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Innovation in Construction
An innovation Framework for Infrastructure reconstruction Projects

by Mohammadali Noktehdan

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in
Engineering

January 2017
Department of Civil and Environmental Engineering
University of Auckland
بِنَبِيِّ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ
Dedicated to my parents, for their love, with mine
Abstract

This thesis describes the management process of innovation through construction infrastructure projects. This research focuses on the innovation management process at the project level from four views. These are categorised into the separate yet related areas of: “innovation definition”, “Project time”, “project team motivation” and “Project temporary organisation”. A practical knowledge is developed for each of these research areas that enables project practitioners to make the best decision for the right type of innovation at the right phase of projects, through a capable project organisation. The research developed a holistic view on both innovation and the construction infrastructure project as two complex phenomena.

An infrastructure project is a long-term capital investment, highly risky and an uncertain. Infrastructure projects can play a key role in innovation and performance improvement throughout the construction industry. The delivery of an infrastructure project is affected in most cases by critical issues of budget constraint, programme delays and safety Where the business climate is characterized by uncertainty, risk and a high level of technological change, construction infrastructure projects are unable to cope with the requirement to develop innovation.

Innovation in infrastructure projects, as one of the key performance indicators (KPI) has been identified as a critical capability for performance improvement through the industry. However, in spite of the importance of infrastructure projects in improving innovation, there are a few research efforts that have developed a comprehensive view on the project context and its drivers and inhibitors for innovation in the construction industry. Two main reasons are given as the inhibitors through the process of comprehensive research on innovation management in construction. The first reason is the absence of an understanding of innovation itself. The second is a bias towards research at a firm and individual level, so a comprehensive assessment of project-related factors and their effects on innovation in infrastructure projects has not been undertaken.
This study overcomes these issues by adopting as a case study approach of a successful infrastructure project. This research examines more than 500 construction innovations generated by a unique infrastructure alliance. SCIRT (Stronger Christchurch Infrastructure Rebuild Team) is a temporary alliancing organisation that was created to rebuild and recover the damaged infrastructure after the Christchurch 2011 earthquake. Researchers were given full access to the innovation project information and innovation systems under a contract with SCIRT Learning Legacy, provided the research with material which is critical for understanding innovations in large, complex alliancing infrastructure organisation. In this research, an innovation classification model was first constructed. Clear definitions have been developed for six types of construction innovation with a variety of level of novelties and benefits. The innovation classification model was applied on the SCIRT innovation database and the resultant trends and behaviours of different types of innovation are presented. The trends and behaviours through different types of SCIRT innovations developed a unique opportunity to research the project-related factors and their effect on the behaviour of different classified types of innovation throughout the project’s lifecycle.

The result was the identification of specific characteristics of an infrastructure project that affect the innovation management process at the project level. These were categorised in four separate chapters. The first study presents the relationship between six classified types of innovation, the level of novelty and the benefit they come up with, by applying the innovation classification model on SCIRT innovation database. The second study focused on the innovation potential and limitations in different project lifecycle phases by using a logic relationship between the six classified types of innovation and the three classified phases of the SCIRT project. The third study result develops a holistic view of different elements of the SCIRT motivation system and results in a relationship between the maturity level of definition developed for innovation as one of the KPIs and a desire though the SCIRT innovation incentive system to motivate more important innovations throughout the project. The fourth study is about the role of the project’s temporary organisation that finally results in a multiple-view innovation model being developed for project organisation capability assessment in the construction industry.
The result of this thesis provides practical and instrumental knowledge to be used by a project practitioner. Benefits of the current thesis could be categorized in four groups. The first group is the innovation classification model that provides a clear definition for six classified types of innovation with four levels of novelty and specifically defined outcomes and the relationship between the innovation types, novelty and benefit. The second is the ability that is provided for the project practitioner to make the best decision for the right type of innovation at the right phases of a project’s lifecycle. The third is an optimisation that is applied on the SCIRT innovation motivation system that enables the project practitioner to incentivize the right type of innovation with the right level of financial gain. This drives the project teams to develop a more important innovation instead of a simple problem-solving one. Finally, the last and probably more important benefit is the recommended multiple-view innovation model. This is a tool that could be used by a project practitioner in order to empower the project team to support innovation throughout the project.
Acknowledgment

First and foremost, I would like to thank the Almighty God for instilling in me the potential and the drive to pursue knowledge.

There are many people including friends, family and colleagues whose contributions have made this work possible. I am very thankful to them all.

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Much of my gratitude is given to Dr Mehdi Shahbazpour for giving me the opportunity to undertake research in this area. I can still remember that when English became a big challenge, he was always kind to help. Much of this accomplishment is actually indebted to the comprehensive and breakthrough academic achievements of his PhD. I am also very grateful to him for providing me with supervision, advice, support and numerous valued recommendations throughout the study.

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Chapter 1. Introduction

1.1. Background

The construction industry is critical to the functioning of a domestic economy. In New Zealand, the construction industry is one of the largest sectors of the economy, accounting for 8% of total employment in the country (Bill, 2011). However, in spite of its importance to the national economy in terms of size, it seems to be lagging behind other sectors in terms of productivity and innovation. In 2010, the construction industry in New Zealand established the Building and Construction Sector Productivity Partnership to actively address the problem of low productivity in the sector (Wilkinson, Kempton, & Gleeson, 2012). Although the early focus was on identifying and quantifying the problems that led to low productivity, over recent years the focus has shifted to problem solving and addressing the cultural and mechanistic change that is needed to resolve the well-documented problems (Wilkinson et al., 2012).

One of the areas that the partnership identified as critical for achieving significant improvements in the sector’s productivity is innovation. The ultimate goal was for 20% productivity improvement by 2020, but this required a shift in methodology. The Construction Sector Productivity Partnership advocated for new, innovative, approaches as required in order to significantly improve performance at the same cost or maintain the same level of performance at a much lower cost. Unfortunately the construction industry is one of the least innovative sectors compared to other industries such as manufacturing and traditional services, (Reichstein, Salter, & Gann, 2005). The R&D report produced by Statistics New Zealand indicates that R&D expenditure in the construction industry accounts for a low 5% of the total expenditure in the sector (Statistics NZ, 2012). Indeed, this problem is not limited to New Zealand as, internationally, the construction industry is seen as a traditional or low-technology sector with low
levels of expenditure on activities associated with innovation (Loosemore & Richard, 2015; Seaden, Guolla, Doutriaux, & Nash, 2003).

Effective management of innovation first requires a clear and comprehensive definition of innovation at construction projects. Both innovation and construction projects are complex phenomena, therefore a clear and comprehensive definition is essential. An incomplete understanding of innovation could create problems for construction through confusion and poor practice. Various definitions have been developed for innovation in order to make innovation more understandable. These provide a broad definition of innovation as “…doing things differently or better across products, processes or procedures for added value and/or performance” (Brown, 1994; Noktehdan, Shahbazpour, & Wilkinson, 2015, p. 299). (Shahbazpour, 2010, p. 17; West & Altink, 1996) provide a similar, but perhaps more complete, definition of innovation as the “…intentional introduction and application within a role, group or organisation of ideas, processes, products or procedures, new to the relevant unit of adoption, designed to significantly benefit the individual, the group, the organisation or the wider society”. The problem with these definitions is that, they do not lead to practical and instrumental innovation processes that could be used by project practitioners and researchers. To provide practical processes requires an innovation classification system which can be used to categorise the innovations implemented in a project. After a review of the literature, it was found that the most commonly accepted innovation classifications have mainly been developed by analysing innovation within the manufacturing and services context (Noktehdan et al., 2015). There are significant differences between construction and other industries. Consequently, in order to develop an appropriate innovation classification system for the construction industry, modifications should be made to these classification systems and, where appropriate, new categories developed.

A failure throughout the literature was found in a bias toward research on innovation management at the level of firms which did not translate into overall increases in project performance. Several recent researchers indicate this failure as the reason that construction industry lagged behind others in innovation development. G. Winch (1998, p. 273) indicated this failure, “However, unlike many other industries, innovations in construction are, typically, not implemented within the firm itself, but on the
projects upon which the firm is engaged adoption decisions by firms have to be implemented on projects”. Loosemore (2015b, p. 67) named innovation in project level as “hidden Innovation” due to the project-based nature of the construction industry where developed innovations at the project level disappear after the project is over. He referred to this as, “hidden innovations do not generally take the form of new radical technologies but are based on adapting and borrowing ideas from elsewhere (reinvention) and by applying them to new problematic contexts (such as a new construction project). Ozorhon (2012, p. 455) indicates that “… the analysis of innovation at the project level is essential”. She also stated the problem as, “…, most of the literature has focused on investigating innovation at the firm level, and the project level has largely been ignored”. Bygballe and Ingemansson (2014, p. 516) indicated the importance of project context for innovation management by stating that “Projects represent decentralized environments, and are seen to provide unique opportunities for innovation, because they allow for exploration”. Comprehensive project-based innovation research is needed in order to understand more fully the means by which innovations can be generated for the benefit of the construction industry.

An innovation framework as a tool by project practitioners is used for managing innovation at project level. This research is aimed to develop an innovation framework based on the live experience of an innovative infrastructure project. Comprehensive knowledge of project-related factors and their impact on innovation process at project context is essential at first stage of research. Addressing this, four project-related factors (Task, Team, Time and Transition) are aimed in order to identify how they would impact on innovation process through an infrastructure project. Using this comprehensive knowledge of innovation stance at project level, the researchers would be able to address the main aim by developing an innovation framework for infrastructure projects.

“Project Time”, “Project Task”, “Project Team” and “Project Transition” allow a multi-view approach to innovation to be made. In terms of project task, an innovation classification model develops a set of clear definitions for different types of innovation that would have happened through different project tasks. Secondly, an incentive structure for the project teams is needed in order to move innovative thinking and culture through the project lifecycle. Thirdly, the project time as a limited resource
provides a dynamic condition that would affect different types of innovation behaviours throughout the project lifecycle. Finally, project temporary organisation, created to address the project transition, plays a key role on the innovation process.

Innovation has been difficult to achieve for many construction companies and on construction projects. An incentive structure has been considered as a key requirement that improves (Reichstein et al., 2005). E Sarah Slaughter (2000, p. 8) found that incentives are a requirement through the successful innovation management, stating, “in addition, the construction company can provide explicit rewards to personnel involved in the innovation process”. G. Winch (1998, p. 274) referred to the importance of the incentive for managing innovation in construction projects as, “Incentives for innovation in construction cannot be improved without the development of a gain/sharing approach, where rewards are split between clients and the actors in the project coalition”.

New innovative ways of managing the relationship between the project clients and their supplier have been discussed by G. M. Winch (2010) which are aimed at aligning incentives within the project teams in order to improve relationships. Similarly, performance measurement systems provide another element of an incentive system that introduces key performance indicators (KPIs) as the defined benchmarks through the project. The pain/gain commercial model as another way of incentivising through an integrated delivery system such as an alliancing contract in order to motivate the project team to compete for better performance (Department of Treasury and Finance 2006). G. M. Winch (2010, p. 132) indicated the importance of an incentive structure in integrated project delivery system as, “Although there would be no contract if there were no coalition of interest between the two parties, there remains plenty of room for divergence of interest unless appropriate incentive arrangements are in place”. Despite the literature about the importance of the KPI system, performance measurement methods and the performance-based commercial models, there is still no research to address the ways an incentive arrangement could be optimized in order to motivate different types of innovation.

