main cities in New Zealand, enabling trains in this line to travel in both directions at the same time and deliver more continual and effective services. The project also involves the construction of four new station platforms, improvements of the railway level crossing, upgrades of two existing rail stations, construction of the stations' shelters, and construction of a new pedestrian and cycleway underpass. The total cost of this project was over NZD 60 million, and the overall project duration to the practical completion was about 23 months, from early May 2020 to the end of March 2022 (Wellington, 2022).

7.5.10 Project Case Study (7)

For the organization case study (C), the main Highway upgrade and bridge construction project has been selected in this research as the first project case to study for this organization. An alliance mainly managed the project, a group of organizations working together, including the main project client to deliver the project, sharing the project's costs, and managing the risks under the main contractor's management. The responsibility of organization (C) in this project was mainly the construction and the delivery of the project expansions from the south and the north. However, for this project, the organization (C) was part of the project alliance providing ICT infrastructure support, provisional management consultation, and project coordination. The main project scope was to widen a 5 km long highway and upgrade the motorway infrastructure to improve one of the main motorways in the Auckland region in New Zealand that links the western cities to the central city. The project involved constructing two bridges, upgrading a stormwater line, and modifying and upgrading the cycleway. The total cost of this project was over NZD 220 million, and the final project duration to the practical completion stage was about 36 months, from November 2013 to December 2016 (Corbett, 2018; Corbett & Watterson, 2016).

7.5.11 ***Project Case Study (8)***

The eighth project case study and the second case study from organization (C) selected in this research is an airport terminal expansion project. This project is the biggest stage of the airport multistage development projects for an international airport in the Auckland region in New Zealand which involved increasing the size of the international terminal departure processing zone, passenger lounge and retail hub areas. The main project scope was the construction of a new passengers processing hall, expansion of the passengers' lounge zone, reconfiguration of the farewell area, the construction of a new security screening zone, and essential upgrading of the duty-free retail regions. This project was completed in about 32 months, from early March 2016 to the end of October 2018, costing over NZD 220 million (Philp, 2018; Scott-Woods, 2011).

7.5.12 ***Project Case Study (9)***

This research's final selected case study is the largest-sized project compared to the previous cases mentioned above. It involved the construction of a covered road tunnel in the Auckland region of New Zealand. This project was managed and delivered by the organization (C), and it created safer and faster journeys for an additional 150,000 vehicles a day from Auckland's central city to the other Auckland region cities. The total cost of this project was over NZD 410 million, and the construction project duration to the completion of the physical works was about 29 months, from early November 2009 to the end of March 2012. The main scope of this project was the construction of half a kilometre three lanes cut-and-cover tunnel and a widening of the existing motorway on both sides of the tunnel, including all related construction activities such as cycleway upgrading, retaining walls construction and a new stormwater line installation (Cudby, 2010; McDonald et al., 2011).

7.5.13 Project Performances Data and Analysis

The organization performance reports, monthly project reports, and as-built project schedules are just a few examples of the internal project history documents mined for information on the performance of each case study project in this research. For the total performance calculation, the Duration Performance Index technique (DPI) has been used in this study (Khamooshi and Golafshani 2014, Votto, Lee Ho et al. 2020).

Earned Value Management (EVM) is an effective method for monitoring schedule adherence (Kim, Wells Jr et al. 2003). However, since EVM estimates depend on the project cost, they may be deceiving when used to gauge how long a project takes to complete. Earned Value Management (EVM) produces erroneous results because it fails to account for the correlation between schedule performance and costs (Kim, Wells Jr et al. 2003). Earned Duration Management (EDM) provides a more accurate indicator for schedule performance that eliminates these problems (Lipke, Zwikael et al. 2009, Khamooshi and Golafshani 2014). According to the findings, it is advised to use statistical quality control charts to monitor the duration performance index of the EDM (Khamooshi and Golafshani 2014).

Another challenge is inaccurate projections due to activity adjustments to address project delays. Since project managers and construction control engineers rely heavily on schedule performance measurements, this research considers the Duration Performance Index (DPI) as the primary instrument to analyze and monitor project activities (Khamooshi and Golafshani 2014, Votto, Lee Ho et al. 2020). The duration performance index for a project is a metric for evaluating how well tasks are completed on time. The Duration Performance Index (DPI) can be calculated using the following equation (Eq. 1) (Khamooshi and Golafshani 2014, Votto, Lee Ho et al. 2020):

$$DPIi = \frac{EDi}{ADi}$$

Where (EDi) represents the Earned duration or the planned duration of Task (i) as of the measurement date of (DPIi) from the baseline schedule, and (ADi) represents the actual duration spent on Task (i). Therefore, if the DPI value is greater than 1, then the project is doing well and progressing more quickly than predicted (Khamooshi and Golafshani 2014). On the other hand, if the value of DPI is less than 1, the project can be considered behind schedule and delayed (Khamooshi and Golafshani 2014, Votto, Lee Ho et al. 2020). However, when a project progresses according to the plan, the schedule will balance out at 1. It reveals how effectively the Task is being completed (Khamooshi and Golafshani 2014, Votto, Lee Ho et al. 2020). Table 7.1, Table 7.2, and Table 7.3 summarise the collected projects' performance data which have been collected from the three organizations used as cases in this study.

To determine the project's actual duration, baseline duration, and delays, we used a time scale of working days, considering the locally permitted working calendars defined by the selected case study organization (Gonzalez, González et al. 2014). Client-accepted causes of delay, such as a change in scope or design, are not the contractor's responsibility and are not compensable delays (Gonzalez, González et al. 2014). Further, the client-approved time and cost variance was the sole factor in the compensable delays (Meng 2012). Delays caused by factors beyond the project's control, such as productivity issues, inadequate management, a shift in project management, difficulties sourcing materials, or problems with subcontractors, are not compensable (Meng 2012). To plan for the potential of rain, a specific wet weather calendar assignment or a risk on the building activity was included in the calendar for every exterior infrastructure project (Gonzalez, González et al. 2014). This included most pavement works, structures, and earthworks (Gonzalez, González et al. 2014). Reducing the potential for project delays caused by rainy days requires including a wet weather estimate in the schedule (Gonzalez, González et al. 2014).

Table 7.1: Projects' performance data for the organization case study (A)

Project Name	Actual Start Date	Actual Finish Date	Baseline Finish Date	Actual Duration	Baseline Duration	Variance Duration	Non-Compensable Delay	Compensable Delay	Revised Baseline Duration	DPI	Reasons for Compensable Delays
Project #1: land development and infrastructure (1)	10 Feb 2020	12 Aug 2022	16 Dec 2021	564	421	−143	−90	−53	474	0.84	EPA (design amendment) COVID-19 Change request/additional scope
Project #2: Roading and Utilities Upgrade	06 Apr 2021	29 Jul 2022	10 Jun 2022	301	267	−34	0	−34	301	1.00	EPA (design amendment) COVID-19
Project #3: land development and infrastructure (2)	09 Aug 2021	05 Aug 2022	31 Aug 2022	217	235	+18	+18	N/A	235	1.08	N/A
Organization Case Study (A)				**1082**	**923**	**-159**	**-72**	**-87**	**1010**	**0.93**	

Table 7.2: Projects' performance data for the organization case study (B)

Project Name	Actual Start Date	Actual Finish Date	Baseline Finish Date	Actual Duration	Baseline Duration	Variance Duration	Non-Compensable Delay	Compensable Delay	Revised Baseline Duration	DPI	Reasons for Compensable Delays
Project #4: Airport Pier Extension Construction	08 Feb 2016	16 Feb 2018	29 Jun 2018	438	514	+76	+76	N/A	514	1.17	N/A
Project #5: Airport Network Transportation Upgrade	12 Aug 2019	24 Sep 2021	25 Feb 2021	531	386	−145	0	−145	531	1.00	COVID-19 Change request/additional scope
Project #6: Double Tracking Railway Project	04 May 2020	25 Mar 2022	10 Dec 2021	421	365	-56	-24	-32	397	0.94	COVID-19 Change request/additional scope Relocation of public service
Organization Case Study (B)				**1390**	**1265**	**-125**	**+52**	**-177**	**1442**	**1.04**	

Table 7.3: Projects' performance data for the organization case study (C)

Project Name	Actual Start Date	Actual Finish Date	Baseline Finish Date	Actual Duration	Baseline Duration	Variance Duration	Non-Compensable Delay	Compensable Delay	Revised Baseline Duration	DPI	Reasons for Compensable Delays
Project #7: Main Highway Upgrade and Bridge Construction	04 Nov 2013	15 Dec 2016	29 Feb 2016	779	580	−199	−51	−148	728	0.93	design amendment Change request/additional scope
Project #8: Airport Terminal Expansion Project	07 Mar 2016	31 Oct 2018	16 Feb 2018	663	487	−176	−48	−128	615	0.92	COVID-19 Change request/additional scope
Project #9: Cover Road Tunnel Construction	02 Nov 2009	30 Mar 2012	31 Aug 2011	459	325	-128	-128	0	325	0.71	N/A
Organization Case Study (C)				**1901**	**1392**	**-503**	**-227**	**-276**	**1668**	**0.87**	

7.5.14 Data Collection of the ICT infrastructure and Process

Information on ICT infrastructure has been extracted from internal documents of the organizations used in this research, particularly from each organization's innovation department (Rad and Rowzan 2018, Eliwa, Babaeian Jelodar et al. 2020, Eliwa, Jelodar et al. 2022). Table 4 summarises the information gathered and categorized from each organization's case study on the ICT infrastructure level. The following classifications have been developed from this categorization and classified as the main criteria, which consider the most critical variables that might have an impact on an organization's overall ICT infrastructure level from other studies and research (Amusan Lekan, Oloniju Leke et al. 2018, Eliwa, Jelodar et al. 2018, Rad and Rowzan 2018, Eliwa, Babaeian Jelodar et al. 2020, Eliwa, Jelodar et al. 2022):

- IC01: Data centre infrastructure/hardware (including servers; storage subsystems; networking devices, such as switches, routers, and physical cabling; and dedicated network appliances, such as network firewalls)
- IC02: Internet infrastructure, including fibre optic
- IC03: Cloud-based infrastructure
- IC04: Training systems
- IC05: ICT support systems
- IC06: Software upgrading systems
- IC07: ICT hardware for the organization's staff
- IC08: Distance working facility for the organization's staff

Moreover, the ICT application utilization categorization - as one of the main factors that affect the ICT infrastructure strength level – has been collected from other studies and classified as the following (Adriaanse et al., 2004; Eliwa et al., 2018; Hasan et al., 2019; Padayachee & Shano, 2019; Plantinga et al., 2020; Rad & Rowzan, 2018):

- A01: Sharing tools, cloud storage, and web conferencing: this collection includes the communication technology tools which facilitate the organization or project communication and information sharing system.
- A02: Job-site data collection and reporting: this collection covers the most common usage of software or tools in any project size, which involves the daily reporting support tools and can be used by non-professional construction teams.
- A03: Computer-aided drafting (CAD): CAD systems provide drawing entities with robust construction, editing, and database techniques to produce drawings and models of what buildings will look like when finished.
- A04: Planning and project management: this collection covers software or tools that allow managing complicated business processes by planning, organizing, and managing the various resource pools available.
- A05: Building information modelling (BIM): BIM software can directly and interactively present design concepts in a form that represents physical and natural images of the building to allow designers to identify clients' needs and provide solutions to these needs promptly and effectively.

The rating system in Table 7.4 (Low, Medium, and High) was established to assess the extent to which each category is put into practice inside the organization (Eliwa et al., 2018; Eliwa et al., 2022; Hasan et al., 2019; McAdam et al., 2019). According to the grading scheme, the organization receives a "High" rating for any of the factors for a certain ICT class if it consistently applies that class to all its initiatives (Eliwa et al., 2018; McAdam et al., 2019; Plantinga et al., 2020). Thus, a "Medium" grade has been assigned in case the organization uses this classification on more than half of its projects or in a medium capacity inside the organization (Eliwa et al., 2018; McAdam et al., 2019). Finally, the ranking has been judged to be "Low" if the business has applied the given class in less than 20% of its projects or if the classification has a minimum implementation inside the organization (Chau et al., 2020; Eliwa et al., 2018; McAdam et al., 2019). Other studies have also been used as a reference to the rating assignment on each ICT infrastructure strength factor (Adriaanse et al., 2004; Eliwa et al., 2018; Eliwa et al., 2022; McAdam et al., 2019; Padayachee & Shano, 2019; Plantinga et al., 2020; Rad & Rowzan, 2018).