The dynamic nature of a project and its effects on innovation behaviour through a construction project’s lifecycle is another research area that has been lacking in the literatures. The changing pattern of innovation through the project life cycle was previously identified by Ford and Sullivan (Ford &
Sullivan, 2004) who argued that for innovation “… the meaning and impact of novel contribution changes during a project team’s lifecycle” (Ford & Sullivan, 2004, p. 279). Utterback and Abernathy (1975) developed a conceptual model that presented the pattern of two types of Product and Process innovation behaviour through three phases of project lifecycle.

It has been suggested that innovation occurs in different ways at different times throughout the project life cycle. For instance, the importance of timing for innovation management was stated by Tzokas and Saren (1997, p. S91), “Whilst the role of strategy in the development of new products and processes has received a lot of attention, the link between strategy and timing of innovation adoption is acknowledged to be of a complex, multivariate, non-recursive, dynamic and asymmetric nature”. Addressing the changing environment, the Project Management Body of Knowledge (PMBOK) shows how life cycles change and affect the different project elements such as “cost and staffing level”, “risk and uncertainty level” and “stockholder influences level” through the project lifecycle (Rose, 2013). Edwards (2013, p. 72) suggested changes over time, and linked this to project success, ”the probability of successfully completing a project is lowest and hence risk and uncertainty are highest at the start of the project, the probability of successfully completion generally get progressively higher as the project continues”. Different project lifecycle phases provide various types of potentials and limitations for innovation process. Depending on who is involved on the project and what the main tasks and responsibilities on a specific time of project are, the type of innovation change through the project lifecycle. A project starts with activities such as “feasibility study” and “concept design” at the very early phase to provide an open-minded environment as the main characteristics of project condition. “Detailed design”, “tendering process” and “early involvement of contractors” are the main activities of the second phase of a project. Different phases provide different options to innovate. The changing environment through the project lifecycle and its effect on different types of innovation behaviour has not be properly assessed.

Recent literature indicates the importance of organisational capability at the project level Loosemore (2015b, p. 69). He identified the process of innovation in the construction industry as, “The grassroots approach argues that innovation is not an individual act and does not just happen within the industrial
supply side or as a result of the articulation of user demand, but through a complex set of processes that link many different actors together”. G. Winch (1998, p. 276), identified the importance of the project organisation for innovation management as, “more attention needs to be given to creating these intra- and extra-organizational infrastructures in which innovation can flourish”. The importance of a capable project organisation was revealed as one of the key elements of innovation success through recent huge infrastructure projects such as Heathrow, Crossrail and London Olympic 2012 as well (Davies, MacAulay, DeBarro, & Thurston, 2014). However, despite a large body of knowledge about the importance of the organisational context for innovation management in a construction project, there is still a lack of a comprehensive innovation model that could be used in order to empower the project organisation to be more innovative. A multiple-view comprehensive innovation model that synthesised different organisational factors in a single model could be useful for assessing and empowering project organisation to innovate. Addressing this need, the successful achievement of other industries such as manufacturing could help the construction innovation.

The main aim of this research is to use developed knowledge of the four research areas (Task, Team, Time, and Transition) in order to provide a strategic plan for managing innovation at project level. The innovation framework is a best practice document which includes a variety of different managerial advices for innovation at each phases of infrastructure projects.

1.2. Problem statement

In summary, infrastructure projects provide an opportunity for improving innovation in the construction industry. However, despite the importance of the project environment for innovation, most research have tended to focus on firm and individual levels in order to identify local innovations. The efforts of the innovation researchers and project practitioners are often hindered by their incomplete understanding of a unique and complex dynamic of innovation in infrastructure projects. An analysis of infrastructure project potential for innovation and the development of an understanding of different aspects of a project context and its effects on the innovation process is needed. Addressing this need, current research identified the main aim as understanding of innovation management process at project
level. An innovation framework was aimed by the researchers to be developed as a tool for managing innovation through infrastructure projects. Four research areas will form the knowledge of this research to develop the innovation framework: Innovation task definition, Project Team, Project Time and Project Organisation. First, an Innovation classification system will develop different definitions for variety types of innovation and tasks in a construction project. A project incentive structure is developed in order to motivate the project teams to develop more important types of innovation. A phase-based innovation assessment is developed, in order to illustrate the types of innovation through the project lifecycle. Finally, the role of project organisation is assessed by testing a successful innovation model from the manufacturing industry on the construction data which would make project managers able to understand how the project organisation can innovate more. This research will provide practical knowledge for project practitioners in order to manage the innovation process for infrastructure projects.

The research in this thesis is based on a large and detailed case study of the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), which was a multi-party alliance which had at the heart of its operation innovation. SCIRT developed innovation processes, KPI’s and actively managed innovation. SCIRT provided the innovation database and access to SCIRT personnel during this research.

1.3. Research Aims and Objectives

The study presented in this thesis developed an understanding of the process of managing innovation in the construction infrastructure projects. This research was therefore conducted to fill the five identified knowledge gaps. The first and main aim is to fill the knowledge gap about an innovation strategic and practical plan at the project level. The further four aims are supposed to support by providing enough knowledge of the project context and its impact on innovation process.
Research Aim 1

The first and most important aim of this study is to provide a comprehensive knowledge of strategic plan for managing innovation at project level. A bias of researchers towards innovation at firms/company levels caused a knowledge gap about the innovation strategic plan at project level. Addressing this gap, current research identified the main aim to assess the way of applying an innovation action plan throughout the project lifecycle. Along this journey, the researchers focused on providing knowledge of the four project related factors and the impact they would have on innovation process throughout the project. Innovation management advices are expected to be developed based on the live experience of an innovative infrastructure project (SCIRT) in NZ. The research provides draft best-practice guidelines for managing innovation at project level. Therefore, research objective 1 became:

Research Objective 1: Develop a phase-based innovation framework for construction infrastructure projects which can be used to guide innovation at project level.

Research Aim 2

The second aim of this research is to further understand of “Task” as one of the four project related factors. This aim is supposed to provide enough knowledge of variety of different types of task and the impact they would have on innovation at project level. Innovation should be defined through a classification model in order to address the variety of different tasks. Understanding innovation classifications will allow for the development of a comprehensive definition for construction innovation. Diversity and differences through the +500 innovations produced by SCIRT were identified by the researchers and an initial assessment on the SCIRT innovation database carried out. SCIRT has developed diverse types of tasks and activities in order to respond to the disaster reconstruction of Christchurch’s piping, bridges, walls and roads. This diversity of tasks and activities resulted in a database of different types of innovation with a variety of levels of novelty and benefits across the construction life cycle. Using the initial assessment results, the research developed separate definitions
for different types of innovation with a variety of levels of novelty and benefits in the format of a synthesised innovation classification model. An understanding of different types of innovation was developed as a result of the innovation classification. Results of the innovation classification model application revealed some trends through different types of innovations in the SCIRT database. In order to further understanding of innovation classification, the first research objective became to:

**Research Objective 2: Develop an innovation classification model as a comprehensive definition of innovation in the construction industry.**

**Research Aim 3**

The third aim of this thesis is to know about the second project related factor (Team) and its impact on innovation at infrastructure project. The people should be incentivised for providing more innovation at their work through the project. This aim focused on SCIRT’s innovation rewarding structure and its capability to incentivise teams and individual through the project’s lifecycle. Firstly, an understanding of different elements of SCIRT’s reward structure was aimed. Two main mechanisms were identified as the key elements of the SCIRT rewarding structure: ‘performance measurement system’, and ‘pain/gain commercial model’. The performance measurement system introduced the performances’ key indicator (KPI) as the benchmark in order to assess the team performance through the project lifecycle. Performance scores were developed for each of the KPIs in order to be used as references through the pain/gain commercial model. This was used by SCIRT as a complementary mechanism in order to indicate an extra financial benefit based on the performance scores that were calculated by the measurement system. Innovation was one of the KPIs. The research examined the KPI system and other reward systems for incentivising innovation. Using the KPI system as a starting point the research aimed to see if improvements could be made to the system used by SCIRT. Therefore, research objective 3 became:

**Research Objective 3: Assess the SCIRT’s innovation incentive system and develop an optimisation in SCIRT’s innovation scoring formulate.**
**Research Aim 4**

The fourth aim of this thesis is to understand how innovation would be affected by “Time” as the third project related factor. This aim is to know where innovations can be developed throughout the project lifecycle. An initial assessment of SCIRT innovations and the impact of ‘Time’ on the innovation process revealed a relationship between SCIRT innovation and the project lifecycle. A constant changing environment in the project team, priority, activities and resources resulted from the dynamic nature of SCIRT illustrated the changing behaviour of different types of innovation through different phases of the project. The analysis allowed for the development of an innovation lifecycle model that illustrated the innovation’s behaviour throughout the SCIRT project lifecycle. A project is dynamic and that affects the process of innovation throughout the project lifecycle. The changing behavior of innovation through different phases of a project lifecycle would be addressed by using the SCIRT innovation database. Behavior of different classified types of SCIRT innovation are analyzed through different phases of project. These innovation lifecycle models illustrated a clear relationship between the project and the patterns of different types of innovation during the project. Developing an assessment of the life cycle in respect to innovation appeared to be an avenue worth exploring. The research objective 4 became:

**Research Objective 4: Assess the SCIRT’S lifecycle to determine where different types of innovation occur across a variety levels of innovation novelty and benefits.**

**Research Aim 5**

The fifth aim of this thesis is to describe the importance of the “Transition” on innovation process at project level. The result of the literature review of construction innovation models revealing an incomplete knowledge of organisational factors and their effect on the innovation process. The ability of a temporary organisation (such as SCIRT) in driving innovations in infrastructure project was a focus of this research. Addressing the lack of understanding of the effects of organisations on innovation, an organisational innovation model was developed and applied to SCIRT to understand the organisational processes required to improve innovation. Research objective 5 became:
Research Objective 5: Apply an organisational innovation model on SCIRT as a tool for improving innovation for temporary project organisations in the construction industry.

1.4. Thesis structure

This research is presented in following nine chapters (excluding the introductory chapter) as follows:

- Chapter 2 reviews the main theme of managing innovation process throughout the infrastructure project environment.

- Chapter 3 presents the research methodology used in the thesis and the final research design is also presented.

- Chapter 4 develops a construction innovation model that defines different types of innovation.

- Chapter 5 provides an analysis of the SCIRT innovation incentive structure and develops a holistic view of the incentive structure and the way it works through the projects.

- Chapter 6 shows innovation behaviour throughout the project lifecycle. The result of analyses on the SCIRT project timing and the timing of +500 innovations is presented in this chapter. The result show different types of innovation throughout the lifecycle.

- Chapter 7 determines what role the project organisation would play in innovation process success in the construction industry. This chapter presents the result of testing of a multiple-view innovation model.
The innovation model was collected from manufacturing industry literature. The proposed innovation model was validated by applying on the SCIRT.

- Chapter 8 develops a phase-based innovation framework that proposes practical advice for managing innovation for each of the four phases of a project. The result of the comprehensive, multiple-view research, (developed through previous chapters of current thesis) have been used for proposed advice.

- Chapter 9 provides conclusions and recommendations for future researches.

Note: Regarding the fact that addressing the main of this thesis (innovation framework) is totally dependent on the developed knowledge of the further four aims (Task, Team, Time and Transition), this thesis starts with focusing on the four aims through chapters 4-7 and then finish the findings with the main aim in chapter 8.