Table 7.4: Data Collection of the ICT infrastructure for each organization and the rating system

ICT infrastructure and Process strength criteria	Organization Case Study (A)	Organization Case Study (B)	Organization Case Study (C)
IC01: Data centre infrastructure/hardware	***[High]*** the full system applied in all projects and the organization	***[High]*** the full system applied in all projects and the organization	***[High]*** The full system is applied in all projects, and the organization
IC02: Internet infrastructure	***[High]*** the full system applied in all projects and the organization	***[High]*** the full system applied in all projects and the organization	***[High]*** The full system is applied in all projects, and the organization
IC03: Cloud-based infrastructure	***[Mid]*** Cloud-based inf applied in the organization and some of its projects	***[High]*** the full system applied in all projects and the organization	***[Mid]*** Cloud-based inf applied in the organization and some of its projects
IC04: Training systems	***[Mid]*** Technical training and ICT training are available for popular systems and can be provided for special systems in request	***[Mid]*** Technical training and ICT training are available for popular systems and can be provided for special systems in request	***[Mid]*** Technical training and ICT training are available for popular systems and can be provided for special systems in request
IC05: ICT support systems	***[Mid]*** Fundamental support system / not all ICT systems support is outsourcing and hardware support in house	***[Mid]*** Fundamental support system / not all ICT systems support is outsourcing and hardware support in house	***[Low]*** Fundamental support system / ICT systems support is outsourcing and hardware support in house
IC06: Software upgrading systems	***[High]*** The organization has an automatic ICT upgrading system notification and automatic upgrading approval	***[Low]*** Tough to get ICT software updated with a complicated approval process – Cost and budgeted issue	***[High]*** The company policy urges the ICT support to provide the up-to-date version of all ICT tools available with a regular check every six months
IC07: ICT hardware for the organization's staff	***[High]*** All organization staff have their own laptop from the first day with a regular upgrade facility	***[High]*** All organization staff have their own laptop from the first day with a regular upgrade facility	***[Low]*** Some organization staff have their own laptop, but the upgrade facility is very limited
IC08: Distance working facility	***[Mid]*** The organization provides distance working support but not support for the special hardware and networking	***[High]*** Very high distance working support system including hardware and networking	***[Low]*** Very limited distance working support system
A01: Sharing tools, cloud storage, and web conferencing	***[High]*** These ICT applications are applied in all projects, and the organization	***[High]*** These ICT applications are applied in all projects, and the organization	***[High]*** These ICT applications are applied in all projects, and the organization
A02: Job-site data collection and reporting	***[High]*** These ICT applications are applied in all projects, and the organization	***[High]*** These ICT applications are applied in all projects, and the organization	***[High]*** These ICT applications are applied in all projects, and the organization
A03: Computer-aided drafting (CAD)	***[Low]*** Two ICT applications under this cat are available in just some organization departments	***[High]*** variety of this ICT application available in this organization by default in some departments and by request in other departments	***[Low]*** Two ICT applications under this cat are available in just some organization departments
A04: Planning and project management	***[High]*** variety of this ICT application available in this organization by default in some	***[High]*** variety of this ICT application available in this organization by default in some	***[Mid]*** Planning ICT applications are available at an acceptable level,

	departments and by request in other departments	departments and by request in other departments	but the other project management ICT is very limited
A05: Building information modeling (BIM)	***[Low]*** There is no actual BIM system available in this organization, and all requested BIM projects by the client were outsourcing	***[Mid]*** The BIM system is adopted in this organization, but it is limited and under development	***[High]*** The organization has made good progress in applying the BIM system for its large-size projects, especially using the 4D and 5D planning technology

7.5.15 Data Collection of the Organizational infrastructure and Process

Similar to the ICT infrastructure information, the organizational infrastructure data has been gathered from the case study organizations' documentation and the organisations' senior professionals in different organization departments (Eliwa et al., 2020; Rad & Rowzan, 2018).

Table 7.5: Data Collection of the organizational infrastructure and Process for each organization and the rating system

Organizational infrastructure and Process strength criteria	Organization Case Study (A)	Organization Case Study (B)	Organization Case Study (C)
OC01: ICT application implementation is part of the organization's annual budget	***[Low]*** There is no consideration of the ICT implementation and development in the organization's annual budget	***[Mid]*** ICT implementation is mentioned as a part of the P & G section in the firm budget	***[Low]*** There is no consideration of the ICT implementation and development in the organization's annual budget
OC02: innovation/ICT department is part of the organization's structure	***[Mid]*** The organization just own a general/basic ICT support department	***[High]*** The organization has an innovation and IT development department in addition to the default ICT support department	***[Mid]*** The organization just own a general/basic ICT support department
OC03: ICT skills that the organization has	***[Mid]*** As identified by the organization's HR, the organization has less than five skills at a senior level	***[Mid]*** As identified by the organization's HR, the organization has less than five skills at a senior level	***[Mid]*** As identified by the organization's HR, the organization has less than five skills at a senior level
OC04: ICT/cyber security is part of the organization's policy	***[High]*** ICT/cyber security is part of the organization's policy and training service. Also, the ICT department is up to date with any ICT security level for the low to high-risk level	***[High]*** ICT/cyber security is part of the organization's policy and training service. Also, the ICT department is up to date with any ICT security level for the low to high-risk level	***[Mid]*** ICT/cyber security is not part of the organization's policy, but there is limited security training by the organization for new employees. There is a consideration by the ICT department regarding the cyber security issues
OC05: the organization uses an online system for communication, reporting and requests	***[High]*** Online communication is the default communication system in the organization. Some examples of this system: • Using the MS Team for general staff chat and announcements • Email system for all communication and sharing • Sharepoint server for file sharing • 12d Synergy for docs sharing and submittals	***[High]*** Online communication is the default communication system in the organization. Some examples of this system: • Using the MS Team for general staff chat and announcements • Email system for all communication and sharing • Sharepoint server for file sharing • Oracle Aconex for docs sharing and submittals	***[High]*** Online communication is the default communication system in the organization. In addition to the MS Team, email, and dropbox, the organization has it is own private communication application and system

OC06: ICT department support duration/resolved issue vs on hold issues	***[Mid]*** The average support ticket resolution time is more than 16 working hours, and 12% of the support ticket closed without a solution or waiting for third-party feedback	***[Mid]*** The average support ticket resolution time is more than 16 working hours, and 7% of the support ticket closed without a solution or waiting for third-party feedback	***[Low]*** The average support ticket resolution time is more than 30 working hours, and more than 18% of the support ticket closed without a solution or waiting for third-party feedback
OC07: Inside organization digital assets	***[High]*** Digital assets include – but are not limited to - high standard audio and visual service in all meeting rooms, a varied range of monitor and desktop equipment, high standard security system, digital registration system etc	***[High]*** Digital assets include – but are not limited to - high standard audio and visual service in all meeting rooms, a variety range of monitor and desktop equipment, high standard security systems, digital registration system etc	***[High]*** Digital assets include – but are not limited to - high standard audio and visual service in all meeting rooms, a varied range of monitor and desktop equipment, high standard security system, digital registration system etc

These collected data types were based on the literature considering the main factors determining the strength of the organisational infrastructure (Eliwa et al., 2018; McAdam et al., 2019; Rad & Rowzan, 2018). Table 7.5 summarises the information gathered and categorized from each organization's case study on the organizational infrastructure level. Based on Table 7.5, the classified data related to the factors that - based on the literature - have a direct effect on the strength of the organizational infrastructure domain in the strategic alignment model as the following (Adriaanse et al., 2004; McAdam et al., 2019; Rad & Rowzan, 2018):

- OC01: the consideration of the ICT application implementation in the annual organization's budget or as a part of the internal projects’ budget for the selected organization (McAdam et al., 2019).
- OC02: The organization owns a special department for ICT technology and development, which could be called an innovation department, ICT department, or similar, and this department is part of this organization's structure, considering that the ICT support department can be regarded as a medium level of the organizational infrastructure strength (Chau et al., 2020; Eliwa et al., 2018).
- OC03: This factor is related to the volume of the ICT skills that the organization owns, the level of these skills experience, and the professional level of these skills (Plantinga et al., 2020).

- OC04: There is a section in the organization's policy regarding the ICT and cyber security training, utilization, development, and monitoring process (Chi et al., 2020).
- OC05: This factor is related to the method of communication that the organization adopted between the employees. To apply this factor in a high rating, a standard online communication and reporting system has to be the default communication method for the organization's staff, from the basic utilization using the emailing system to the advanced communication application such as the Aconex system (Adriaanse et al., 2004; Eliwa et al., 2018; McAdam et al., 2019).
- OC06: One of the main factors that rating the organizational infrastructure strength is the level of professionality that the ICT support department in the organization has and the ability of this department to solve the most critical ICT and security issues in an acceptable timeframe that minimizes or eliminate the effect of this issue on the ICT structure inside the organization (Chau et al., 2020; Chi et al., 2020).
- OC07: The final factor in this research in determining the organizational infrastructure strength is the volume or size of the organisation's digital and ICT assets. These assets could be ICT software, ICT applications, digital equipment, digital transformation system, or other digital supporting systems (Eliwa et al., 2018; McAdam et al., 2019).

The same rating system in terms of Low, Medium, and High has been used for the organizational infrastructure as well, which is presented in Table 7.5 to assess the extent to which each of the above organizational infrastructure categories is put into practice inside the organization (Eliwa et al., 2018; McAdam et al., 2019). Likewise, according to this grading scheme, the organization receives a "High" rating for any of the factors for a particular ICT class if it consistently applies that class to all its initiatives (Chi et al., 2020; Eliwa et al., 2018; McAdam et al., 2019). Consequently, a "Medium" rating has been assigned in case the organization uses the specific category at a medium or less level considering other studies and research considerations (Chau et al., 2020; Eliwa et al., 2018). Finally, the “Low” ranking level has been considered if the requirements of the above categories or factors are not applied or have been considered in a low value in other studies (Eliwa et al., 2018). Thus, other studies have also been used as a reference to the rating assignment on each organizational infrastructure strength factor (Adriaanse et al., 2004; Chau et al., 2020; Chi et al., 2020; Eliwa et al., 2018; McAdam et al., 2019).

7.6 Discussion

Based on the performance data for each organization in this study; organization (B) performed better compared to other organizations. The performance for each organization was determined by an empirical evaluation of the case studies' projects associated to each organisation and presented in Table 7.1 to 7.3. Based on that and based on Tables 7.1, 7.2 and 7.3, it can be concluded that the performance results of organization (A) are better than the performance results of organization (B).

On the other hand, it can be observed that the organization (A) and the organization (B) have better rating in terms of the ICT infrastructure and the organizational infrastructure compared with the organization (C) (Table 7.4 and 7.5). This high rating results in both ICT infrastructure and organizational infrastructure in the same organizations' case study can be translated as an existing functional integration alignment in these organizations (Eliwa et al., 2022; Henderson & Venkatraman, 1999; Jouirou & Kalika, 2004). Moreover, the good performance results for these organizations with optimal functional integration alignment could signify a direct or indirect relationship between the organization's performance and the organization's strategic alignment level (Eliwa et al., 2022; Park & Park, 2020; Wetering et al., 2017).

Figure 7.3 visually uses the radar charts comparing the strength of the ICT and organizational infrastructure for this study's three organizations' cases considering the factors codes presented in Table 7.4 and Table 7.5. Based on Figure 7.3, organization (B) has a broader rating than organization

(A) and organization (C) in the ICT infrastructure, with the only weakness in the software upgrading system in this organization. On the other hand, organization (A) and organization (B) have the same level of strength in the organizational infrastructure, which is generally wider than the organization (C). To present the rating of each factor on the charts in Figure 7.3, a scaling system has been used from 1 to 3 level to reflect the rating of these factors from low to high (Chi et al., 2020; Eliwa et al., 2018; McAdam et al., 2019).

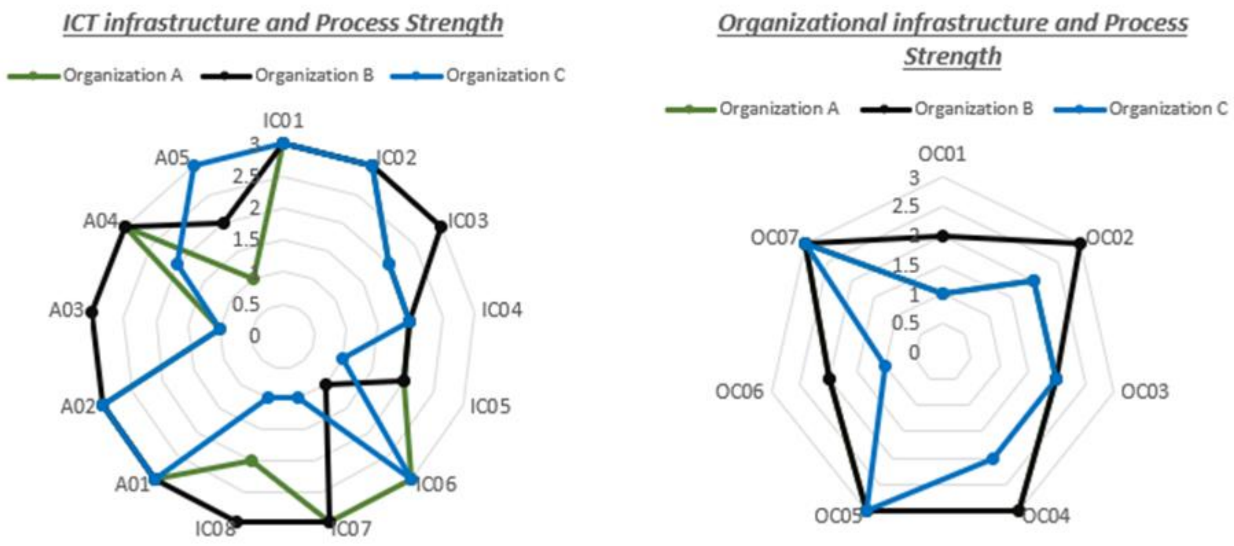

Figure 7.3: ICT infrastructure and organizational infrastructure strength for the organizations' study cases

In general, the ICT support system and the ICT training system are the weakest factors of ICT infrastructure amongst all organizations considered in this study. However, a common and strongest ICT infrastructure factor in these cases was the availability of an exemplary data centre infrastructure, including the related hardware as well as the stable internet infrastructure. From the ICT utilization point of view, the most common ICT application usage in the construction organization – considering the limitation of this study – are the sharing tools category, including the cloud storage applications and the applications related to the Job-site data collection and reporting.

Regarding the organizational infrastructure factors, the construction organizations - considered in this study - demonstrated availability of good level of online communication system (OC05 in Table 7.5). This communication system factor is referred to the strength of the online communication internally inside the organization and externally between the organization's projects. On the other hand, these organizations still need to consider creating a solid ICT support department as one of their weaknesses; this can effectively solve critical ICT issues in the organization and indirectly improve the general work performance. Another issue may be unavailability and inclusion of ICT implementation budget organizations' annual budget, which could limit approval and utilisation of ICT tools.

A bubble chart illustrates a general numerical assessment of the collected case study data in Figure 7.4. This provides insight into how well each organization's ICT infrastructure aligns with its organizational infrastructure, how ICT was utilized inside those organizations, and how effective that alignment is on the organisation's performance and outcomes (Onorati et al., 2018). This was accomplished by considering the average ICT infrastructure and process strength, the average organization infrastructure and process strength, and the organization DPI value for each organization (Figure 7.4). The numerical conversion of the case study data was illuminating using the DPI value for the performance calculation and a scaling system which has been used from 1 to 3 level to reflect the average rating of ICT infrastructure and organizational infrastructure from low to high (Table 7.4 and Table 7.5), even though the data was acquired in various ways and has been individually examined (Johansson, 2007; Pandey & Pandey, 2021). This is particularly true if a large variety of data is gathered, and all of it has to be analysed together to provide a single result (Johansson, 2007; Pandey & Pandey, 2021). As a result, Figure 4 bubble chart was created using a scale devised for ICT infrastructure and organizational infrastructure categorization from each organization. Therefore, the above rating system, which has been discussed in section 7.5.14 and presented in Table 7.4 and Table 7.5, has been considered for bubble chart creation (Coleman & Papp, 2006; Eliwa et al., 2022). Based on Figure 7.4, organization (B) has an acceptable alignment between their organizational infrastructure and ICT infrastructure, and concurrently, it has achieved a satisfactory performance result. On the other hand, the organization (C) case study has lower performance outcomes than the previous cases in the research and has been delivered using less alignment of ICT infrastructure and organizational infrastructure.

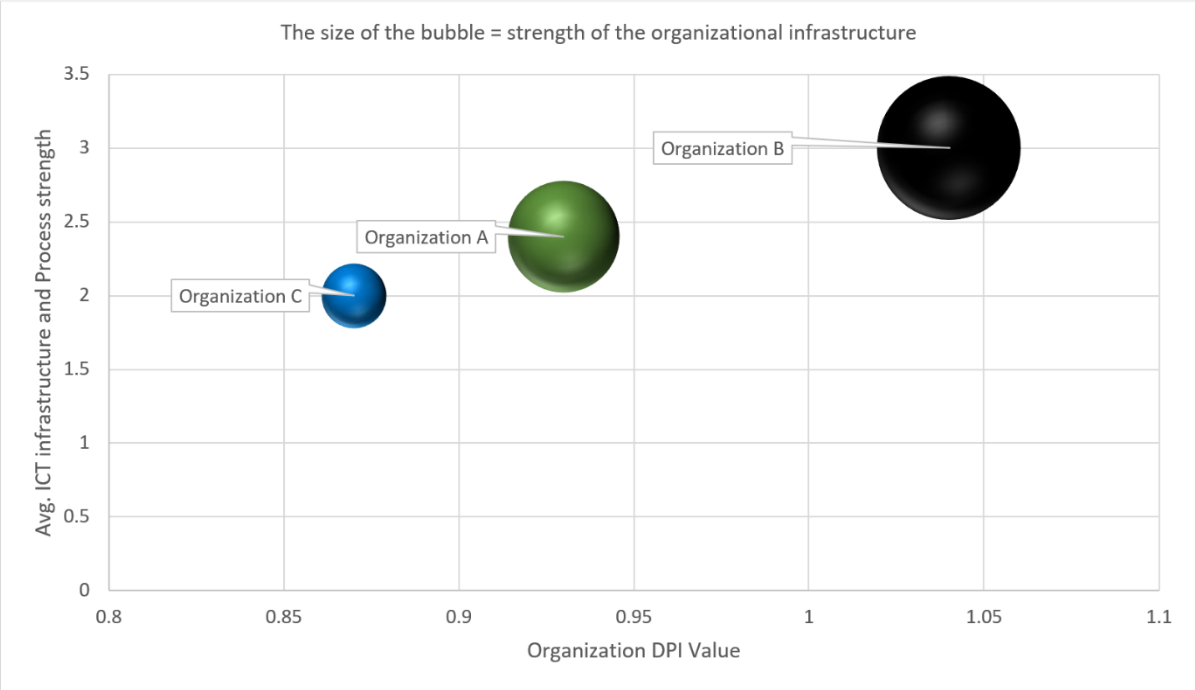

Figure 7.4: The relationship between the alignment of the ICT and organizational infrastructure and the organization's performance

Based on the research findings, a well-aligned strategic alignment between the organization's ICT infrastructure and its organizational infrastructure is essential in facilitating the organization's project delivery and enhancing its outcomes (Bhattacharya, 2018; Eliwa et al., 2018; Eliwa et al., 2022). However, many other factors, including the experience of the construction teams, the availability of resources, the management of the organization's staff, the frequency of management changes, the level of the organization's management, and the working conditions, also affect the organization's performance (El-Mashaleh et al., 2006; Eliwa et al., 2022; Park & Park, 2020; Poshdar et al., 2018). High or poor performance cannot be attributed only to the degree of ICT strategy alignment (Eliwa et al., 2018; Padayachee & Shano, 2019; Rimmimgton et al., 2015).

Another application of this research is to use it as a decision support system (DSS) for the construction organization to improve the organization outcomes and then as an executive support system (EIS) for the senior managers in the organizations to take decisions that assist the organization in achieving its strategic goals (Jelodar et al., 2014; Wahono & Ali, 2021).

Thus, an additional empirical study is needed to determine the impacts of proper alignment between ICT infrastructure and organizational infrastructure from other locations and working conditions. Finally, this study can analyse the effect of efficient functional integration on an organization's performance in the construction industry, which leads to optimal strategic utilization. These empirical studies provide information that the construction industry may use to improve project delivery quality, timeliness, and cost-effectiveness, all while maintaining stakeholders' satisfaction.

7.7 Conclusions

This research used a diagnostic approach to case studies and investigated how the strategic alignment between the organizational and ICT infrastructure affects the organization's performance. The research focused on three major construction companies in Auckland, New Zealand, with three project cases chosen for each organization. Historical information about the projects' performance, ICT adoption, ICT infrastructure level, and organizational infrastructure data was acquired. In addition, to study and compare the functional integration and performance indicator results, a radar and a bubble analysis histogram were used.

Numerous case study techniques, including looking at previous data and projects, were used to investigate and present the findings. Strategic alignment between ICT infrastructure and organizational infrastructure may enhance the organization's performance if the organization's project conditions are optimum. The findings of this study have real-world applications and can be used to examine how the optimum strategic use of ICT might improve project performance in the construction sector. Organizations in the construction industry may benefit from the described methods by improving the strategic alignments between their infrastructure and their use of ICT. By doing so, businesses are able to get a deeper appreciation for the roles that ICT infrastructure and resources play in boosting project success. On the other hand, case study feedback may help pinpoint less efficient ICT and organizational infrastructure and make way for more objective and project-based results.

Additionally, this is one of the few studies that examine the challenges of strategic ICT alignment in the construction industry. This expands our understanding of how to use and make use of cutting-edge technologies in the construction industry. Moreover, a strategy for analyzing and tracing the presence of ICT and organizational infrastructure has been presented. Thus, construction industry research may further investigate this using various research approaches or extensive empirical investigations in multiple places and study situations.

An in-depth investigation of the ways in which strategic fits and their relation to functional integration might boost project success would be highly beneficial for future research and education suggestions. Further study may, for instance, contrast conventional management initiatives with cutting-edge, technology-driven alternatives. Moreover, methodological research is required to understand how integrating other strategic alignment domains influences project results. Different methodologies could include structured interviews or focus group gatherings with construction management experts. Longitudinal studies attempting to quantify the effect of ICT deployment on various construction projects and organizations of varying sizes would be beneficial, despite the methodological challenges they would provide.

Construction organizations can enhance strategic alignments between organizational infrastructure and ICT infrastructure based on the approaches discussed. This allows organizations to better understand the functions of ICT applications and infrastructure in improving organizational outcomes and performance. Inversely, the results from the case studies enable the identification of less effective ICT infrastructure and can cater for more objective and project-based outcomes. Moreover, as the issues of strategic ICT alignment have been investigated in this study for the construction industry, this adds to the body of knowledge on new technology applications and utilizations in construction. Hence, this study proposes the incorporation of the ICT and organization infrastructure alignment into the construction organizations' work process and frameworks to reach better performance and outcomes for the organizations' projects as a theoretical contribution. As a practical contribution, the analysed data from the selected cases in this study can act as a decision-making tool in construction organization management as a case study.

Finally, due to the nature of the research, the scope of this study is limited to large construction projects managed by large-sized construction organizations within New Zealand work condition and work environment. Moreover, the selection of the study cases in this research was based on organizations with ICT usage history and ability to provide strong ICT infrastructure. In this study the focus was on organizations with a proven track record of ICT adoption and the resources to deploy a robust ICT and organizational infrastructure which can be considered as another limitation of this research.

Chapter 8: Conclusion and Recommendations

8.1 Research Overview

This doctoral thesis attempts to fill the knowledge gap in the strategic alignment of construction ICT and business and identify the issues behind the underperformance of ICT implementation in construction organisations. As mentioned in the first chapter, The construction industry is applying ICT, but it is evident that it does not realise its full potential and it is underperforming, although other industries are using the benefits of ICT and are extremely successful (Sarshar et al., 2004; Acar et al., 2005; Goh, 2006; Boddy et al., 2008; Wilkinson, 2012; MBIE, 2021; SRG, 2017; CCC, 2017; Enqing et al. 2017; Churbanov, 2018). It appears the construction sector's performance has not significantly improved for 50 years of the science ICT revolution, and there is still a growing performance and productivity deficit relative to other industries. As ICT application has dramatically impacted the performance of different industries, the underperformance of the construction industries could be mainly due to the underperformance of ICT in the construction industry and the implementation of these technologies (Kang, 2012; Andres & Poler, 2017; MBIE, 2021; SRG, 2017; CCC, 2017; Alberto et al., 2018; Churbanov, 2018). Prior to the ICT revolution, organisations developed their fit-for-purpose information systems; however, after ICT, information systems were commercialised and acquired by a third party. Hence, alignment becomes a necessity within the organisation because they often use products not developed (Sarshar & Isikdag, 2004).