1.5. Thesis with papers

The thesis is presented as a thesis with papers which means that each chapter has been developed as a working paper for submission in international conferences and journals. Each chapter can be considered as a discrete piece of work alone. This thesis work publications have followed UOA “Doctoral Candidates - Including Publications in a Thesis policy and procedures”.
Chapter 2. Innovation in construction

Working paper to be submitted to:


2.1. Introduction

This chapter aims to further understanding of innovation stance in construction. The chapter develops an understanding of the relationship between the characteristics of construction industry and innovation process. The relationship between types of construction delivery systems and innovation behaviour is studied at this chapter. In the first part of this chapter, knowledge will be developed for innovation in the construction industry. Different types of innovation models and strategies in construction will be discussed at this part.

The second part of this chapter focuses on the innovation stance in New Zealand construction industry. ‘SCIRT’ as an innovative infrastructure project in NZ construction industry will be introduced by this chapter.

2.2. Innovation in construction

The key role of innovation in different aspects of human life has developed a movement through diverse industries for developing researches on innovation process. This diversity of innovation definitions has made it difficult for researchers to reach agreement. Zairi (1994, p. 27) stated this issue as, “What makes innovation challenging is the fact that it is very difficult to agree on a common definition”. “Whilst there is some overlap between the various definitions of innovation, overall the number and diversity of definitions leads to a situation in which there is no clear and authoritative definition of innovation” (Baregheh, Rowley, & Sambrook, 2009, p. 1324). Despite a lack of agreement, there is still one common
statement through all innovation literature: the concept of ‘innovation’ is completely different to the ‘invention’ (Fagerberg, 2004). The practicality and applicability of innovation has made it benefit the prime cause of an increase in economic growth (Schumpeter, 1961) and in productivity (Noktehdan et al., 2015). Fagerberg (2004), stated this phenomenon as: “Although both invention and innovation are associated with novelty, invention stops at the point of the creation of the new idea. Innovation, on the other hand, occurs when the new idea is implemented and commercialised”. The practicability of innovation means the broad benefit it could have for diverse areas such as “Tools”, “Product”, “Process”, “Organisation”, “Business and economics”, etc. (OECD, 2005). Shahbazpour (2010, p. 16) identified this diversity of the innovation impact as: “Another common misconception is that innovation is often viewed in terms of a new product or service”. Barrett and Sexton (2006, p. 333) said, “In summary, within the general and construction literature there appears to be an ongoing shift from viewing innovation as an ‘end’ in itself, to innovation being a ‘means’ to achieve sustainable competitiveness”. A holistic picture of innovation in different types with various levels of novelty and benefit could help researchers, practitioners and managers to have a complete understanding of innovation concept, as an initial step towards pushing them to be more innovative (Noktehdan et al., 2015).

The construction industry could be naturally considered as an innovative phenomenon due to the unique characteristics of all products developed as a final result of different projects. The “one of a kind” nature of the construction product, makes innovation a daily requirement for all activities, materials, designs and management processes through a construction project lifecycle (G. Winch, 1998). Barrett and Sexton (2006, p. 333) defined innovation in the construction industry as “the act of introducing and using new ideas, technologies, products and/or processes aimed at solving problems, viewing things differently, improving efficiencies and effectiveness, or enhancing standards of living”. The key role of innovation in construction productivity improvement has been identified by Noktehdan et al. (2015). The construction industry’s performance has lagged behind others, according to the Egan report “Rethinking Construction” (Murray, Murray, & Langford, 2003).
Despite the large body of knowledge about innovation in manufacturing and service industries, innovation research in the construction industry is still in its infancy (Barrett & Sexton, 2006). Five different innovation models have been developed by E. Sarah Slaughter (1998) as an initial innovation literature in the construction industry. The low level of innovation’s success in the construction industry has been stated by several literatures (Drejer & Vinding, 2006; Force & Britain, 1998; Manley, 2004; Pries & Janssen, 1995; Reichstein et al., 2005). Reichstein et al. (2005, p. 642) stated this failure as, “The statistical analysis shows that construction firms are distinct in their innovative behaviour and attitudes. In some respects, they are ‘last among equals’, exhibiting a low number of firms engaged in product and/or process innovation”. This innovation failure is supported by a survey covering the period 1998–2000. The survey found that, while 58% of firms in the manufacturing industry and 44% of firms in trade and services had introduced new products or services during the period covered by the survey, the corresponding figure in the construction industry was only 22% (Drejer & Vinding, 2006). However, despite a common statement that introduced innovation as a lagged-behind industry, a large number of innovations were identified in daily problem-solving formats (Loosemore, 2015b; G. Winch, 1998). Taylor (2005) identified this misunderstanding as, “much of the innovation that occurs in sectors, such as construction, is invisible to the innovation metrics traditionally used to rank industries in many countries, and it is for this reason that they appear to underperform in comparison with other industries“.

The reason behind this common misconception about the innovation condition is identified as a lack of strategic planning for innovation in the construction industry (Manley, 2004). This lack of strategic planning for innovation was identified by Loosemore (2015b) as a reason that makes most construction innovation into a small matter of problem-solving that is developed daily in order to address project difficulties.

The more ambitious targets for constructing performance were identified as one of the five main pieces of advice by the Egan report, in order to cope with a large performance failure. The need for change has been stated by Force and Britain (1998) as, “the Task Force's ambition for construction is informed by our experience of radical change and improvement in other industries, and by our experience of delivering improvements in quality and efficiency within our own construction programmes”.

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Innovation achievement, as one the best practices, successfully used by manufacturing, could be followed by the construction industry as well. Learning to become a world-class industry has been followed by various successful infrastructure projects in the construction industry. Crossrail, an innovative infrastructure project, developed its innovation strategy based on learning from world-class innovative companies such as Apple and software companies. “Crossrail is learning from organisations outside the construction industry that have world-class innovation programmes” (L. Crossrail, 2013, p. 6). Foreword David Gann CBE, the head of the Innovation and Entrepreneurship Group stated, “During the preparation for Heathrow Terminal 5 in the 1990s Sir John Egan, CEO of BAA, recognised the importance of learning and adopting best practices from other industries, the role of intelligent client, collaborative teams, and modularity adopted from oil and gas and lean production, just-in-time logistics, and concurrent engineering from the car industry” (L. Crossrail, 2013, p. 3; 2015).

The special differences between construction and other industries make the process of learning challenging for researchers. E. Sarah Slaughter (1998, p. 226) stated this challenge as, “However, certain key differences distinguish construction from manufacturing activities, and the nature of these differences can provide insights into how the existing innovation models and theories must be modified to reflect the characteristics of the construction-related activities”. Understanding the innovation environment in the construction industry requires the researchers to know about the unique characteristic of this industry. This knowledge would provide an opportunity to develop a comprehensive and holistic picture of the innovation behaviour in the construction industry. Tawiah and Russell (2008) found that innovation is hampered because of the unique characteristics of infrastructure projects, such as: project complexity and scale, budget constraints, programme delay and quality concern, a complex stakeholder environment, process and product risk and also socioeconomics and political factors. The risk associated with innovation in terms of the consequences of failure with regards to public safety and loss of investment, and the limited opportunities to appropriate the benefits of innovation in an industry, are some of the major concerns in construction projects that result in low levels of innovation (Tawiah & Russell, 2008). Complexity, durability, immobility, costliness and
social impacts are some of the unique characteristics that have been identified for construction industry (Vrijhoef & Koskela, 2000).

*Project based-opportunistic industry:*

Time should be considered as a limited resource in construction as a project-based industry. An opportunity for innovation can only be developed in the limited time of the project; it ends when the project is over (G. M. Winch, 2014). The lack of a feedback loop is a result of the project-based and opportunistic environment of the construction industry. This feedback loop is available in a long-term business that carries out a stable market such as a production-based industry (Koskela & Vrijhoef, 2001). The “pressure-cooker” environment as a result of the time and money shortage in the construction project makes the innovation process very opportunistic. Long term research and development (R&D), one of the most important preconditions for innovation in production-based industry, is not available in construction (Loosemore, 2015b). The emergency condition of construction projects requires the project teams to focus on the project’s priority (time, cost, safety etc.) instead of innovation, a risky environment. Lack of a competitive environment in the construction industry, such as a market-based competitor, makes innovation an optional factor for construction practitioners (Reichstein et al., 2005). Competition in a market is a result of a long-term involvement of different brands producing same product or service in manufacturing and service industry. The lack of long-term market-based activities in the construction industry change the concept of the competition completely (Koskela & Vrijhoef, 2001). Collaboration as an innovation driver in construction would address this lack of competitive market in construction (G. M. Winch, 2010). The time and resources shortage of the project could be addressed by innovation being developed by relying on an integrated project delivery system. Innovation could be developed in emergency conditions of the construction project by relying on different project teams’ knowledge and resources that are shared through a collaborative approach.
Complex, multiparty and site based industry:

The high level of uncertainty and complexity of infrastructures is caused by the site-based nature of construction industry (Koskela & Vrijhoef, 2001). The unique characteristics of soil, ground condition, workforce, material availability and domestic regularity develop into an unknown environment in the construction projects. This incomplete understanding of the construction at the earlier stages requires diverse types of knowledge, expertise and experiences in order to address the unknowns through the project lifecycle. Gann (1997) developed a model of the construction system as a supply chain, showing the activities of the different actors in the system as the inventions deriving from research and development (R & D) programmes diffused and implemented on specific projects. Diverse types of knowledge and experiences would be available through a multiparty temporary organisation in order to address the high level of uncertainty and complexity in a construction project (G. Winch, 1998). Managing innovation through a multiparty temporary organisation that is introduced as a “complex system industry” by G. Winch (1998) should be completely different to other industry.

The factory-based condition of the manufacturing industry provides an environment with more known and experienced condition along long-term activities. Unlike the manufacturing industry, managers in the construction industry would not be able to rely on the competitor as a driver for innovation process (Koskela & Vrijhoef, 2001). Innovation in the construction industry should be developed in order to address the unknown difficulties through an infrastructure project’s lifecycle. Collaboration of diverse project teams with different types of knowledge and experiences is required as a temporary form of business (G. Winch, 1998). Collaboration as the main driver of innovation has focused on areas of delivery system research.

Public influence and social impact industry:

A wider public impact of infrastructure projects develops a challenging environment for innovation processes in construction. A durable and long-term impact of the infrastructure projects (at least one decade) has developed domestic strict roles and building codes. Every single plan and specification
must satisfy the strict rules that have been developed by building consent authorities for the work to proceed. Innovation as a new plan, tool, product or process always cost a lot of time and energies to achieve the regulatory confirmation through different national and domestic authorities. A simple change as an innovation in an infrastructure project must guarantee the health and safety of the community. The importance of the regulatory role has been demonstrated by the research of Bazin (1993) who analysed the regulatory regime, and saw there was space for innovation without regulatory change. Governments as conservative infrastructure owners are responsible to keep taxpayers satisfied about the project outcomes as they are the main financial source of the project. “One of the distinctive features of the construction industry in many countries is the role of government funded national construction research organizations who also play a vital brokering role” (G. Winch, 1998, p. 275).

Unlike the manufacturing industry, innovation in the construction industry is a complex system, and is not under the control of a single authority. Collaboration, as innovation’s key driver, is required in order to push the social, political and regular authorities forward to give better support.