This dissertation was based on recommendations from previous studies such as Acar 2005, Goh 2006, boddy 2008, Kang 2012, Bhattacharya 2017, and Churbanov 2018 that it is necessary to analyse the connection between ICT strategy and construction organisation or construction project strategy before ICT implementation in the construction organisations (Acar et al., 2005; Boddy, Boonstra, &

Kennedy, 2008; Goh, 2006; Kang, 2012; Bhattacharya, 2017; Churbanov, 2018). However, most of the previous researchers concluded that the common problem of construction organisations is the weak link between the organisation's infrastructure and ICT infrastructure, which affects the efficiency of ICT implementation (Bernat & Karabag, 2018). The mixed results across various studies appealed for more empirical research to investigate the link between strategic alignment and organisational performance. In addition, there is a lack of research and empirical evidence on the strategic alignment of ICT in the construction industry and the challenges in adopting these technologies. Thus, it is required to study this area in depth and present it in a practical manner that can benefit the construction industry in the future and the other researchers in this field of study and what this thesis tried to achieve.

This doctoral thesis aims to investigate the underperformance of information and communication technology in construction organisations through a correlational study between the construction organisation's performance and strategic alignment. This chapter is committed to summarising and assorting the main findings of this thesis. The following research objectives and achievements have been discussed and analysed in this thesis:

1. Studying the holistic research status and evolutionary trend from the perspective of publications by investigating the state-of-the-art trends of ICT in collaborative working in construction.
2. Presenting a critical literature review on the application of ICT in construction organisations and analysing the holistic research by exploring the construction body of knowledge by classifying the existing ICT-related research and evolutionary trends.
3. Identifying problems and challenges leading to ICT underperformance by empirically studying construction organisations' weakest strategic alignment domains. To achieve that, this study followed a practical approach to understanding the requirements, reality and complexity of ICT implementation.

4. Identify the impact of ICT infrastructure and organisational infrastructure alignment on construction organisation performance by:
    a. Investigating whether the effect of ICT utilisation on project performance may be restricted and affected by its alignment with the ICT infrastructure level in the organisation.
    b. Investigating whether the strength of the alignment between the ICT infrastructure and the organisational infrastructure may restrict the construction organisations' performance.
5. Evaluate the alignment of ICT infrastructure and organisational infrastructure within construction organisations by qualitatively investigating the effect of the alignment of the organisational infrastructure and ICT infrastructure on the construction organisations' performance.
6. Assess the decision-making process regarding ICT infrastructure and organisational infrastructure requirements, procurement, and alignment. This objective has been achieved with a judgement model developed in this thesis for the ICT infrastructure alignment and organisational infrastructure in construction organisations.
7. Provide recommendations to construction organisations and suggestions for future research.

8.2 Objective Development

For the first research objective achievement, systematically reviewed publications related to ICT in the construction industry from 2000 to 2019 have been studied by using the systematic analysis method. In this study, 376 papers were selected for co-citation analysis, keyword co-occurrence, cluster analysis, and burst detection to investigate the state-of-the-art trends of information technology in collaborative working in construction. This study found that Automation in Construction, Journal of Management in Engineering, Advanced Engineering Informatics, and Journal of Intelligent & Robotic Systems were identified as the four major journals associated with research on ICT applications in the construction industry. Moreover, and by measuring the high-frequent co-occurrence keywords, the major research topics in this area include “Building information modelling in construction”, “The impact of technology on construction”, “Information and communication technology in construction”, “Case study on the implementation of technology in construction”, “Construction Management”, “The use of IT in construction”, and “IT adoption in construction”.

As a detailed literature review related to this thesis topic, the second research objective has been achieved using the scientometric analysis method on publications related to ICT in the construction industry to provide a comprehensive knowledge summary of the ICT application in the construction industry. This study has presented a comprehensive framework for ICT application in the construction industry. The overall trends of ICT application in the construction industry from 2009 to 2021 were summarised as a transformation from traditional management concepts to an external and internal challenge analysis to innovative management practices and organisational strategy. The main knowledge domains of ICT application in the construction industry were identified and further classified into four columns (Figure 3.7) or domains, and future study directions were eventually discussed. Moreover, this study contributes to the construction industry’s body of knowledge by classifying the existing ICT-related research, evolutionary trends, providing current status and lending to a comprehensive knowledge framework and future directions. The research findings can provide observations, helping researchers and practitioners better understand the recent research related to ICT applications in the construction sector. The evolutionary trend and knowledge domains can offer a clear and in-depth cognition of construction ICT research. The study found that the knowledge gap related to summarising and reviewing the depth and breadth of the technology application studies, especially the ICT applications and their effect on construction organisations, has been identified. Also, a large amount of research has been devoted to technology applications in different industries. ICT is still unclassified within the construction sector and organisational research. This identified knowledge gap provides specific needs and research directions for construction ICT research.

In order to fulfil the third objective of this thesis, the quality of ICT usage by New Zealand construction organisations has been analysed in chapter 4 by studying the implementation of the strategic alignment model in New Zealand construction organisations. In the New Zealand construction industry, firms have common requirements relating to building information technology capability, and at the policy level, it is important to address domain-specific concerns. This research identified possibilities for New Zealand construction organisations in focus to increase their strategic alignment level as it has proposed actions the organisations can take by identifying the weak domains in the strategic alignment model and the performance criterion. This study has considered the experts' and the literature suggestions and discussed possible actions to effectively align ICT utilisation with the organisation's business strategy. It was identified that the overall action that needs to be taken in order to align information technology with the business strategy is transforming the overall perception of information technology as a costly department toward information technology as a provider of competitive advantage. Based on this study, organisational and ICT infrastructure are two areas identified as having an opportunity to be addressed through the deployment of information and communication technology as a strategic resource.

As concluded in chapter 4, the weakest strategic alignment model domains are the ICT infrastructure and the organisation infrastructure, leading us to achieve this thesis's fourth objective in chapter 5 at the beginning. In this research, case studies have been diagnostically analysed to investigate the effect of the strategic alignment between the organisation's ICT infrastructure and the project's ICT utilisation on project performance. Four project cases have been selected in two large-sized organisations in Auckland, New Zealand. Historical data from each organisation has been collected related to the project performance, project ICT implementation, and ICT infrastructure level. Thus, all the collected data have been organised into a bubble analysis histogram to compare and investigate the ICT results and performance outcomes.

The findings have been analysed and presented based on a multiple case study framework, which included a review of project records and historical data. The strategic alignment between ICT infrastructure and ICT utilisation can be one of the factors that can improve the final project performance, considering the best-case scenario in terms of the project conditions. Moreover, it has been recommended that more empirical research in the same field of study is required to obtain more accurate results in answering the main research questions of this study. Based on the approaches discussed, construction organisations can enhance strategic alignments between organisational infrastructure and actual ICT utilisation. This enables organisations to understand better the functions of ICT tools and infrastructure in enhancing project performance. Conversely, the feedback from the case studies allows for the identification of less effective ICT infrastructure and can cater for more objective and project-based outcomes. In addition, the issues of strategic ICT alignment have been investigated in construction for the first time. This adds to the body of knowledge on new technology applications and utilisations in construction.

Thus, the second weakest strategic alignment model domain concluded in chapter 4 was the organisational infrastructure. This leads us to achieve the second part of the thesis's fourth objective in chapter 6. In this chapter, a two-stage research method was constructed to investigate whether the construction organisations' performance may be restricted and affected by the strength of the alignment between the ICT infrastructure and the organisational infrastructure domains. A quantitative expert survey questionnaire methodology was selected in the first stage, and then an expert Semi-structured open-ended interview using (H. K. Eliwa et al., 2022) case study framework research was chosen as the second stage of this study as a qualitative method to verify the first stage methodology's results. The survey questionnaire was developed and distributed to a targeted group of construction industry professionals and then organised and analysed using the principal component factor analysis method for selecting variables.

Consequently, multiple regression analysis was used to evaluate the impact of the functional integration of the internal domains in the strategic alignment model on the construction organisations' performance and outcomes. Based on the research findings and the resulting equation models, it is observed that the alignment of the function integration can positively affect the construction organisation's performance and outcomes. In terms of the practical implications of this study and as an achievement of the sixth objective of this thesis, a decision support system or tool can be developed based on this research model that provides recommendations and guidance to construction organisations in terms of practical ICT implementations. Moreover, this research can analyse the effect of efficient function integration in the strategic alignment model on the organisation's performance in the construction industry, which leads to optimal strategic utilisation. A method of investigating and evaluating the ICT infrastructure and the organisation infrastructure alignment on the organisation's performance has been proposed.

Finally, this thesis's fifth and sixth objectives have been achieved in chapter 7. In this chapter, a diagnostic approach to case studies has been used to investigate how the strategic alignment between the organisational infrastructure and the ICT infrastructure affects the organisation's performance. Three major construction companies in Auckland, New Zealand, with three project cases chosen for each of these organisations used in this study and historical information about the projects' performance, ICT adoption, ICT infrastructure level, and organisational infrastructure data were acquired. In addition, a radar and a bubble analysis histogram were used to study and compare the functional integration and performance indicator results. Case study techniques, including looking at previous data and projects, were used to investigate and present the findings. Strategic alignment between ICT infrastructure and organisational infrastructure may enhance the organisation's performance if the organisation's project conditions are optimum. Based on the research findings, a well-aligned strategic alignment between the organisation's ICT infrastructure and its organisational infrastructure is essential in facilitating the organisation's project delivery and enhancing its outcomes.

Another application of this research in chapter 7 is to use it as a decision support system (DSS) for the construction organisation to improve the organisation outcomes and then as an executive support system (EIS) for the senior managers in the organisations to take decisions that assist the organisation in achieving its strategic goals. Organisations in the construction industry may benefit from the described methods by improving the strategic alignments between their infrastructure and their use of ICT. By doing so, businesses are able to get a deeper appreciation for the roles that ICT infrastructure and resources play in boosting project success. On the other hand, case study feedback may help pinpoint less efficient ICT and organisational infrastructure and make way for more objective and project-based results. The results of this study have real-world applications and can be used to examine how the optimum strategic use of ICT might improve project performance in the construction sector.

8.3 Theoretical implications and Recommendation

As the issues of strategic ICT alignment have been investigated in this study for the construction industry, this adds to the body of knowledge on new technology applications and utilizations in construction. Hence, this study proposes the incorporation of the ICT and organization infrastructure alignment into the construction organizations' work process and frameworks to reach better performance and outcomes for the organizations' projects as a theoretical contribution. In general, the thesis findings in the first and second chapters can help researchers and practitioners quickly understand the current research related to IT applications in the construction industry. In particular, knowledge domains and the evolutionary trend can offer precise and in-deep cognition of construction IT research. Considering the complete thesis study, this is one of the few studies that examine the challenges of strategic ICT alignment in the construction industry. This expands our understanding of how to use and make use of cutting-edge technologies in the construction industry. Moreover, a strategy for analysing and tracing the presence of ICT and organisational infrastructure has been presented. Thus, construction industry research may further investigate this using various research approaches or extensive empirical investigations in multiple places and study situations. This research has potential significance to both the theory and the practice of construction performance. It determines fundamental problems and issues, such as performance and strategic planning, while discussing the significant function of strategic alignment in improving organisational performance. It tries to fill the knowledge gap in strategic alignment of construction ICT and business strategy and accordingly study the applicability of the relationship between organisational performance and strategic alignment across construction organisations. In problem-solving, spending more time in the problem area is required before moving to the solution area (Bjork, 1997). This study attempts to apply this philosophy in addressing the continual business-ICT alignment problem. The idea is to develop a structured framework that will force the users to thoroughly understand the situation in which it exists before attempting to find a solution, which is the primary significance of this study.

For future research and education recommendations, an in-depth exploration of how the other domains' alignment in the strategic alignment model can improve the performance of a construction organisation would be very helpful. Further research might compare, for instance, traditional management projects with modern or ICT-based management projects. Moreover, other methodologies could include structured interviews or focus group gatherings with construction management experts. Although methodologically challenging, it would be very useful to conduct longer-term studies seeking to quantify the impact of ICT implementation on different types of construction projects and organisations at different size levels. An in-depth investigation of the ways in which strategic fits and their relation to functional integration might boost project success would be highly beneficial for future research and education suggestions. Longitudinal studies attempting to quantify the effect of ICT deployment on various construction projects and organisations of varying sizes would be beneficial, despite the methodological challenges they would provide. Finally, it is recommended that more empirical research in the same field of study is required to obtain more verification results, especially on the organisation's infrastructure alignment and its effect on the organisation's performance.