### 2.3. Innovation context in the construction industry

A number of studies have shown that collaborative procurement strategies such as PPP and Alliancing lead to increased innovation potential (Force & Britain, 1998; Tawiah & Russell, 2008; Thoms, 2000; G. M. Winch, 2010). This has been mainly attributed to the collaborative and no-blame culture along with better optimisation of investment and achieving long-term economies of scale associated with integrated project delivery systems. In fact, research indicates “most innovation emerges throughout the project delivery phase” (Lloyd-walker, Mills, & Walker, 2014, p. 231). This has brought attention to the significant role that procurement strategies play in driving or inhibiting innovative behaviour (Tawiah & Russell, 2008).

The unique characteristics of the construction industry develop completely different innovation behaviour in the industry. “Competition” is one of the main innovation drivers in developed strategies for manufacturing industries. Innovation as the main priority in manufacturing strategies has been introduced by Skinner (1969) as a “hidden competitive weapon”. Competition has also been identified
by Shahbazpour (2010, p. 25) as a phenomenon that spreads through a hierarchical management structure, as “competitive strategies are devised by senior executives and translated into functional level strategies through a top-down process.” The role of the competitors in the innovation process in manufacturing has been identified by Shahbazpour (2010, p. 25) as being “based on the notion that the primary way manufacturing adds value to the business is through enabling it to do certain things better than its competitors.” However, competition as the key driver of innovation in the manufacturing and service industry behaves completely different to the construction industry. Despite the production-based industry, a lack of long-term business market, factory-based conditions and hierarchical management structure in the construction industry has replaced the “collaboration” as the main innovation driver in construction. Collaboration has been identified as one the five main recommendations in the Egan report which said, “integrate the process and the team around the product”. Egan identified a need for an updated delivery system in order to improve collaboration throughout the construction industry. He stated this need as “to achieve these targets the industry will need to make radical changes to the processes through which it delivers its projects,” (Force & Britain, 1998). However, this potential for increased innovation is only realised if the factors impacting innovative behaviour are managed appropriately.

Lack of security and continuity of projects to encourage longer-term work programmes that help to develop research and development skills, are among typical characteristics of procurement strategies that stifle innovation in the construction industry (Fairclough, 2002). High pressure condition of projects with multiple expertise from several experts, that work together to deal with unknowns, develops a fragmented context for innovation. The collaborative long-term business context has been identified as one of the most important drivers of innovation.

Two modes of construction innovation have been introduced by Sexton and Barrett (2003a), based on the interaction environment when innovation occurs in a construction project. “A single-project, cost-oriented client relationship” is the first innovation mode, which has resulted in a constraining environment. In comparison to the first innovation mode, “Multi-project, value oriented, client relationship focused” innovation mode was introduced as the result of an enabling interactive
environment. In Mode 1 innovation, small construction firms view markets as highly competitive, with little scope for negotiation and collaboration between firms and clients. The clients are concerned primarily with reducing cost and delivery time, and tend to favour price-competitive procurement methods. Innovation by firms in Mode 1 is focused primarily on maintaining existing clients in known markets through project-specific “problem solving” innovation, incremental improvement in the organisation of work technology and having people flexible in the organisational model of innovation. On the other hand, Mode 2 innovation constitutes construction firms that have agreements with clients. The client offers continuity and predictability of workload for a significant period of time which, in return, provides a more secure, longer term context. Firms are able to innovate and provide the client with a competitively superior service. Mode 2 innovation focuses primarily on improving business arrangements through innovation in business strategies and market positioning. Integrated project delivery is built on collaboration, which in turn is built on trust. Effectively structured, trust-based collaboration encourage parties to focus on outcomes rather than individual goals. Without trust-based collaboration, IPD will falter and participants will remain in the adverse and antagonistic relationships that plague the construction industry today. From this perspective there are broadly two categories of construction procurement strategies (Akintoye, Goulding, & Zawdie, 2012): Conventional procurement methods and Collaborative procurement methods (see Table 2.1).
<table>
<thead>
<tr>
<th>Procurement</th>
<th>Type</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Designer-led competitive tendering</td>
<td>Traditional lump sum approach</td>
</tr>
<tr>
<td></td>
<td>Designer-led construction managed</td>
<td>Management contracting</td>
</tr>
<tr>
<td></td>
<td>For a fee</td>
<td>Construction management</td>
</tr>
<tr>
<td></td>
<td>Packaged Deal</td>
<td>Turnkey</td>
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<tr>
<td></td>
<td></td>
<td>Design and build construction</td>
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<tr>
<td>Collaborative Integrated Project Delivery</td>
<td>Packaged Deal</td>
<td>Public Private Partnership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design, build, finance and operation</td>
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<td></td>
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<td>Prime contracting</td>
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<td></td>
<td>Framework agreement</td>
<td>Partnering/Alliancing strategic and project joint venture</td>
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<tr>
<td></td>
<td>Partnering</td>
<td>Supply chain management</td>
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Table 2-1. Procurement, categories, types and strategies (Akintoye et al., 2012)

A project delivery system is used in order to handle multiple issues such as the project commercial model, communication roles and conditions and project dispute resolution methods. A continuous improvement has resulted in a variety of types of updated delivery systems over time in the construction industry (AIA Colifornia Council, 2007). This development journey was started by “Design Bid Build”, a traditional format of a delivery system that forces the lowest cost for a construction project through a tendering process. A tendering process is carried out through the traditional delivery system in order to select a contractor based on the lowest price tendered. The tendering process is carried out after the
detailed design is ready; it means the lowest level of contractor involvement through the developed plans. This low level of contractor involvement develops a gap between contractors and designers as the two main project participants (AIA California Council, 2007). Addressing this failure of the traditional delivery system, an updated format has been proposed in order to integrate the design and construction process. This single project-based firm would be responsible for the whole of the project’s processes and risks. The owner’s impact on the project is introduced at the lowest level in this delivery system. With “Design Build” the owner usually participates through to completion of the design and then seeks to minimize input and involvement to protect the clear silos of responsibility and risk. As a result opportunities for project improvement and innovation are unfortunately also minimized (AIA California Council, 2007). The lack of the owner’s impact on the project would limit the role they could play as one of the main innovation supporters in the construction industry. The final updated delivery system focuses on the more collaborative context between the owner and the project-based firms through the project lifecycle. Using the power of both the owners and the project-based firm, an integrated project delivery (IPD) system is developed, especially for complex infrastructure projects. A diversion of focus from the lowest cost to the performance-based attitude is the greatest achievement of the IPD through the construction industry (AIA California Council, 2007). The project owners and the project-based firms as the main key players work closely together in order to improve their performance through the industry. A novel compensation method is used by IPD in order to motivate better performance along the project lifecycle. Despite the traditional delivery system, project risks are shared fairly between the partners by IPDs. The lowest cost and risk transfer, as the main attitude of the traditional delivery system, act as innovation inhibitors through the industry. Despite the traditional system of delivery, project teams would be glad to share more information within and across the project boundary. By focusing on the performance, the IPD would be able to motivate more innovations, as one of the project’s Key performance indicators (KPI), across different partners. The benefit of the better performance that is measured by the KPI system, would be shared between the project partners equally. More innovation by the project participants is developed as an opportunity to gain better, as a result of the higher performance score.
2.4. Integrated Project Delivery (IPD)

AIA California Council (2007, p. 1) defined the integrated delivery system as, “Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction”. IPD is built on collaboration, which in turn is built on trust. Effectively structured, trust-based collaboration encourages parties to focus on outcomes rather than their individual goals. Without trust-based collaboration, IPD will falter and participants will remain in the adverse and antagonistic relationships that plague the construction industry today. Under a multiparty agreement (MPA), the primary project participant executes a single contract specifying their respective role, rights, obligations and liabilities. For a MPA to be successful, the participants must be committed to working as a team to achieve a team goal. Project Alliance, Single Purpose Entity, Relational Contract, are three types of multiparty agreement (AIA California Council, 2007). The breakthrough success of integrated delivery system in several infrastructure projects around the world reveals the important role they play on performance improvement throughout the construction industry. “A34 Newbury Bypass”, “Heathrow Express Coffier Dam” and “London Underground Earth Structures” are three innovative infrastructure projects that identified the integrated project delivery system as a driver of performance improvement (Thoms, 2000). Alliancing is an alternative to other infrastructure procurement methods and is suitable for larger, more complex projects where the specific output requirements are less well defined. A project alliancing is a commercial/legal framework between a department, agency and government-backed enterprise (GBE) as owner-participants and one or more “private sector” parties as “service provider” or non-owner participants (NOPs) for driving one or more capital work projects (Department of Treasury and Finance 2006). Alliancing reflects the shift from more traditional procurement methods which focus on strict risk allocation, to a collaborative approach. A project alliance is based on the clearly understood principles to which all participants are fully committed (Department of Treasury and Finance 2006). These are:
● All participants win or all participants lose.

● The participants have a peer relationship where each has an equal say in decisions for project.

● Risk and responsibilities are shared and managed collectively, rather than allocated to individual participants.

● All participants provide “best in class” resource.

● The participants are committed to developing the culture that promote and drives innovation and outstanding performance.

● There is a clear definition of responsibilities in a no-blame culture.

● All transactions are to be fully open-book.

● Communication between all participants is open, straightforward and honest.

2.5. Temporary organisations

An independent branding for the project’s temporary organisation by the integrated delivery system provides an opportunity to have a context for applying the best practice in the construction industry. A temporary project organisation developed with the integrated delivery system provide a collaborative environment under which different project partners work closely in order to achieve their final target with the highest level of performance.

The importance of the temporary organisation concept for developed construction project management theories has resulted in different assertions (G. M. Winch, 2010) such as:

● Projects are temporary organisations consisting of a coalition of firms chartered by a client; as such they have distinctive properties which no current theory of organisation can comprehend.

● Projects move through distinctive life cycle because of their determinate character as temporary organisations; the termination date for the temporary organisation is typically specified more or less accurately at its foundation.
Projects are embedded in contexts that are both organisational and institutional, simultaneously shaping and being shaped by these contexts.

The Project Management Institute in the 5th Edition of its Project Management Body of Knowledge defined the temporary organisation concept as, “a temporary endeavour undertaken to create a unique product, service or result” (Rose, 2013, p. 2).

**2.5.1. Conceptual models for temporary organisation**

Two conceptual models will be discussed in this part in order to illustrate the main elements of a temporary organisation.


Three main participants of a temporary organisation are identified by G. M. Winch (2014) as “Project owners”, “Project-based firms” and the “Project & Programs”. Two separated Permanent organisation (owners and the project-based firm) work together closely to develop the target of the project’s temporary organisation. The partnership between these three elements is presented through a conceptual model (G. M. Winch, 2014) (figure 2.1):

![Figure 2-1. conceptual model for temporary organisation](image)
As mentioned by G. M. Winch (2014), the interaction environment between the three temporary organisation elements is more important for the project performance improvement. The project manager’s important role is to facilitate these interactive relations in the project’s temporary organisation in order to smoothly support the process of innovation through the project. G. M. Winch (2010, p. 378) stated this important role of the project manager as, “in other words, the construction project manager is responsible for the problem of interoperability at the project level in order to enable the most effective possible implementation of the Project management Information System (PMIS)”. “Governance” is introduced by G. M. Winch (2014) as the interface environment between the owners with the project, as one of the key drivers of the innovation on the infrastructure projects. The support of the project owners for innovation is facilitated through an appropriate platform that provides a capable culture through the project organisation. Enough funding could be provided by the supportive owners in order to drive big innovations through the project. “Commercial” is the interactive environment between two main permanent firms (Owners and Project-based firms) as the main elements of the project’s temporary organisation. Information Technology (IT) has been identified as the most important enabler in this interface environment. IT as a recent common concept in project management systems, provide an appropriate communication environment where information can easily flow through different project teams. The important role of IT was stated by G. M. Winch (2010, p. 394) as; “in essence, just as the interfaces between the resources based within the project coalition need to be managed, so do the interfaces between the ICT system used by those resources base”.