8.4 Practical implications

This research will allow engineers, construction managers, researchers and construction organisation executives to identify the impact of strategic alignment on construction organisation productivity performance and assess the organisational and alignment decision-making regarding ICT and organisational infrastructure. This research, therefore, presents a practical use of the Strategic Alignment Model (SAM), facilitating businesses in managing factors affecting alignment and providing scholars with empirical data on strategic alignment and organisational performance of construction organisations, paving the way for further research in this area.

Moreover, this study also introduces the determination of the strategic focus areas or sources within the organisation that provide the goals to align as an important factor to be considered in the alignment process. Yet another factor that is particular to the organisation's culture within which the ICT function exists is to determine who should initiate alignment-related actions such as planning, communication and sharing of visions. In trying to achieve the research objectives, this study will introduce to the construction organisations the role of the ICT function, the method of operation of the ICT function and the sourcing options of the ICT function as antecedent variables to the alignment of the organisation infrastructure with ICT infrastructure within the organisation. It is suggested that evaluating these variables should set the boundary conditions for the business-ICT alignment problem.

The analysed data from the selected cases in this study can act as a decision-making tool in construction organization management as a case study. Therefore, a decision support system or tool can be developed based on this research model that provides recommendations and guidance to construction organizations in terms of effective ICT implementations. Also, this research can analyse the effect of efficient function integration in the strategic alignment model on the organization's performance in the construction industry, which leads to optimal strategic utilization. A method of investigating and evaluating the ICT infrastructure and the organization infrastructure alignment on the organization's performance has been proposed. It can be further explored in the construction industry and ICT research using different methodologies.

8.5 Research Limitations

Considering the research method in this thesis's first and second chapters, the articles used for scientometric analysis were collected only from the Scopus and WOS database. Moreover, the study is mainly concentrated on the quantitative analysis in regard to the articles frequently merging in the ICT applications in the construction industry, which were used to indicate the hot topics. Finally, results may change differently with the updating databases. For the case study methodology in this thesis, the scope is limited to advanced large construction projects managed by large-sized construction organisations within the Auckland region in New Zealand, as the Auckland region mostly covers national construction demand in New Zealand. Thus, the study provides insights into the impact and challenges of implementing information technology tools, concepts and applications on New Zealand's construction industry performance. The study cases in this research were selected based on organisations with ICT usage history and the ability to provide strong ICT infrastructure. In our investigation, we focused on organisations that have both a proven track record of ICT adoption and the resources to deploy a robust ICT and organisational infrastructure.

Appendices

Appendix 1: Ethics Approval and Documentation

Appendix 2: Interview Methodology Documentation

Appendix 3: Expert Structured Questionnaire

Appendix 4: Statement of Contribution form

Appendix 1: Ethics Approval and Documentation

From: humanethics@massey.ac.nz
Sent: Monday, 8 June 2020 8:56 am
To: Hassan.Eliwa.1@uni.massey.ac.nz; M.B.Jelodar@massey.ac.nz; W.Yi1@massey.ac.nz
Cc: humanethics@massey.ac.nz
Subject: Human Ethics Notification - 4000022560

HoU Review Group

Ethics Notification Number: 4000022560
Title: UNDERPERFORMANCE OF INFORMATION TECHNOLOGY IN CONSTRUCTION; DIAGNOSIS AND DECISION SUPPORT TOOL

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz. "

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter, please login to the RIMS system, and under the Reporting section, View Reports you will find a link to run the LR Report.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and

GRADUATE RESEARCH SCHOOL

AUT

Private Bag 92006 Auckland 1142
+64-9-921-9907
grs@aut.ac.nz

Ref: 17973302

19 February 2019

Hassan Eliwa
[redacted]

Dear Hassan,

Re: Confirmation of Candidature

Congratulations!

I am pleased to inform you your PGR9 was approved by the Faculty of Design & Creative Technologies and was noted at the University Postgraduate Board at their meeting held on 19 Feb 2019. You have now completed all conditions placed on your provisional admission to your programme, and the Board will now confirm your candidature in the Doctor of Philosophy.

The completion of this milestone marks a significant point in the career of every doctoral student, and represents the successful passage from provisional to confirmed candidature. It demonstrates your maturity as a doctoral researcher capable of contributing an original contribution to your field of enquiry. It also demonstrates that your project is of a suitable scope and standard for your degree, and that you have the capacity, resources, and potential to complete your research at the required level.

Data Collection

If your research does not require ethics approval, you may now begin data collection. If your research does require ethics approval, you may begin data collection once you have ethics approval.

Expected Submission Date

Currently, we are expecting that you will submit for examination on 16 Nov 2021. We are currently updating our records and if you feel this is incorrect, please contact your faculty contact person listed below.

Business Cards

As a recognition of this milestone, the University would like to provide you with your own AUT business cards for you to use when attending conferences and networking with other researchers. We have attached the 'AUT Business Card Order Form' for you to complete and return by email only (no hard copies required) to Scott Pilkington (pgresearch@aut.ac.nz).

The University will cover this initial printing expense, however, reprints will be at the candidate's expense. Please contact the Graduate Research School when a reprint is required.

www.aut.ac.nz/study-at-aut/postgraduate-study/graduate-research-school

Faculty Contacts

Your primary supervisor is Mostafa Babaeian Jelodar

Your secondary supervisor is Mani Poshdar

Your supervisory team mentor is John Tookey

The Associate Dean (Postgraduate) is Rosser Johnson, ext 7818

Your faculty doctoral contact person is Angela Anderson, ext. 6761, doffice@aut.ac.nz

Graduate Research School Contact

Your enrolment contact at the Graduate Research School is Jessica Yamamoto, ext. 8220, jessica.yamamoto@aut.ac.nz

Congratulations Again

On behalf of all staff involved in the programme we would like to acknowledge the challenge of undertaking research at this level as well as the commitment and application which are required to pass this significant milestone in your research career.

If you have any questions, please feel free to contact me.

Yours sincerely

Martin Wilson
Manager, Graduate Research School
martin.wilson@aut.ac.nz
+64-9-921-9999 ext 8812

cc: Mostafa Babaeian Jelodar, Mani Poshdar, John Tookey, Angela Anderson DI, Jessica Yamamoto

Appendix 2: Interview Methodology Documentation

Consent Form

For use when interviews are involved.

Project title: ***UNDERPERFORMANCE OF INFORMATION TECHNOLOGY IN CONSTRUCTION; DIAGNOSIS AND DECISION SUPPORT TOOL***

Project Supervisor: ***Dr Mostafa Babaeian Jelodar and Dr Mani Poshdar***

Researcher: ***Hassan Eliwa***

- ○ I have read and understood the information provided about this research project in the Information Sheet
- ○ 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):

....

....

....

....

Date:

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

Participant Information Sheet

Date Information Sheet Produced:

10 Feb 2019

Project Title

UNDERPERFORMANCE OF INFORMATION TECHNOLOGY IN CONSTRUCTION; DIAGNOSIS AND DECISION SUPPORT TOOL

An Invitation

Hello, I'm Hassan Eliwa and I am conducting some research as part of my practice research for a PhD in Construction Engineering and Management at Auckland University of Technology. You are invited to participate in a research exploring the construction industry underperformance issues; which will be looking at the eliminating quality issues via development of technological oriented workflow and integration of IT. The study aims to amend organisational structures in favour of more technology implementation; which can specially give the residential construction sectors better tools to deliver projects and potentially facilitate medium density projects.

What is the purpose of this research?

The purpose of this research is to develop a guidance that assist the construction organization in New Zealand to solve the construction industry underperforming, the alignment of IT in construction industry, and to improve the probability of arriving at a specific alignment solution for the construction organization by determining the strategic alignment impact between IT and business on organizational performance of construction organizations.

The idea of information technology uptake specially by focusing on the tools and technologies used in the process of construction. The key issues addressed alongside this project is how do industry practitioners choose their technological tools. Are these tools optimised to the max and fit for purpose. Does the more permanent organisational structure and the temporary project structure have the capacity and skill sets to utilise these tools to the max.

Through the study of weaknesses and strength and simulating decisions in the application of technological tools; guidelines will be offered in dealing with different KPI especially quality issues in construction. An independent workflow model and ali8gnment strategy with the aim of enhancing construction outputs will be derived, this will have practical implications for residential and medium density housing projects.

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

You have responded to an email which has been sent by me regarding to this research. Those interested in participating will need to meet the following criteria: will be working in construction organization in New Zealand in the higher tier of management roles and been used the information technology during his daily works. The sample population are holding high ranked positions in their organizations, making them well informed and experienced individuals. Interested participants have been asked to contact me directly for more information about the research. Participants will be selected in order of application and recruitment will cease once the maximum number of participants is reached.

How do I agree to participate in this research?

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

What will happen in this research?

This study involves a one-on-one interview with myself which will take approximately one hour of your time. The interview can take place in your workplace or via Skype/phone, depending on your preference. Only my supervisors and I will have access to the data collected for this study. Only the analyses of the results will be published, and individuals will not be identifiable.

What are the discomforts and risks?

Provide a full, and friendly, description.

How will these discomforts and risks be alleviated?

Discussion about personal experiences may evoke some discomfort for you. I will be mindful of managing any discomfort or distress as much as possible. You are invited to have a support person with you for the duration of the interview if you wish. Participation is also completely voluntary, and you may withdraw from the study at any time. Additional time will be given to any questions that may be distressing as well as the opportunity to not provide an answer.

In addition, AUT Health Counselling and Wellbeing is able to offer three free sessions of confidential counselling support for adult participants in an AUT research project. These sessions are only available for issues that have arisen directly as a result of participation in the research, and are not for other general counselling needs. To access these services, you will need to:

- drop into our centres at WB219 or AS104 or phone 921 9992 City Campus or 921 9998 North Shore campus to make an appointment. Appointments for South Campus can be made by calling 921 9992
- let the receptionist know that you are a research participant, and provide the title of my research and my name and contact details as given in this Information Sheet

You can find out more information about AUT counsellors and counselling on http://www.aut.ac.nz/being-a-student/current-postgraduates/your-health-and-wellbeing/counselling.

What are the benefits?

There is no direct benefit in participating in this research however, I am hoping that you will find it valuable to share your experience. This study will introduce to the construction organizations the role of the information technology function, the method of operation of the information technology function and the sourcing options of the information technology function as antecedent variables to the alignment of the organization infrastructure with information technology within the organisation. It is suggested that the evaluation of these variables should set the boundary conditions for the business-information technology alignment problem.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

Confidentiality will be upheld through the use of a participant number or a pseudonym and identifying information will be disguised. Only my supervisor and I will have access to the data during data collection and analysis stage. All data will be kept securely for a period of six years, after which it will be destroyed.

What are the costs of participating in this research?

There are no financial costs involved in participating. However, it is anticipated that the interview will take around one hour of your time.

What opportunity do I have to consider this invitation?

Participants are encouraged to contact me within two weeks of receiving the invitation.

Will I receive feedback on the results of this research?

A summary of results may be sent to participants via email if they wish. You can indicate whether you would like to receive this on the consent form.

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. Mostafa Babaeian Jelodar, mostafa.bjelodar@aut.ac.nz, and Phone: +64 9 9219999 ext 8730*.

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 Safety Protocol

Project title and brief description:

UNDERPERFORMANCE OF INFORMATION TECHNOLOGY IN CONSTRUCTION; DIAGNOSIS AND DECISION SUPPORT TOOL

This study seeks to investigate the underperformance of information technology tools and infrastructure within New Zealand construction industry and provide diagnostic analysis for major issues in order to provide a decision support tool for industry participants. A mixed-method research methodology in five phases has been adopted to address the research problem which are literature review, structured expert survey, focus groups, choice based conjoint analysis, case study and decision support system development. The findings of this research will be useful in improving the probability of arriving at a specific alignment solution for the construction organization by determining the strategic alignment impact between IT and business on organizational performance of construction organizations.

Applicant

Dr. Mostafa Babaeian Jelodar - the primary supervisor - AUT

Primary Researcher

Hassan Khames Eliwa

Where is the research being undertaken?

What current travel warnings are in effect in the area in which the research will take place?

None

At whose property will the research be undertaken?

Construction organizations workplace

Who is likely to be present at the research location?

Project managers, construction managers and engineers

What access permissions are needed to undertake the research at the chosen location?

Just appointment with the participant.

What maps and guides has the researcher consulted to ensure familiarity with the locations?

Google map mobile application

What reliable local public transport is available?

All public transport will be available

Which reputable taxi firms are easy to access?

Uber

Where is it safe to use private cars and leave them in the area?

Personal / Private car – always available

What local rendezvous or contact points are available for researchers?

All construction organizations in New Zealand are available in areas with good services infrastructure.

How close to your research location are hotels or safe accommodation?

All construction organizations in New Zealand are available in areas with good services infrastructure.

Who will be collecting the data and interacting with participants?

Who will be accompanying the researcher?

None

How will the safety of any dependent children accompanying the researcher be assured?

N/A

How will the safety of any translators, interpreters, intermediaries or transcribers be assured?

N/A

How familiar is the researcher with the social or cultural context of the research?

What level of familiarity does the researcher have with the social context of the participants and the research?

I have been working in the construction field for over 14 years now in Saudi Arabia, Egypt and New Zealand as a contractor engineer and client-side engineer with construction people from different culture

What level of familiarity does the researcher have with the cultural context of the participants and the research?

See above.

What consultation has taken place?

N/A

What language support is needed?

No language support is needed

What local tensions are there?

N/A

How strongly active are any cultural, religious or racial divisions?

N/A

What do local sources, such as the police or local leaders, say about risks in the research area?

No risk

Which local 'community leaders' have been spoken with to explain the research and gain their endorsement?

N/A

How safe are the activities in which the researcher is taking part?

Does the research involve sports or activities that may be hazardous in nature?

No

What safety protocols are in place?

The safety police for construction works and Building safety instructions

Will sufficient qualified personnel be in attendance to supervise the activity or respond swiftly to any emergency?

Yes

What level of access to support is available?

Who will be available to provide assistance should it be required?

The participant

How will the researcher ensure that those providing support will be aware of any need that arises?

By asking this question to the participant

What emergency plans are in place? Who can help?

What training or support is needed and how will it be accessed?

No training required

What University policies are relevant to your project? Have you read and understood them?

None.

How have significant local actors, such as statutory and community organisations been contacted?

N/A

Who has been in touch with potential participants and what advice have they given?

The primary researcher, building reaching and arriving advices

Who else is aware of the researcher's itinerary and research schedule?

Dr. Mostafa Babaeian Jelodar - the primary supervisor - AUT

How will the researcher keep key support people informed of what is happening?

By emails and face to face meetings

Don't forget to update your safety protocol regularly:

Date for next review

November 2019

Expert Interview

The Purpose of the Survey:

- Explore the current practices and utilization of IT infrastructure within New Zealand construction organizations
- Identify problems and challenges leading to underperformance and shortcomings of IT utilization in New Zealand construction organizations
- Identify the impact of strategic alignment on construction organization productivity performance
- Evaluate the IT infrastructure alignment organizational infrastructure in New Zealand construction organizations

Participants

The selection process will consider that all the interviewees will be working in construction organization in Auckland New Zealand in the higher tier of management roles and been used the information technology during their daily works. The sample population are holding high ranked positions in their organizations, making them well informed and experienced individuals.

How will data be gathered and processed?

Method 1: By sending an appointment request to managers from construction organizations in New Zealand who have their email available in the organization website.

Method 2: By sending a private message with appointment request using Linkedin.com to construction managers in New Zealand.

How will the data be analysed?

Content analysis using NVIVO software to be in the term of "agree" and "disagree". In this regard, the percentage of "agree" results will be calculated and distributed on the related domain

What is the survey duration?

30 to 45 minutes

The Interview Questions

Q01: What information technology applications have you used in your organization and project?

Answer: ……

……….

Comment: ……

……….

Q02: In which of the following project types do you typically utilize information technology?

Answer: ……

…….

Comment: ………

…….

Q03: For which functions do you use information technology in your organization?

Answer: ……

…….

Comment: ………

…….

Q04: What has gone well with the use of information technology in your organization and project?

Answer: ……

…….

Comment: ………

…….

Q05: What has not gone so well?

Answer: ……

…….

Comment: ………

…….

Q06: What problems have you had with implementing and using information technology in your organization?

Answer: ……

…….

Comment: ………

…….

Q07: How have the above problems been addressed?

Answer: ……

………

Comment: ……

………

Q08: Has the use of information technology improved communications in the contact?

Answer: ……

………

Comment: ……

………

Q09: How have you and/or your organization overcome administrative and legal issues associated with using technology as opposed to traditional methods of communication?

Answer: ……

………

Comment: ……

………

Q10: What type of communication are most suited to information technology process?

Answer: ……

………

Comment: ……

………

Q11: Has information technology improved efficiency on the project?

Answer: ……

………

Comment: ……

………

Q12: Has information technology assisted relationships on the project?

Answer: ……

…….

Comment: ……

…….

Q13: Would you recommend the use of information technology instead of traditional method on construction project?

Answer: ……

…….

Comment: ……

…….

Q14: Would information technology be usefull for pre-construction or maintenance activities? if so, how?

Answer: ……

…….

Comment: ……

…….

Q15: What should one or/and organization do to more effectively use information technology?

Answer: ……

…….

Comment: ……

…….

Q16: Kindly include any additional comments, recommendations, etc. regarding the implementation of information technology.

…….

…….

…….

Appendix 3: Expert Structured Questionnaire

IT infrastructure within construction organizations

Start of Block: Introduction

This voluntary survey is part of a research study led by Massey University. The purpose of this research is to explore the current practices and utilisation of IT infrastructure within construction organisations, to identify problems and challenges leading to underperformance and shortcomings of IT utilisation in construction organisations and to evaluate the IT infrastructure alignment organizational infrastructure in construction organizations.
Your data shall be processed for this research purpose only. In order to ensure that we cannot identify you and to keep your responses confidential, we do not collect your name or any other personal data from you. Published results will be aggregated and will not identify you individually or your responses.
We would be grateful if you could take a few minutes to respond to this survey. Please select the option that is relevant to your opinion and if none of the options accurately describes your option, please use the "other" option and type in brief details. Survey duration 7 - 10 Minutes

I confirm that I understand the above and consent to take part in this survey run by a researchers in from the Massey University (If you have questions about the study please contact: H.K.Eliwa@massey.ac.nz; Massey University, Albany Campus, Auckland, New Zealand)

○ Yes (1)

○ No (2)

Skip To: End of Survey If I confirm that I understand the above and consent to take part in this survey run by a researcher... = No

End of Block: Introduction

Start of Block: The judgment of the participants

Q1 What is your current position in the construction organisation?

- Engineer (1)
- Architect (5)
- Construction Manager (2)
- Project Manager (3)
- Quantity Surveyor (6)
- Student (Construction Related) (7)
- Other: (4) ____

Q2 How many years of experience do you have in the construction industry?

- 0 - 4 Years (1)
- 5 - 9 Years (2)
- 10 - 14 Years (3)
- 15 - 20 Years (4)
- More than 20 years' experience (5)

Q3 Which construction sectors have/had you worked in? (Select all that apply)

- Public sector (1)
- Private sector (2)
- Public-Private Partnership (PPP) sector (3)

Q4 What type of construction work have/had you worked in? (Select all that apply)

- Building and residential (1)
- Civil and infrastructure (2)
- Commercial (3)
- Industrial (4)
- Other (5) ____

End of Block: The judgment of the participants

Start of Block: The Main Survey

Q5 Which IT's Products or Application categories have / had you used during your experience in construction industry: (Select all that apply)

- Building Engineering Application: (Such as ATEAN (Carrier), CARGASW (Climasoft), CALCULUX, CYPE INGENIEROS, COSMOS and DUCTSIZE) (1)
- Accounting: (such as Sage, Viewpoint, Quickbooks, CMiC, Jonas Software and Deltek Vision) (2)
- Bidding and Tendering: (such as CMiC, iSqFt, Procore, SmartBidNet, Textura, Viewpoint, eBid Exchange and Pipeline Suite) (3)
- Estimating and Take-off Software: (such as On-Screen Takeoff, HeavyBid, Bluebeam Revu, Planswift, B2W Estimate, Trimble Accubid, ProEst, Sage Estimating and WinEst) (4)
- Planning and Project Management: (such as Primavera, Microsoft Project, Power Project, Agile, JobMaster, Prolog, PlanGrid, Constructware, and CMiC) (5)
- Building Information Modeling (BIM) and Computer-aided Design (CAD): (such as AutoCad, Revit (Autodesk), Navisworks (Autodesk), Sketchup (Trimble), Tekla (Trimble), QTO (Autodesk), AutoVue, ArchiCad and Assemble Systems) (6)
- Job Site Data Collection & Reporting: (such as Microsoft Office Package, Autodesk's BIM360, B2W, HCSS, PlanGrid, and NoteVault) (7)
- Customer Relationship Management (CRM): (such as Cosential and FollowUp Power) (8)
- Cloud Storage, Sharing, and Web Conferencing: (such as DropBox, Adobe Acrobat, Aconex, Microsoft Team etc.) (9)

Q6 For each software package you have selected in the previous question, please rate your usage based on your experience: (rate 0 to 100 as 0 means you don't have any experience in using this software package and 100 means an Expert / professional level of experience)

Extremely unprofessional	Moderately unprofessional	Slightly unprofessional	Neither professional nor unprofessional	Slightly professional	Moderately professional	Extremely professional	Not Applicable

Building Engineering Application: (Such as ATEAN (Carrier), CARGASW (Climasoft), CALCULUX, CYPE INGENIEROS, COSMOS and DUCTSIZE) ()	
Accounting: (such as Sage, Viewpoint, Quickbooks, CMiC, Jonas Software and Deltek Vision) ()	
Bidding and Tendering: (such as CMiC, iSqFt, Procore, SmartBidNet, Textura, Viewpoint, eBid Exchange and Pipeline Suite) ()	
Estimating and Take-off Software: (such as On-Screen Takeoff, HeavyBid, Bluebeam Revu, Planswift, B2W Estimate, Trimble Accubid, ProEst, Sage Estimating and WinEst) ()	
Planning and Project Management: (such as Primavera, Microsoft Project, Power Project, Agile, JobMaster, Prolog, PlanGrid, Constructware, and CMiC) ()	
Building Information Modeling (BIM) and Computer-aided Design (CAD): (such as AutoCad, Revit (Autodesk), Navisworks (Autodesk), Sketchup(Trimble), Tekla (Trimble), QTO (Autodesk), AutoVue, ArchiCad and Assemble Systems) ()	
Job Site Data Collection & Reporting: (such as Microsoft Office Package, Autodesk's BIM360, B2W, HCSS, PlanGrid, and NoteVault) ()	
Customer Relationship Management (CRM): (such as Cosential and FollowUp Power) ()	
Cloud Storage, Sharing, and Web Conferencing: (such as DropBox, Adobe Acrobat, Aconex, Microsoft Team etc.) ()	

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Building Engineering Application: (Such as ATEAN (Carrier), CARGASW (Climasoft), CALCULUX, CYPE INGENIEROS, COSMOS and DUCTSIZE)

Q7 Based on your selection of **Building Engineering Application: (Such as ATEAN (Carrier), CARGASW (Climasoft), CALCULUX, CYPE INGENIEROS, COSMOS and DUCTSIZE)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Accounting: (such as Sage, Viewpoint, Quickbooks, CMiC, Jonas Software and Deltek Vision)

Q10 Based on your selection of **Accounting: (such as Sage, Viewpoint, Quickbooks, CMiC, Jonas Software and Deltek Vision)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	○	○	○	○	○
The use of this application makes project management easy (2)	○	○	○	○	○
The use of this application is not costly regarding resources, time and effort (3)	○	○	○	○	○
The use of this application could reduce the number of staff employed (4)	○	○	○	○	○
The use of this application is an effective tool for staff of all abilities (5)	○	○	○	○	○
The use of this application eases the pressure on organization staff (6)	○	○	○	○	○
The use of this application motivates staff to get more involved in project activities (7)	○	○	○	○	○
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	○	○	○	○	○
The diversity of this application increases project achievement (8)	○	○	○	○	○
The cost of using this application acceptable and does not affect the budget (9)	○	○	○	○	○
The use of this application does not require software-skills training that is too time-consuming (10)	○	○	○	○	○
Available this application resources for training and support (11)	○	○	○	○	○
Easy transforming and re-configuring business process to suit with this application (12)	○	○	○	○	○
Easy alignment between business strategy and this application (13)	○	○	○	○	○
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	○	○	○	○	○
Using of this application to solve a problem or reporting is more productive (15)	○	○	○	○	○
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	○	○	○	○	○
The organization staff received a good amount of in-service training on using this application (17)	○	○	○	○	○
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	○	○	○	○	○
The organization has a good and effective technical support related to this application (19)	○	○	○	○	○