A Building Information Model (BIM), as one of the last updated information technologies, is used for managing the project information flow process. An innovation process could be supported through BIM as a transparent and clear way of sharing innovative ideas between and within the project teams. G. M. Winch (2010, p. 394) identified the role of the BIM on innovation process as; “the project manager will also need to manage the ‘wakes of innovation’, that is, the new opportunity generated by the use of BIMs introduced through the project coalition”. An integrated agreement between two Permanent organisations could be managed appropriately using the IT systems in the construction industry. “Resources” is the interactive environment between “Project-based firms” and the “Projects”. The
workforce and material availability in a timely and safely manner is the main aim of this interface environment. “The relationship between the firms or departments providing the resources to the project and the mobilisation of those resources to deliver the project mission creates a classic matrix management situation” (G. M. Winch, 2010, p. 422). The project manager plays a key role in the innovation process at this interface by following a creative solution that was developed by the project-based firms at the construction site. The important role of the project manager in this context is revealed when the “problem-solving” innovations have constituted the most of the construction innovation through the industry (Loosemore, 2015b).


The classified context of Lundin and Söderholm (1995)’s theory for temporary organisations provides an opportunity to study the relationship between innovation and the ‘project-based’ nature of construction industry. Four basic interrelated concepts have been introduced by Lundin and Söderholm (1995)’s theory that can help us to understand how a temporary organisation works (figure 2-2).

![Diagram](image)

Figure 2-2. A Theory for temporary organisation

**Time:** “Time is a concept frequently linked with temporary organizations by authors in the field, as a means for differentiating them from permanent organizations” (Lundin & Söderholm, 1995, p.
The linear nature of time in temporary organisation was compared with circular nature of time in permanent organizations by Lundin and Söderholm (1995).

**Task:** despite the devotion of permanent organizations to ‘goals’, Lundin emphasised the importance of tasks in temporary organisations as the function-based environments.

**Team:** “Any temporary organization needs to be designed by and around people” (Lundin & Söderholm, 1995, p. 441). The importance of people in driving innovations should be assessed as an independent concept in temporary organisations.

**Transition:** Lundin and Söderholm (1995) defined transition as; “It focuses on perceptions of causal relationships, ideas about how to proceed from the present state to the final outcome and conclusion of the project” (Lundin & Söderholm, 1995, p. 443).

These four concepts (time, task, team and transition) can be used in the description or classification of any organization. Each one provides some insights into the way innovation process could be affected by a temporary organisation in construction. The classified nature of the Lundin and Söderholm (1995)’s theory provides an opportunity for assessing the relationship between temporary organisation and innovation process in construction. Despite a verity of different types of conceptual models through literatures, they mainly followed deep and narrow approaches for illustrating the anatomy of temporary organisation (Bannerman, Reich, Sauer, & Liu, 2013; Feldbrugge, 2015; Packendorff, 1995). This research requires a straightforward roadmap for assessing the relationship between innovation and temporary organisation in the construction industry. After a deep literature review, current research will use the Lundin and Söderholm (1995)’s theory as a roadmap for assessing the relationship between construction temporary organisations and innovation. The classified, multiple-view and comprehensive approach of this theory provides an opportunity for the research to assess innovation potentials and limitations from four different views.
2.6. Innovation models in construction literatures

A capable innovation model could be used as a tool for understanding the anatomy of the project’s temporary organisation. The knowledge an innovation model provides would play a key role in the successful application of innovation strategy on the project’s organisation. An understanding of the effective organisational factors and the way they would affect the innovation process through an infrastructure project would be developed by using an innovation model. Organisational capability, as one of the most effective contexts in the innovation process could be assessed by using a comprehensive model. An innovation model could develop the opportunity to assess the project’s organisational dynamics by focusing on the organisational potentials and limitations.

Following a literature review of the academic studies in innovation in the construction industry, it has been identified that innovation research is still in its infancy level. Making this clear, three main innovation models for the construction industry have been analysed by the research at this stage. The shared characteristic of these three models are that the innovation process has been analysed from a broad viewpoint at the industry level.

The innovation process in the construction industry has been analysed by G. Winch (1998) as a complex system through conceptual model. The role of ‘Firm’ and ‘Project’ as two main elements of a complex system have been analysed through the innovation process (Figure 2-3). Two main processes were identified as ‘Implementation’ and ‘Problem Solving’ by G. Winch (1998):

![Innovation model by Winch 1998](image)
The innovation process has been classified into three main levels by Loosemore (2015b) as, ‘Engagement’, ‘Allow it’ and ‘Catch it’. The ‘Fifth generation’ of innovation models is the basic concept that has been used by Loosemore (2015b) in order to illustrate the process through his model in the construction industry. He argued that innovation is no longer neither ‘technology-push’ nor ‘market-pull’. The integration has been identified as the core of the innovation process by Loosemore (2015b)’s innovation model. The interesting point about this innovation model is the middle stage of the model (‘Allow it’) that was part of the organisational capability (figure 2-4).

![Innovation Model](image)

The third innovation model was developed by Barrett and Sexton (2006, p. 332), two of the main innovation researchers in the construction industry. They introduced the innovation process through their model as; “the generic innovation model shown in figure 2-5 which argues that successful innovation outcomes are achieved through an appropriate innovation focus that is responsive to contextual factors, realized by appropriate organizational capabilities and channelled through effective and efficient innovation processes.“ As can be seen clearly in the Sexton model, he also introduced four main research areas for innovation process at the industry level. The four main research areas introduced by Sexton model are actually four main research proposals for future academic efforts. An
interesting point about this model is also about the organisational capability that has been identified as one of the main research areas in the construction industry. He developed ‘organisational capability’ as a research proposal for future research by developing two research questions:

(1) What are the key cognitive and organisational capabilities for innovation in small construction firms?

(2) How are these capabilities developed and used in innovation activity?

The researcher referred to one innovation model as a successful achievement in manufacturing literatures. The advantage of successful researches from industries that are leaders in performance development has been identified as an opportunity for the construction industry by Shahbazpour (2010). The scientific finding on innovation management through world-class industries, such as manufacturing, could be used to advantage. “This then is our ambition for a modern construction industry in UK: adopting of the model of dramatic performance improvement that other industries have followed with such success” (Murray et al., 2003). “Can construction learn from the success of manufacturing service industry? The Task Force believe it can” (Murray et al., 2003). ‘Crossrail’ as a successful infrastructure
project on innovation, followed the successful experiences of innovative leader companies from other industry. “Crossrail is learning from organisation outside the construction industry that have world class innovation programmes” (L. Crossrail, 2013, p. 6).

2.6.1. Multiple-View Model of System and Process Innovation

Current research aims to assess the applicability of an innovation model in the construction industry. The comprehensive innovation model developed by Shahbazpour (2010) as a manufacturing academic achievement, has been selected by the research. The applicability of multiple-view innovation model will be assessed by the research in order to be used as a tool for assessing the organisational capability of the infrastructure projects. The comprehensive and multiple-view innovation model developed by Shahbazpour (2010) is considered to be an answer to the need for a comprehensive innovation model in construction that could cover all of the innovation effective factors in a single conceptual model.

The multiple-view innovation model includes six different views: ‘Culture’, ‘Control’, ‘Structure’, ‘Knowledge’, ‘Process’, ‘Resource’. This holistic and comprehensive innovation model has been developed as a result of separate analyses for each of the six views (Shahbazpour, 2010). A consolidated model that synthetizes all of the organisational factors that would affect the innovation process in six views has been developed by Shahbazpour (2010) (feature 2-6).
The potential of the Shahbazpour (2010) innovation model for interpreting the organisational condition of a construction project is assessed at this stage. Each of the six classified views of the innovation model is assessed based on their viability for construction project organisation. The result of this assessment reveals a potential viability of the Shahbazpour (2010) innovation model for empowering a construction project organisation. The innovative capability of the ‘partnering’ as a novel delivery system for infrastructure projects is assessed using the multiple-view innovation model:

**2.7. Innovation strategy**

A lack of strategic planning for innovation in the construction industry has caused most innovation to happen in an ad-hoc management in small problem-solving format. The need for a strategic plan for innovation has been identified by various innovative infrastructure projects around the world. Crossrail is an innovative infrastructure project that introduced an innovation strategy as a practical plan intended to improve innovation potential through the integrated project delivery system. (Davies et al., 2014;
Lingard, Albert, & Levinson, 2008, p. 459) stated the importance of a strategic plan for innovation in construction projects as: “Raising the performance bar to the next level requires strategic efforts to promote innovation and learning from one project to the next”. A comprehensive and holistic view is considered an effective factor for the success of an innovation strategy in integrated delivery system. A variety of different challenges are required to be covered through a comprehensive innovation strategy in the construction industry. Key effective factors such as “safety”, “environment”, “risk”, “time and cost shortages” and “strict regulatory environment” are the challenges that an innovation strategy should be able to address through an infrastructure project. Covering the roles of both owners and project based-firms as two main elements are also key for a successful innovation strategy. Crossrail innovation strategy developed an innovation model in order to cover all of an infrastructure project’s issues through a holistic-view conceptual model (L. Crossrail, 2015), (figure 2.7).

![Figure 2-7. Innovation model developed by Cross Rail innovation strategy](image)

The 3Cs is a conceptual model developed by Crossrail innovation strategy in order to show how a comprehensive view works in an infrastructure project (figure 2.8). The three main Cs stand for,
“Culture”, “Collaboration” and “Capability” in order to handle the multiple effective areas on the innovation process. Using these three concepts, an innovation strategy would be able to cover multiple effective environments on innovation process through an infrastructure project such as Crossrail.

“Culture”, as the shared belief and values in an infrastructure project, plays a key role on driving innovation in an organisation. The hierarchical structure of the cultural issues reveals the important role the organisational positions play in shaping a supportive innovation environment. Owners as the main project funders play a key role in shaping the cultures in a project’s temporary organisation. The project manager should help the owners to create an innovative culture for the project organisation. A supportive culture makes a conservative owner able to accept higher level of risk developed by an innovation. “Leadership” as one of the key elements of supportive culture has been identified by Crossrail innovation strategy. L. Crossrail (2013, p. 3) stated the importance the leadership for a successful innovation strategy as; “The success of this innovation programme depends on focused and committed leadership throughout Crossrail’s supply chain”. The financial support of an innovation is revealed as one of the key effective factor in the success of Crossrail. “Mark Thurston is responsible for leading the innovation programme and providing the resources to support the brokering of innovative ideas among organisations in the supply chain”. IT was also introduced by Crossrail as a key tool for the owner to be able to create a supportive culture through the project lifecycle. “The on-line Innovation portal (www.crossrail.co.uk/innovation) acts as a single point of access for managing
innovation in Crossrail. It incorporates tools to capture and promote innovation including an idea management system, a stage gate development process and reward system”.

“Collaboration” as the second “C” in Crossrail innovation model introduces the importance of interactive environment between project partners (Owners and Project based firms). A partnership agreement between the two main project participants provides a collaborative environment as an innovation deriver throughout the project lifecycle. “Crossrail is driving innovation by building effective collaboration among partners in the supply chain, including universities, railway operators, users and other stakeholders”. An innovation incentive environment would be developed using a performance-based compensation model. This collaboration has not been limited within the Crossrail project boundaries but it is defined to use external financial supports for innovation as well.

“Capability” as the last “C”, would focus on the role that the “Project-based firms” play on driving innovation through the construction industry. Capable companies have been identified as the key driver for innovation in Crossrail strategy as, “We have engaged world-class organisations as our contractors, designers, technology providers and supply-chain partners. “Crossrail innovation strategy identified “people and tools”, “People & technical expertise”, “Tools and techniques”, “Data and information systems”, “Training” and “Facilities” as the main areas to invest to improve the innovative potential of the project. The role of individuals on innovative activities through the project is revealed, critically, as; “People with technical expertise and experience are fundamental to the successful delivery of the strategy”. A creative idea should be supported by project managers to become a successful innovation. This innovation could address the project-related difficulties and problem through a capable innovation management system identified by the strategy. Online information-sharing portals could also help innovators in construction project to receive as much as feedback from different project participant. “The innovation portal is now being piloted at our Liverpool St, Paddington and Connaught Tunnel sites. This new tool aims to provide a more direct route to implementation for innovative ideas across the Crossrail programme”.

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2.8. Innovation in New Zealand construction industry

The Construction industry is critical to the functioning of a domestic economy in many countries (Murray, Murray, & Langford, 2003). In New Zealand, the construction industry is one of the largest sectors of the economy accounting for 8% of total employment in the country (Smith, 2011). However, in spite of its importance to the national economy in terms of size, the construction industry seems to be lagging other sectors in terms of productivity (Wilkinson et al., 2012). In 2010, the construction industry in New Zealand established the Building and Construction Sector Productivity Partnership to actively address the issue of low productivity in the sector. Although the early focus was on identifying and quantifying the problems that lead to low productivity, over the recent years the focus has shifted to problem solving and addressing the cultural and mechanistic change that is needed to resolve the well documented problems (Wilkinson et al., 2012). One of the areas that the partnership has identified as critical for achieving significant improvements in the sector’s productivity is innovation. The ultimate goal of 20% productivity improvement by 2020, cannot be achieved by repeating the old ways of doing things. New innovative approaches are required in order to significantly improve performance at the same cost or maintain the same level of performance at much lower cost. Unfortunately, the construction industry is one of the least innovative sectors compared to other industries such as manufacturing and traditional services, (Reichstein, Salter, & Gann, 2005). The research and development report produced by Statistics New Zealand indicates that R&D expenditure in the construction industry accounts for a low 5% of the total expenditure in the sector (Statistics NZ, 2012). Indeed, this problem is not limited to New Zealand, as internationally the construction industry is seen as a traditional or low-technology sector with low levels of expenditure on activities associated with innovation (Seaden et al., 2003).

An initial motivation to focus on innovation concept in this thesis was actually developed through access to a local infrastructure project in New Zealand. SCIRT is a purposeful infrastructure project developed in order to address the 2012 Christchurch earthquake’s damage to roads, bridges and underground pipes. SCIRT is an alliance between Christchurch City Council, Canterbury Earthquake Recovery Authority (CERA), New Zealand Transport Agency (NZTA), City Care, Downer, Fletcher Construction, Fulton
Hogan, and McConnell Dowell. An integrated project delivery system used by SCIRT is considered an opportunity to develop an understanding of innovation behaviour through the IPDs. SCIRT is considered as a perfect case study due to the huge success on innovation development, having more than 500 construction innovations developed through a strategic plan.

2.8.1. Research Case study

The performance database of huge infrastructure projects is always considered as a unique opportunity for research to understand managerial areas. The unique characteristics of infrastructure projects make it really difficult for the researchers to have a full access to a project database. However, the impact of the project contextual information, such as project performance database, makes it a key factor for management research success. “High pressure condition”, “multiparty environment” and “community influence” are some of the unique characteristics of an infrastructure project. These characteristics require project management systems to follow such a conservative control system that it limits the researcher’s access to the project contextual data. “Another explanation for the scarcity of constructive studies in the academic publications can be found in the nature of consulting. Consulting reports are typically confidential, and they contain business secrets” (Kasanen, Lukka, & Siitonen, 1993, p. 252). Addressing this, project lessons, knowledge and experiences have been recently collected, analysed, and shared through a purposeful project, known as “Learning Legacy Projects”, in successful infrastructure projects around the world. The “London Learning Legacy” has been established by the UK government in order to share the knowledge and lesson learned from the Olympic London 2012 construction project (London, 2012). “Through the Learning Legacy project, London 2012 is sharing the knowledge and the lessons learned from the construction of the Olympic Park and preparing and staging the Games, to help raise the bar within construction and event sectors, and to act as a showcase for UK plc”. The “Crossrail Learning Legacy” is another successful learning project, carried out in UK in order to share the knowledge and lessons learned through the largest European infrastructure project (Crossrail & Ltd, 2016). “Crossrail is working in collaboration with academic partners to coordinate a series of research projects as well as to ensure that the learning legacy material can be adapted for use in school lessons and university lectures” (Crossrail & Ltd, 2016). “SCIRT Learning Legacy” is one of
the most recent local learning projects by the NZ government that is in progress at the time of this writing. It aims to share the lessons learned from a huge disaster recovery project (L. SCIRT, 2016b). Full access by the researchers to this learning legacy project was central to the success of their current research. An understanding of the innovation process through an infrastructure project became available as a result of SCIRT Learning Legacy Project linkage.

2.8.2. ‘Stronger Christchurch Infrastructure Rebuild Team’ (SCIRT)

The repair and reconstruction of infrastructure in the Canterbury region was one of the largest and most complex civil engineering projects in New Zealand’s history (Council, 2011). It was estimated that a large number of resources over a period of more than five years were needed to cope with infrastructure repair and rebuild demands (CERA, 2012). The policy response to the task of horizontal infrastructure reconstruction was the creation of the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), with a mandate until the end of 2016. SCIRT adopted an alliance-like project management model to deliver the recovery of horizontal infrastructure projects.

Alliancing is a project delivery model, which is often used by governments to procure significant infrastructure. A key value proposition of alliance contracting is that government entities reduce their traditional contractual rights (under a ‘risk transfer’ contract) in exchange for Non-Owner Participants (NOPs) bringing to the project their good faith, acting with the highest level of integrity and making decisions which are best-for-project (Australian Government Department of Infrastructure and Transport, 2011). Following the February 2011 earthquake, the New Zealand government recognized the need for a different approach to deliver the horizontal infrastructure reconstruction. The Government sought guidance from the New Zealand Transport Agency (NZTA) on an appropriate response to restoring the earthquake damaged infrastructure. Experienced in alliancing-based project delivery, NZTA supported the alliance approach, believing that it would enable optimal delivery with the speed required post-earthquake, in comparison with other possible models (Auditor, 2013).

The SCIRT alliance was therefore set up in September 2011, and made up of eight partner organizations, consisting of three owner participants and five non-owner participants. The three owner participants are
the Christchurch City Council (CCC), CERA, and NZTA, each of which plays a different role: CCC and NZTA are the asset owners and funders while CERA is the Crown funder and is mandated to coordinate the overall rebuild activity on behalf of the central government. Five private construction companies were chosen as non-owner participants within the alliance. They are City Care, Downer Construction, Fletcher Construction, Fulton Hogan and McConnell Dowell. As illustrated in Figure 2-4, there was an Alliance Leadership Team (ALT) for governance, under which an Alliance Management Team (AMT) was set up to manage the operations undertaken by an Integrated Alliance Team (IAT). The IAT acted in a project facilitator’s role to deliver the planning, design and management functions to enable the delivery teams to do the work. The delivery teams consisted of five main contractors described above. Together with their subcontractors and suppliers, the delivery teams are responsible for undertaking the repair and reconstruction works on the ground. The alliance model was built via a ‘gain-share, pain-share’ mechanism among five main contracting teams. Under this mechanism, the client and contractor can work together to assess in advance the most likely cost of the works and agree on a method for sharing any cost overruns or cost savings. The ‘gain-share, pain share’ mechanism gives an incentive to the contractor to identify efficiencies and make savings (Le Masurier, 2014). Construction work for each team was allocated based on their performance. Integrating professional and construction services into the alliance model meant that SCIRT could serve as a ‘one-stop shop’, offering flexibility in the way the infrastructure rebuild stakeholders were coordinated.
The SCIRT learning legacy project was launched in 2014 in order to share the knowledge and experiences of the project. More than 148 subprojects developed diverse types of knowledge through the SCIRT project’s lifecycle. These valuable lessons and knowledge have been stated as; “The unique opportunity to explore and implement smarter and more effective ways of repairing and replacing Christchurch’s horizontal infrastructure is too good an opportunity to miss” (L. SCIRT, 2016b). Full access by the researchers to the SCIRT learning project has been guaranteed through a contract between the University of Auckland and The SCIRT learning legacy project. Interviews data, project monthly reports and technical reports with a database of more than 500+ construction innovations have all become available for the researchers.

The first set of databases received was a spreadsheet of complete technical and managerial information for each of the +500 SCIRT innovations. All the reported innovation had been registered through a systematic portal through the SCIRT lifecycle. This idea-registering mechanism was used to support an innovation from a very early stage of a ‘creative idea’ until it became a real ‘innovation’. “Value register” is introduced by SCIRT as a mechanism in order to capture, approve and support the reported creative idea through becoming a successful solution in the project. Registering innovations through the SCIRT strategic plan developed a unique innovation database with more than 500 construction innovations.

2.9. Conclusion

This chapter developed an understanding of innovation stance in the construction industry. The relationship between the unique characteristics of construction industry and innovation process was discussed. Integrated project delivery (IPD) was identified as one of the main area on success of construction projects in innovation. The importance of temporary organisation in construction projects was discussed by assessing various innovation models and theories through literatures. Finally, ‘SCIRT’, an innovative infrastructure project in NZ construction industry, was introduced as the research case study in this thesis.
2.10. References


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Chapter 3. Research Methodology

This chapter aims to develop an understanding about the process of the research in this thesis. The research design and research methodology that has been followed by the current thesis will be presented in this chapter.

3.1. Introduction

Research on innovation process through an infrastructure project requires the researcher to collect data in various types.

A clear definition for innovation in construction is required as the first stage of the research. A lack of comprehensive and practical innovation definition in the construction literatures required the researcher to develop a comprehensive definition of innovation at the initial stage. An access to a real construction innovation database including various types of innovation with different types of benefits is required in order to develop a broad view. This innovation database provides a unique opportunity for the researchers to have first-hand information in order to develop an understanding about different types of innovation with a variety of levels of novelty and benefits.