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Bidding and Tendering: (such as CMiC, iSqFt, Procore, SmartBidNet, Textura, Viewpoint, eBid Exchange and Pipeline Suite)

Q11 Based on your selection of **Bidding and Tendering: (such as CMiC, iSqFt, Procore, SmartBidNet, Textura, Viewpoint, eBid Exchange and Pipeline Suite)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Estimating and Take-off Software: (such as On-Screen Takeoff, HeavyBid, Bluebeam Revu, Planswift, B2W Estimate, Trimble Accubid, ProEst, Sage Estimating and WinEst)

Q12 Based on your selection of **Estimating and Take-off Software: (such as On-Screen Takeoff, HeavyBid, Bluebeam Revu, Planswift, B2W Estimate, Trimble Accubid, ProEst, Sage Estimating and WinEst)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Planning and Project Management: (such as Primavera, Microsoft Project, Power Project, Agile, JobMaster, Prolog, PlanGrid, Constructware, and CMiC)

Q13 Based on your selection of **Planning and Project Management: (such as Primavera, Microsoft Project, Power Project, Agile, JobMaster, Prolog, PlanGrid, Constructware, and CMiC)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Building Information Modeling (BIM) and Computer-aided Design (CAD): (such as AutoCad, Revit (Autodesk), Navisworks (Autodesk), Sketchup(Trimble), Tekla (Trimble), QTO (Autodesk), AutoVue, ArchiCad and Assemble Systems)

Q14 Based on your selection of **Building Information Modeling (BIM) and Computer-aided Design (CAD): (such as AutoCad, Revit (Autodesk), Navisworks (Autodesk), Sketchup(Trimble), Tekla (Trimble), QTO (Autodesk), AutoVue, ArchiCad and Assemble Systems)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Job Site Data Collection & Reporting: (such as Microsoft Office Package, Autodesk's BIM360, B2W, HCSS, PlanGrid, and NoteVault)

Q15 Based on your selection of **Job Site Data Collection & Reporting: (such as Microsoft Office Package, Autodesk's BIM360, B2W, HCSS, PlanGrid, and NoteVault)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Customer Relationship Management (CRM): (such as Cosential and FollowUp Power)

Q16 Based on your selection of **Job Site Data Collection & Reporting: (such as Microsoft Office Package, Autodesk's BIM360, B2W, HCSS, PlanGrid, and NoteVault)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

Display This Question:

If Which IT's Products or Application categories have / had you used during your experience in const... = Cloud Storage, Sharing, and Web Conferencing: (such as DropBox, Adobe Acrobat, Aconex, Microsoft Team etc.)

Q17 Based on your selection of **Cloud Storage, Sharing, and Web Conferencing: (such as DropBox, Adobe Acrobat, Aconex, Microsoft Team etc.)**, please rate the following statements on a scale of 1 to 5 based on your experience:

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
The use of this application Increases project achievement (1)	o	o	o	o	o
The use of this application makes project management easy (2)	o	o	o	o	o
The use of this application is not costly regarding resources, time and effort (3)	o	o	o	o	o
The use of this application could reduce the number of staff employed (4)	o	o	o	o	o
The use of this application is an effective tool for staff of all abilities (5)	o	o	o	o	o
The use of this application eases the pressure on organization staff (6)	o	o	o	o	o
The use of this application motivates staff to get more involved in project activities (7)	o	o	o	o	o
Your organisation has a strong planning methodology which incorporate this IT application and all business unit heads (20)	o	o	o	o	o
The diversity of this application increases project achievement (8)	o	o	o	o	o
The cost of using this application acceptable and does not affect the budget (9)	o	o	o	o	o
The use of this application does not require software-skills training that is too time-consuming (10)	o	o	o	o	o
Available this application resources for training and support (11)	o	o	o	o	o
Easy transforming and re-configuring business process to suit with this application (12)	o	o	o	o	o
Easy alignment between business strategy and this application (13)	o	o	o	o	o
Easy upgrading previous version of this application and acceptable costs of changing to a new application version (14)	o	o	o	o	o
Using of this application to solve a problem or reporting is more productive (15)	o	o	o	o	o
The organization staff have acquired the ability to use a broad spectrum of this application competently (16)	o	o	o	o	o
The organization staff received a good amount of in-service training on using this application (17)	o	o	o	o	o
The organization staff is gaining a sense of self-confidence in using of this application for specific tasks. (18)	o	o	o	o	o
The organization has a good and effective technical support related to this application (19)	o	o	o	o	o

End of Block: The Main Survey

Appendix 4: Statement of Contribution form

MASSEY UNIVERSITY
TE KUNENGA KI PUREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 2
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:
Lead author, conducted study and wrote the text

Please select one of the following three options:

- (◉) **The manuscript/published work is published or in press**
  Please provide the full reference of the research output:
  Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. Information Technology Applications in Construction Organizations: A Systematic Review. In Proceedings of the 6th New Zealand Built Environment Research Symposium, Auckland, New Zealand (Vol. 26). 2020.
- ( ) **The manuscript is currently under review for publication**
  Please provide the name of the journal:
- ( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

1

Doctoral Research Committee
July 2022

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 3
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:
Lead author, conducted study and wrote the text

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:
Eliwa, H., Babaeian Jelodar, M., Yi, W., & Poshdar, M. (2023). Information and Communication Technology Applications In Construction Organisations: A Scientometric Review. Journal of Information Technology in Construction, ITcon Vol. 28 (2023), Eliwa et al., pg. 286.

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:		Main supervisor's signature:	

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 4
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

Eliwa, H., M.B. Jelodar, and M. Poshdar. Information technology and New Zealand construction industry: An empirical study towards strategic alignment of project and organisation. in Proceedings of the 18th International Conference on Construction Applications of Virtual Reality (CONVR2018), Auckland, New Zealand. 2018.

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 5
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

Eliwa, H.K., M.B. Jelodar, and M. Poshdar, Information and Communication Technology (ICT) Utilization and Infrastructure Alignment in Construction Organizations. Buildings, 2022. 12(3): p. 281.

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

1

Doctoral Research Committee
July 2022

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 6
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

○ **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

◉ **The manuscript is currently under review for publication**

Please provide the name of the journal:

Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. Organizational Infrastructure and Information and Communication Technology (ICT) Infrastructure Alignment in Construction Organizations.
Submitted to ASCE - Journal of Construction Engineering and Management

○ **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	[signature]	Main supervisor's signature:	[signature]

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Hassan Khames Hassan Eliwa
Name and title of main supervisor:	Mostafa Babaeian Jelodar
In which chapter is the manuscript/published work?	Chapter 7
What percentage of the manuscript/published work was contributed by the student?	90

Describe the contribution that the student has made to the manuscript/published work:

Lead author, conducted study and wrote the text

Please select one of the following three options:

○ **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

◉ **The manuscript is currently under review for publication**

Please provide the name of the journal:

Eliwa, H., Babaeian Jelodar, Poshdar, M, & Zavvari, A. A qualitative study on the effect of the functional integration of the strategic alignment model domains on the construction organisations' performance. Submitted to International Journal of Project Management

○ **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:		Main supervisor's signature:	

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis.

Bibliography

Abdirad, H., & Dossick, C. S. (2016). BIM curriculum design in architecture, engineering, and construction education: a systematic review. *Journal of Information Technology in Construction (ITcon), 21*(17), 250-271.

Acur, N., Kandemir, D., & Boer, H. (2012). Strategic alignment and new product development: Drivers and performance effects. *Journal of Product Innovation Management, 29*(2), 304-318.

Agwu, M. (2012). Total safety management: a strategy for improving organisational performance in selected construction companies in Nigeria. *International Journal of business and social science, 3*(20), 210-217.

Ahmad, I. (2000). *Data warehousing in construction organizations.* Paper presented at the Construction Congress VI: Building Together for a Better Tomorrow in an Increasingly Complex World.

Aier, S., Gleichauf, B., & Winter, R. (2011). Understanding enterprise architecture management design-an empirical analysis.

Akinade, O. O., Oyedele, L. O., Bilal, M., Ajayi, S. O., Owolabi, H. A., Alaka, H. A., & Bello, S. A. (2015). Waste minimisation through deconstruction: A BIM based Deconstructability Assessment Score (BIM-DAS). *Resources, conservation and recycling, 105*, 167-176.

Almajali, D. A., Omar, F., Alsokkar, A., Alsherideh, A. A. S., Masa'Deh, R. E., & Dahalin, Z. (2022). Enterprise resource planning success in Jordan from the perspective of IT-Business strategic alignment. Cogent Social Sciences, 8(1), 2062095.

Altheide, D. L. (2018). *Creating fear: News and the construction of crisis*: Routledge.

Ametepey, O., Aigbavboa, C., & Ansah, K. (2015). Barriers to successful implementation of sustainable construction in the Ghanaian construction industry. *Procedia manufacturing, 3*, 1682-1689.

Amirtash, P., Jalal, M. P., & Jelodar, M. B. (2021). Integration of project management services for International Engineering, Procurement and Construction projects. Built Environment Project and Asset Management.

Amusan, L., Oloniju, L. I., Akomolafe, M., Makinde, A., Peter, N. J., Farayola, H., & Osawaru, F. (2018). Adopting information and communication technology in construction industry. *International Journal of Mechanical Engineering and Technology (IJMET), 9*(1), 739-746.

Antuchevičiene, J., Zavadskas, E. K., & Zakarevičius, A. (2010). Multiple criteria construction management decisions considering relations between criteria. *Technological and Economic Development of Economy, 16*(1), 109-125.

Aswathy, S., & Gopikuttan, A. (2013). Productivity pattern of universities in Kerala: A scientometric analysis. *Annals of Library and Information Studies (ALIS), 60*(3), 176-185.

Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. *Journal of Information Technology in Construction (ITcon), 16*(24), 411-432.

Bennett, B., & Cialone, C. (2014). *Corpus Guided Sense Cluster Analysis: a methodology for ontology development (with examples from the spatial domain).* Paper presented at the FOIS.

Berente, N., Baxter, R., & Lyytinen, K. (2010). Dynamics of inter-organizational knowledge creation and information technology use across object worlds: the case of an innovative construction project. *Construction Management and Economics, 28*(6), 569-588.

Blayse, A. M., & Manley, K. (2004). Key influences on construction innovation. *Construction Innovation, 4*(3), 143-154.

Brauers, W. K. M., & Zavadskas, E. K. (2010). Project management by MULTIMOORA as an instrument for transition economies. *Technological and Economic Development of Economy, 16*(1), 5-24.

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A review of Building Information Modelling for construction in developing countries. *Procedia Engineering*, *164*, 487-494.

Chen, C. (2017). Science mapping: a systematic review of the literature. *Journal of Data and Information Science*, *2*(2), 1-40.

Coccia, M., Falavigna, G., & Manello, A. (2015). The impact of hybrid public and market-oriented financing mechanisms on the scientific portfolio and performances of public research labs: a scientometric analysis. *Scientometrics, 102*(1), 151-168.

Coltman, T., Tallon, P., Sharma, R., & Queiroz, M. (2015). Strategic IT alignment: twenty-five years on. In: SAGE Publications Sage UK: London, England.

Darko, A., Chan, A. P., Huo, X., & Owusu-Manu, D.-G. (2019). A scientometric analysis and visualization of global green building research. *Building and Environment*, *149*, 501-511.

Deb, C., & Lee, S. E. (2018). Determining key variables influencing energy consumption in office buildings through cluster analysis of pre-and post-retrofit building data. *Energy and Buildings, 159*, 228-245.

Ding, L., Zhou, Y., Luo, H., & Wu, X. (2012). Using nD technology to develop an integrated construction management system for city rail transit construction. *Automation in Construction, 21*, 64-73.

Dos Santos, I. M., de Miranda Mota, C. M., & Alencar, L. H. (2021). The strategic alignment between supply chain process management maturity model and competitive strategy. Business Process Management Journal.

Doumi, K., Baina, S., & Baina, K. (2013). STRATEGIC BUSINESS AND IT ALIGNMENT: REPRESENTATION AND EVALUATION. *Journal of Theoretical & Applied Information Technology, 47*(1).

Dutot, V., Bergeron, F., & Raymond, L. (2014). Information management for the internationalization of SMEs: An exploratory study based on a strategic alignment perspective. *International Journal of Information Management, 34*(5), 672-681.

Evans, M., & Farrell, P. (2022). A strategic framework managing challenges of integrating lean construction and integrated project delivery on construction megaprojects, towards global integrated delivery transformative initiatives in multinational organisations. Journal of Engineering, Design and Technology, (ahead-of-print).