The second problem is the infrastructure project dynamic and its effect on innovation management process. A bias of construction innovation literatures toward the effect of individuals and firms on innovation process has caused the project and its effect on innovation process to be less well studied. The project-based nature of the construction industry reveals the important role of project contexts on innovation process. Information about different types of project-related effective factors is required in order to shape the research objectives on innovation process through the project lifecycle. The ways an innovation process would be affected by the project environment should be pictured using the effective factors assessment. While there is some research to identify project-related inhibitors and motivations for innovation, the lack of a comprehensive and holistic view of the dynamic of infrastructure project
is still clear through the literature. An access to a real infrastructure project as a case study will develop a unique opportunity for the researchers to access the project environment and collect first hand contextual information. An understanding of the dynamic of a project and its effect on innovation process could be developed using this type of information.

3.2. Grounded theory

3.2.1. Introduction

Grounded theory is an appropriate method for studying the social phenomenon of innovation (Kasanen et al., 1993). The capability of grounded theory for research about the complex phenomenon has been identified by various literatures (Allan, 2003; Lingard et al., 2008; Oliver, 2011). This thesis has used grounded theory in order to explain the process of innovation in a construction project.

Theories are generated by grounded theory instead of testing a developed theory on a controlled set of data (Lingard et al., 2008; Oliver, 2011). A combination of various methodologies (Deductive, Adductive and Inductive) is used by grounded theory. This provides the researchers with a unique opportunity to develop a comprehensive theory that would be able to explain a complex phenomenon appropriately. Utilisation of deductive, abductive and inductive makes the grounded theory a comprehensive method of inquiry (Peirce, 1974). A key feature of grounded theory has been identified by Lingard et al. (2008, p. 459) as “its iterative study design, theoretical (purposive) sampling, and system of analysis”. The simultaneous process of data analysis and data collection by grounded theory would help to avoid the pre-existence perspectives that shape the research objectives. This option answers the requirement of the constructive approach. Based on the constructive approach roles, the theory should be developed based on the data analysis result (pattern) instead of starting with an hypothesis and looking for proof in the data (Cross, 2013).

Both quantitative and qualitative methods are used by grounded theory (Lingard et al., 2008). Although often interview data are the predominant data source in grounded theory, the survey and documentations could be used as statistical analysis references as well (Allan, 2003). However, whatever the gathered
data are, various ways have been identified for analysing them. The common analysis methods are identified as, “coding the data allowing for the generating of categories and concept from which a theory can be derived” (Cross, 2013, p. 29). Allan (2003) “Therefore, key points in each interview were identified and marked ready for analysis and coding”. Lingard et al. (2008, p. 459) identified that “the central principle of data analysis in grounded theory research is constant comparison”. Allan (2003) indicated the process of data analysis by grounded theory as “GT data analysis involves searching out the concepts behind the actualities by looking for codes, then concepts and finally categories”.

3.2.2. Advantages of grounded theory for this thesis

The main advantages are stated as;

■ Both ‘infrastructure project’ and ‘innovation’ as the two main targets of this thesis are categorized as complex and social area. To better understand them, they must be studied systematically and holistically. Grounded theory as a methodology provides a multiple-view analysis for this kind of researches. The comprehensive and multi-approach nature of this research methodology makes it ideal for this thesis.

■ Taking multi-method approach is required to address the thesis’s five different aims. ‘Inductive’, ‘Deductive’ and ‘Constructive’ are the main research approaches that have been followed by this study to address the variety research needs in each of the five aims. Each methodology has a substantial value and could stand alone in each research aim. ‘Data collection’, ‘Data analysis’, ‘Hypothesis shaping’ and ‘Theory development’ are some of the unique components in each of the research approaches. These components have been treated differently from aim to aim in this thesis. Grounded theory develops an opportunity for current research to apply all the research approaches in each of the five aims.

■ Grounded theory is relying on case study as an opportunity for entering the field and collecting data from a real context. SCIRT as a case study provided a rare opportunity for the researchers to enter to an innovative infrastructure project and collecting first-hand database throughout the research journey.
Note; ‘Action research’ is a methodology that uses a case study for testing the ability of a developed model in a real context. This methodology should be used by future researches for testing the ability of the innovation framework (main outcome of current research). Considering limitation of time, this research leaves this aim in the hands of future researchers in order to apply and test the framework on an infrastructure project,

**3.2.3. Discussion of method**

“Grounded theory is often described as a comprehensive method that covers all stages of research” (Cross, 2013). (Table 3-1) presents a summary of the research stages followed in this thesis;
<table>
<thead>
<tr>
<th>Step</th>
<th>Activities</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting started</td>
<td>Definition of research question</td>
<td>Focuses efforts</td>
</tr>
<tr>
<td></td>
<td>Possibly a priori constructs</td>
<td>Provides better grounding of construct measures</td>
</tr>
<tr>
<td>Selecting cases</td>
<td>Neither theory nor hypotheses</td>
<td>Retains theoretical flexibility</td>
</tr>
<tr>
<td></td>
<td>Specified population</td>
<td>Constrains extraneous variation and sharpens external validity</td>
</tr>
<tr>
<td></td>
<td>Theoretical, not random sampling</td>
<td>Focuses efforts on theoretically useful cases- i.e. those that replicate or extend theory by filling</td>
</tr>
<tr>
<td>Data collection</td>
<td>Multiple data collection methods</td>
<td>Strengthens grounding of theory by triangulation of evidence</td>
</tr>
<tr>
<td></td>
<td>Qualitative and quantitative data combined</td>
<td>Synergistic view of evidence</td>
</tr>
<tr>
<td></td>
<td>Multiple investigators</td>
<td>Fosters divergent perspectives and strengthens grounding</td>
</tr>
<tr>
<td>Entering the field</td>
<td>Overlap data collection and analysis, including field notes</td>
<td>Speeds analyses and reveals helpful adjustments to data collection</td>
</tr>
</tbody>
</table>
### Table 3-1. A summarized research approach (Cross, 2013)

<table>
<thead>
<tr>
<th>Analysing data</th>
<th>Flexible and opportunistic data collection methods</th>
<th>Allows investigators to take advantage of emergent themes and unique case features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysing data</td>
<td>Within-case analysis</td>
<td>Gains familiarity with data and preliminary theory generation</td>
</tr>
<tr>
<td>Cross-case pattern search using divergent techniques</td>
<td>Forces investigators to look beyond initial impressions and see evidence through multiple lenses</td>
<td></td>
</tr>
<tr>
<td>Enfolding literature</td>
<td>Comparison with conflicting literature</td>
<td>Builds internal validity, raises theoretical level, and sharpens construct definitions</td>
</tr>
<tr>
<td>Enfolding literature</td>
<td>Comparison with similar literature</td>
<td>Sharpens generalizability, improves construct definition and raises theoretical level</td>
</tr>
</tbody>
</table>

### 3.2.4. Getting started

Saving research time and resources, as key success factors, would be strategically associated with a clear, initially developed, target. In fact without the identified research problems, researchers would easily lose focus and be overwhelmed by the data (Eisenhardt, 1989).

### 3.2.5. Selecting cases

Current research done into a research case study is one of the most important stages of a grounded theory. This provides an opportunity for the researcher to understand the research’s contextual reality.
by analysing and observing it in a real context. The high level of complexity of the selected case study has been identified as one of the most important criteria at this stage of study (Eisenhardt, 1989). Cross (2013) identified the logic behind this as, “if the framework can cope with complex situation, then it should also be able to cope with a simple one”. Eisenhardt (1989) stated the fact as, “selection of an appropriate population controls extraneous variation and helps to define the limits for generalizing the findings”. Addressing this, the researchers selected a multiparty, huge infrastructure project in order to meet the complexity criteria appropriately. SCIRT (Stronger Christchurch, Infrastructure rebuild Team) is a successful recovery project in innovation that has developed more than 500 innovations through its lifecycle. The researcher has received full access to this project as a selected case study. SCIRT provided such a perfect opportunity for academic researchers in New Zealand construction industry, that it convinced the government to provide a learning legacy project in order to capture all the lessons learned from this project. (SCIRT Learning Legacy)”The unique opportunity to explore and implement smarter and more effective ways of repairing and replacing Christchurch’s horizontal infrastructure is too good an opportunity to miss”. First-hand contextual information has been used by the researcher with the full access provided by the learning legacy project.

3.2.6. Data collection

Multiple data collection methods have been recommended by Eisenhardt (1989) as a solution to avoid bias in either data collection methods or researchers. The multiple method of data collection used by this study in order to address the issues around ‘innovation’ and ‘infrastructure project dynamic’ as the two main areas of the current research. The importance of the multiple method of data collection was identified by Cross (2013, p. 43) as, “triangulation made possible by multiple data collection methods provides stronger substantiation of constructs and hypotheses”. Cross (2013, p. 43) stated the importance of the combination of different data collection method as, “using multiple methods can give a more holistic view of the topic and lead to unique findings that may have been missed using a single research method”. Although interview data is traditionally used by the grounded theory, a multiple method of data collection is used by this thesis. “Interview data”, “SCIRT innovation database”, “SCIRT technical documentations”, “project reports” and SCIRT delivery system guideline” are the
data collection methods used as the multiple data collection methods. The “SCIRT innovation database” is the most important as it used full data; it has been used at the very early stage of this thesis in order to develop a comprehensive innovation model. Various types of information have been reported for each of the +500 innovations by a spreadsheet in an Excel file. The “project reports and guidelines” and “interview data” have been used later to create a firm understanding of the infrastructure project dynamic. Entering the field developed a unique opportunity for the researcher to have full access to first-hand contextual information in order to develop a stronger theory about the innovation process in an infrastructure project.

3.2.7. Entering the field

An important concern of grounded theory is the influence of the researcher’s perspective on the research objectives and data analysis process at the time of the field entrance. An initial theory has been avoided by the researcher at the initial stage of the case study entrance in order to avoid prior perspective as one of the most frequent conditions in grounded theory. Simultaneously, a data collection analysis process has been applied by the researchers in order to avoid the bias and perspective on research objectives shaping and the developed theory. This is one of the important requirements of the grounded theory that provides a condition that allows the theory to be developed, based on the data trends instead of the pre-existing perspective of the researcher. This constant data collection and data analysis process developed a phased-base developed theory throughout the research project lifecycle.

The validation of the observed research objectives is another important criterion at this stage of research. A constant assessment process should be done by various research teams’ participants, in order to make sure that the result has been validated through various experts’ viewpoints. This thesis presented each of the developed theories in the format of an academic journal paper by which a constant feedback and assessment process was applied on each of research phases.

3.2.8. Analysing data

Eisenhardt (1989, p. 539) stated that “analysing data is the heart of building theory from case study, but it is both the most difficult and least codified part of the process”. Coding and categorising as the main
methods introduced by grounded theory have been used in this research. Lingard et al. (2008, p. 460) stated the importance of coding method as, “Early detailed coding of every data line or event is intended to break open the data to consider all possible meanings and to move the researcher away from her preconceptions”. He also mentioned that it is “a process of constant comparative analysis whereby the researcher compares information between and within categories to interrogate how the properties and dimensions of each category vary under different conditions”. A description of the relationship between conceptual categories and their synthesis into a theory is the outcome of this progressively abstract analysis. Six classified types of innovation have been developed as a result of categorising methods of analysis in the current research. The interview data were also analysed using a coding method at a later stage of this thesis.