Ganesan, S. (2019). *Employment, technology and construction development: With case studies in Asia and China*: Routledge.

Gao, X., & Yan, Z. (2013). Comprehensive assessment of smart grid construction based on principal component analysis and cluster analysis. *Power system technology, 37*(8), 2238-2243.

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

Gellweiler, C. (2022). IT architects and IT-business alignment: a theoretical review. Procedia Computer Science, 196, 13-20.

Gingras, Y., & Khelfaoui, M. (2018). Assessing the effect of the United States'"citation advantage" on other countries' scientific impact as measured in the Web of Science (WoS) database. *Scientometrics, 114*(2), 517-532.

Goodrum, P. M., Haas, C. T., Caldas, C., Zhai, D., Yeiser, J., & Homm, D. (2010). Model to predict the impact of a technology on construction productivity. *Journal of Construction Engineering and Management, 137*(9), 678-688.

Gries, S. T., & Stefanowitsch, A. (2010). Cluster analysis and the identification of collexeme classes. *Empirical and experimental methods in cognitive/functional research*, 73-90.

Gunasekaran, A., Subramanian, N., & Papadopoulos, T. (2017). Information technology for competitive advantage within logistics and supply chains: A review. *Transportation Research Part E: Logistics and Transportation Review, 99*, 14-33.

Guo, H., Yu, Y., & Skitmore, M. (2017). Visualization technology-based construction safety management: A review. *Automation in Construction, 73*, 135-144.

Haniff, A. P., & Galloway, L. (2022). Modeling strategic alignment in project networks. International Journal of Project Management.

Harzing, A.-W., & Alakangas, S. (2016). Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison. *Scientometrics, 106*(2), 787-804.

He, Q., Wang, G., Luo, L., Shi, Q., Xie, J., & Meng, X. (2017). Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis. *International Journal of Project Management, 35*(4), 670-685.

Heidarinejad, M., Dahlhausen, M., McMahon, S., Pyke, C., & Srebric, J. (2014). Cluster analysis of simulated energy use for LEED certified US office buildings. *Energy and Buildings, 85*, 86-97.

Heilig, L., & Voß, S. (2014). A scientometric analysis of cloud computing literature. *IEEE Transactions on Cloud Computing, 2*(3), 266-278.

Hosseini, M. R., Martek, I., Zavadskas, E. K., Aibinu, A. A., Arashpour, M., & Chileshe, N. (2018). Critical evaluation of off-site construction research: A Scientometric analysis. *Automation in Construction, 87*, 235-247.

Huo, B., Wang, K., & Zhang, Y. (2021). The impact of leadership on supply chain green strategy alignment and operational performance. Operations Management Research, 14(1), 152-165.

Ivancheva, L. (2008). Scientometrics today: a methodological overview. *Collnet journal of scientometrics and information management*, *2*(2), 47-56.

Johnson, A. M., & Lederer, A. L. (2010). CEO/CIO mutual understanding, strategic alignment, and the contribution of IS to the organization. *Information & management*, *47*(3), 138-149.

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, *20*(2), 126-133.

Kaliyaperumal, K. (2015). A scientometric analysis of mobile technology publications. *Scientometrics*, *105*(2), 921-939.

Kanapeckiene, L., Kaklauskas, A., Zavadskas, E. K., & Seniut, M. (2010). Integrated knowledge management model and system for construction projects. *Engineering applications of artificial intelligence*, *23*(7), 1200-1215.

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*, *19*(6), 610-635.

Lee, S., Yu, J., & Jeong, D. (2013). BIM acceptance model in construction organizations. *Journal of Management in Engineering*, *31*(3), 04014048.

Li, J., Zuo, J., Cai, H., & Zillante, G. (2018). Construction waste reduction behavior of contractor employees: An extended theory of planned behavior model approach. *Journal of cleaner production*, *172*, 1399-1408.

Li-ming, X., & Heng-heng, Z. (2011). Application of cluster analysis and grey related degree to affecting factors analysis of construction accident. *Journal of Safety Science and Technology*, *7*(12), 157-162.

Lu, Y., Li, Y., Skibniewski, M., Wu, Z., Wang, R., & Le, Y. (2014). Information and communication technology applications in architecture, engineering, and construction organizations: A 15-year review. *Journal of Management in Engineering, 31*(1), A4014010.

Naoum, S. G. (2016). Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey. International journal of productivity and performance management.

Martín-Martín, A., Orduna-Malea, E., Thelwall, M., & López-Cózar, E. D. (2018). Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *Journal of Informetrics, 12*(4), 1160-1177.

Miriello, D., Barca, D., Bloise, A., Ciarallo, A., Crisci, G. M., De Rose, T., . . . La Russa, M. F. (2010). Characterisation of archaeological mortars from Pompeii (Campania, Italy) and identification of construction phases by compositional data analysis. *Journal of Archaeological Science, 37*(9), 2207-2223.

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics, 106*(1), 213-228.

Morrison, E. D., Ghose, A. K., Dam, H. K., Hinge, K. G., & Hoesch-Klohe, K. (2011). *Strategic alignment of business processes.* Paper presented at the International Conference on Service-Oriented Computing.

Mutesi, E. T., & Kyakula, M. (2011). *Application of ICT in the Construction Industry in Kampala.* Paper presented at the Second International Conference on Advances in Engineering and Technology.

Negahban, S. S., Baecher, G. B., & Skibniewski, M. J. (2012). A decision-making model for adoption of enterprise resource planning tools by small-to-medium size construction organizations. *Journal of Civil Engineering and Management*, *18*(2), 253-264.

Ng, S. T., Wong, J. M., & Zhang, J. (2011). Applying Z-score model to distinguish insolvent construction companies in China. *Habitat International, 35*(4), 599-607.

Oliveira, T., & Martins, M. F. (2011). Literature review of information technology adoption models at firm level. *Electronic Journal of Information Systems Evaluation, 14*(1), 110.

Orlikowski, W. J. (2000). Using technology and constituting structures: A practice lens for studying technology in organizations. *Organization science, 11*(4), 404-428.

Oyewobi, L., Windapo, A., Cattell, K., & Rotimi, J. (2013). Impact of organisational structure and strategies on construction organisations' performance.

Oyewobi, L. O., Windapo, A. O., Rotimi, J. O. B., & Jimoh, R. A. (2016). Relationship between competitive strategy and construction organisation performance: The moderating role of organisational characteristics. *Management Decision, 54*(9), 2340-2366.

Panuwatwanich, K., & Nguyen, T. T. (2017). Influence of organisational culture on total quality management implementation and firm performance: Evidence from the Vietnamese construction industry. *Management and Production Engineering Review, 8*(1), 5-15.

Peansupap, V., & Walker, D. (2005). Exploratory factors influencing information and communication technology diffusion and adoption within Australian construction organizations: a micro analysis. *Construction Innovation, 5*(3), 135-157.

Pekericli, M. K., Akinci, B., & Karaesmen, I. (2004). Modeling information dependencies in construction project network organizations. In *Towards a vision for information technology in civil engineering* (pp. 1-13).

Perkinson, C. L., & Ahmad, I. U. (2006). *Computing technology usage in construction contractor organizations.* Paper presented at the 4th LACCEI International Latin American and Caribbean Conference for Engineering and Technology (LACCET'2006),"Breaking Frontiers and Barriers in Engineering: Education, Research and Practice", 21-23 June 2006.

Pollack, J., & Adler, D. (2015). Emergent trends and passing fads in project management research: A scientometric analysis of changes in the field. *International Journal of Project Management, 33*(1), 236-248.

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction, 31*, 204-214.

Ren, Y.-c., Xing, T., Quan, Q., & Zhao, G.-q. (2010). Fuzzy cluster analysis of regional city multi-level logistics distribution center location plan. In *Quantitative Logic and Soft Computing 2010* (pp. 499-508): Springer.

Rezgui, Y. (2001). Review of information and the state of the art of knowledge management practices in the construction industry. *The Knowledge Engineering Review, 16*(3), 241-254.

Rogers, J., Chong, H.-Y., & Preece, C. (2015). Adoption of building information modelling technology (BIM) perspectives from Malaysian engineering consulting services firms. *Engineering, Construction and Architectural Management, 22*(4), 424-445.

Sanders, N. R., & Premus, R. (2002). IT applications in supply chain organizations: a link between competitive priorities and organizational benefits. *Journal of business logistics, 23*(1), 65-83.

Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J., . . . Xue, H. (2010). Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. *Advanced engineering informatics, 24*(2), 196-207.

Shi, Q., Zuo, J., Huang, R., Huang, J., & Pullen, S. (2013). Identifying the critical factors for green construction–an empirical study in China. *Habitat International, 40*, 1-8.

Sinha, A., Lahiri, R. N., Chowdhury, S., Chowdhury, S. P., & Song, Y. H. (2007, September). Complete it solution for Enterprise Asset Management (EAM) in Indian power Utility business. In 2007 42nd International Universities Power Engineering Conference (pp. 645-650). IEEE.

Son, H., Kim, C., Kim, H., Han, S. H., & Kim, M. K. (2010). Trend analysis of research and development on automation and robotics technology in the construction industry. *KSCE Journal of Civil Engineering, 14*(2), 131-139.

Son, H., Lee, S., & Kim, C. (2015). What drives the adoption of building information modeling in design organizations? An empirical investigation of the antecedents affecting architects' behavioral intentions. *Automation in Construction, 49*, 92-99.

Stewart, R. A., Mohamed, S., & Marosszeky, M. (2004). An empirical investigation into the link between information technology implementation barriers and coping strategies in the Australian construction industry. *Construction Innovation, 4*(3), 155-171.

Sun, C., Jiang, S., Skibniewski, M. J., Man, Q., & Shen, L. (2017). A literature review of the factors limiting the application of BIM in the construction industry. *Technological and Economic Development of Economy, 23*(5), 764-779.

Surulinathi, M., Balasubramani, R., & Kalisdha, A. (2013). Continent wise Analysis of Green Computing Research: a scientometric study. *Journal of Advances in Library and Information Science, 2*(1), 39-44.

Takim, R., Harris, M., & Nawawi, A. H. (2013). Building Information Modeling (BIM): A new paradigm for quality of life within Architectural, Engineering and Construction (AEC) industry. *Procedia-Social and Behavioral Sciences, 101*, 23-32.

Tam, V. W., & Tam, C. M. (2006). A review on the viable technology for construction waste recycling. *Resources, conservation and recycling, 47*(3), 209-221.

Valderrama-Zurián, J.-C., Aguilar-Moya, R., Melero-Fuentes, D., & Aleixandre-Benavent, R. (2015). A systematic analysis of duplicate records in Scopus. *Journal of Informetrics, 9*(3), 570-576.

Valero, E., Adán, A., & Cerrada, C. (2015). Evolution of RFID applications in construction: A literature review. *Sensors, 15*(7), 15988-16008.

Vidogah, W., & Ndekugri, I. (1998). A review of the role of information technology in construction claims management. *Computers in industry*, *35*(1), 77-85.

Wong, J., Wang, X., Li, H., & Chan, G. (2014). A review of cloud-based BIM technology in the construction sector. *Journal of information technology in construction*, *19*, 281-291.

Woo, C., Kim, M. G., Chung, Y., & Rho, J. J. (2016). Suppliers' communication capability and external green integration for green and financial performance in Korean construction industry. *Journal of cleaner production*, *112*, 483-493.

Xiong, B., Skitmore, M., & Xia, B. (2015). A critical review of structural equation modeling applications in construction research. *Automation in Construction*, *49*, 59-70.

Yan, H., & Demian, P. (2008). Benefits and barriers of building information modelling.

Yi-ling, Z. (2011). Our Logistics Industry Cluster Analysis and Construction of Dynamic Mechanism Path [J]. *Logistics Engineering and Management*, *1*.

Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C. M., & Teizer, J. (2015). BIM-based fall hazard identification and prevention in construction safety planning. *Safety science*, *72*, 31-45.

ZHANG, X. (2016). Research on visual analysis of big data based on CiteSpace III. *Management Science and Engineering*, *10*(4), 62-67.

Zhong, B., Wu, H., Li, H., Sepasgozar, S., Luo, H., & He, L. (2019). A scientometric analysis and critical review of construction related ontology research. *Automation in Construction*, *101*, 17-31.

Zhou, Z., Irizarry, J., & Li, Q. (2013). Applying advanced technology to improve safety management in the construction industry: a literature review. *Construction Management and Economics*, *31*(6), 606-622.