3.2.9. Enfolding literature

Despite a misconception about a common failure in grounded theory, the previous knowledge at the time of interring to field of research could be useful as long as the data trends are considered as the only references at the shaping of the research objectives. The concern is about the influence of the perspective on the theory building. The theories should be developed by the data analysis results instead of testing a previous perspective based on grounded theory roles. Using the benefit of the literature’s knowledge while managing their influence on the developed theory would develop the best opportunity for the ground theory. In fact, the literature’s knowledge should be used only after an initial vision has been constructed from the database analyses. "literature reviews can be used as another source of data, but only after the first few iterations of grounded research have taken place to avoid bias” (Cross, 2013, p. 54). Eisenhardt (1989) identified the importance of the timing on literature review as, “Thus the literature was utilised during the third phase of research as a data source to integrate or defend against after the core categories were established as is considered best practice in grounded theory. “

In this thesis, the initial vision about innovation in an infrastructure project has been developed using the result of the +500 innovation analyses. A phased-based consistence data collection and analysis process was used for the current research in order to develop theories based on both the data analyses and literature reviews.
3.3. Research limitation

3.3.1. Generalizability

The research them under investigation in this study is innovation management in construction infrastructure projects and the area of application is infrastructure rebuild projects. In presenting the outcome of this research, many provision must be made in order to clear the generable and non-generable aspects of the development resulting from this thesis.

**Generable aspect:** Considering the shifting approach of this thesis from innovation research at firm/individual to innovation at project level, the findings are applicable at project level only. The temporary organisation of projects as the main component of IPDs are supposed to benefit from the outcomes of this thesis. Huge infrastructure projects, specially the post-disaster rebuilding is the main target of the developments resulting from this thesis. The innovation management framework as the main finding of this thesis could be applied throughout the lifecycle of infrastructure projects in the construction industry.

**Non-generable aspects:** The “pressure-cooker” condition because of an emergency environment of SCIRT as a disaster rebuilding project developed a unique condition for this research. The generalizability of the developed theories could be limited in order to be used in the more mundane ‘business-as-usual’ environment. Future similar researches then should be able to do the same research in a more ‘business-as-usual’ environment. Another area of concern is about the limitation of the research’s time and resources in order to apply the developed theories in a real infrastructure project. Future researches could develop an action research in order to implement the developed theories on a contextual case study. As stated above, the construction firms and companies, neither in small nor big size are not targeted by the developments of this study.
3.4. Ethical consideration

The ethical issues are considered as challenge through managerial researchers where human involvements are concerned through interviews and questioners procedures (Bechhofer & Paterson, 2012; Fellows & Liu, 2015; Kalof, Dan, & Dietz, 2008; A. Liu & Fellows, 1997). Nuremburg code developed a formal approval procedure for obtaining the voluntary consents before collecting data from human participants in order to avoid any possible harm to them (International Sociological).

The researchers began to obtain voluntary consents in order to address the human ethical requirements through the researcher lifecycle. The formal approvals have been identified by the University of Auckland’s “Human Participants Ethic Committee” (UAHPEC) by providing formal forms for signing off by the participants. Participants Information Sheet (PIS) and Consent Form (CF) are the developed forms that have been used through every interview through the research life. These forms developed general information about the research aims and processes in order to convince the participant that their participants in this research would not affect their business and personal life in any way.

The ethical treatment of this thesis is covered by a formal arrangement developed by University OF Auckland named, “Human Participants Ethic Committee” (UAHPEC). Current research ethical issues, as a PhD study for University of Auckland has been approved by the committee under application code (011941).

3.5. Research design

As stated, this research used four project temporary organisation elements developed by Lundin and Söderholm (1995) as, “Project Time”, “Project Task”, “Project Team” and ”Project Transition” as a research roadmap and a means of providing a structure for understanding the temporary construction project context and its effect on the innovation process. These elements gave a view of innovation, and allowed the research aims and objectives to be developed.
3.5.1. Research Design (Task)

Tasks and activities in a construction project are considered as the heart of the innovation. The key role of activities in a temporary organisation has been stated by Lundin and Söderholm (1995) identifying the ‘Action’ at the core of projects. The research design for the first area of knowledge (Chapter 4) started with Research Aim 2, which was to further understand of innovation classification. As stated earlier, this research is designed to start with the second aim since the first aim is dependent to the knowledge of further four aims. Undertaking this aim, the research set the following research objective,

**Research Objective:** Develop an innovation classification model as a comprehensive definition of innovation in the construction industry.

A shared understanding of innovation as a complex phenomenon has been identified by the researchers as one of the first research requirements. A lack of a comprehensive and multiple-view innovation definition in innovation literature was identified at the earlier stage of this thesis. Addressing this failure, the researchers started the research with a review of the literatures in construction innovation and other leading industries in innovation, such as manufacturing. A multiple-view innovation classification model was developed. Six different types of innovation, four levels of novelty and six benefits have
been defined through a synthesised innovation classification model. A full access by the researchers to an innovation database with +500 construction innovations developed an opportunity to apply the innovation classification model on a real construction infrastructure project. The result of this application was used at the final stage, in order to analyse the trends towards different types of innovation with different levels of novelty and benefits. The following diagram shows the research design for this objective, showing the process followed and the outcomes expected.

Figure 3-2. First Research Design
3.5.2. Research Design (Team)

The role of incentives to motivate project teams to innovate is core to successful innovation practice. Addressing this, the research designed with research Aim 3 which was to understand SCIRT’s innovation rewarding structure and its capability to incentivise teams and individual through the project’s lifecycle. Undertaking this aim, the research set the following research objective.

**Research Objective:** Assess the SCIRT innovation incentive system and develop an optimisation in SCIRT’s innovation scoring formulate.

The researchers were required to develop knowledge of the main elements of an incentive system in construction infrastructure project. ‘Performance measurement system’ and ‘Pain/gain commercial model’ are two main players in an innovation incentive system. These elements have been focused upon by the research design at the first stage. A literature review was undertaken on performance measurement systems and reward-based commercial models. This fundamental knowledge has been supported by information of the incentive system in the SCIRT project. Formal monthly reports, a governmental independent assurance report about a performance audit, informal project-related documents, SCIRT website information and the personal observation through a long-term interactive research project are the information resources that have been used.

The next part of this research was to assess the way the incentive system has affected the innovation behaviour in different types in SCIRT project. In order to address this target, the results of innovation classification model application on SCIRT innovation database (Chapter Four: research results) has been used. An improvement of the innovation incentive system was identified after analysing the result of +500 innovation classification process. The researcher proposed an optimization on the innovation incentive system in SCIRT project by which the incentive system would be able to motivate project teams to develop bigger innovations. This optimization includes the developed innovation classification model (Chapter 4: Achievement) as a reference (definition) and an optimized innovation scoring formula that considers both the numbers and nature of the innovations. This optimized innovation incentive system helps the project practitioners to motivate teams for innovation by considering both
innovation quality and quantity. The following diagram shows the research design for this objective, showing the process followed and the outcomes expected.

![Diagram of research design](image)

**Figure 3-3. Second Research Design**

### 3.5.3. Research Design (Time)

The dynamics of the project and its effects on innovation behaviour is the third main parameter that was aimed at by this thesis in the sixth chapter. A project over time can be mapped through a project life cycle. The fourth aim of this thesis is to understand where innovations can be best developed throughout the project lifecycle. Through the life cycle the research looked at the impact of time on the innovation process. The widespread use of lifecycle models for key managerial parameters reveals the important role of project lifecycle in innovation management. The constantly changing nature of project dynamics through different phases makes the lifecycle models important for innovation management research. Using the SCIRT innovation database (+500m construction innovations), the researchers could classify +500 innovations in three SCIRT life cycle phases. Different types of innovation with a variety of levels
of novelty and benefit have been classified in one the three classified phases through the SCIRT project lifecycle. The result of this classification reveals some interesting trends which were analysed by the researchers in order to develop lifecycle models for six classified types of innovation, four levels of Novelty and six Benefits.

**Research Objective:** Assess the SCIRT’s lifecycle to determine where different types of innovation occur across a variety levels of innovation novelty and benefits.

The following diagram shows the research design for this objective, showing the process followed and the outcomes expected.

![Research Design Diagram](image)

**3.5.4. Research Design (Transition)**

The research focused on the organisational capability and its effect on the innovation process as the fifth and final aim. The literature review of construction innovation models showed an incomplete
knowledge of organisational factors and their effect on the innovation process. The ability of a temporary organisation (such as SCIRT) in driving innovations in infrastructure project is the final aim of this research.

**Research objective:** Apply an organisational innovation model on SCIRT as a tool for improving innovation for temporary project organisations in the construction industry. A literature review of the temporary organisation of construction infrastructure projects was developed at the start. An understanding of the main elements of a temporary organisation and their effects on innovation process developed an opportunity for the researchers to focus on innovation models as a way of empowering temporary organisation for innovation. Literature on innovation in construction and other leading industries, such as manufacturing, were reviewed by the researchers at the next step. The lack of a comprehensive and practical innovation model in the literatures throughout the construction industry was identified. The research proposed a multiple-view innovation model that was developed in the manufacturing industry. Since the proposed model required to be tested, the SCIRT temporary organisation has been used by the research in order to apply the innovation model in an innovative project in the construction industry. Personal observations, as a result of a long-term interactive research, plus discussions and interviews, the formal SCIRT’s reports, provided the research with first-hand understanding of the organisational condition of the project. This understanding was used through the process of the innovation model application on SCIRT temporary organisation. Finally, the result of the analysis of this application process reveals the liability and capability of the proposed innovation model to assess the organisational capability of a temporary organisation in an infrastructure project. The following diagram shows the research design for this objective, showing the process followed and the outcomes expected. The following interviews and focus group took place to select the innovations suitable for future construction industry use.
<table>
<thead>
<tr>
<th>Interview with</th>
<th>date</th>
<th>company</th>
<th>Intent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilities Manager</td>
<td>20 May 2015</td>
<td>SCIRT</td>
<td>Discussion on process for innovations</td>
</tr>
<tr>
<td>Value Manager</td>
<td>3 June 2015</td>
<td>SCIRT</td>
<td>How the innovation process is working and future use</td>
</tr>
<tr>
<td>Focus group- 5 SCIRT employees</td>
<td>17 June 2015</td>
<td>SCIRT</td>
<td>Focus discussion on SCIRT innovation process and choice of top innovations</td>
</tr>
<tr>
<td>in SCIRT innovation process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interview- project manager</td>
<td>9 Feb 2016</td>
<td>SCIRT</td>
<td>Refining innovations choice</td>
</tr>
<tr>
<td>Interview- project manager</td>
<td>9 Feb 2016</td>
<td>Fulton Hogan</td>
<td>Refining innovations choice</td>
</tr>
<tr>
<td>Interview- project manager</td>
<td>9 Feb 2016</td>
<td>SCIRT</td>
<td>Refining innovations choice</td>
</tr>
</tbody>
</table>

Table 3-2. Interviews with SCIRT people

Figure 3-5. Fourth Research Design (Transition)
3.5.5. Research Design (Innovation framework)

An innovation framework is required for managing innovation at project level. The strategic plan for managing innovation in construction projects is addressed as a critical knowledge gap through the literatures. This research aimed to develop a phase-based innovation framework for construction infrastructure projects. The first and most important Aim of this thesis was to use the knowledge acquired in the earlier parts of the thesis to develop a phased-based innovation framework for managing innovation through the infrastructure project lifecycle. Such a model could be used to provide construction practitioners with practical advice on managing innovation. The research provides draft best-practice guidelines for managing innovation at project level. Therefore, research objective became:

**Research Objective:** Develop a phase-based innovation framework for construction infrastructure projects which can be used to guide innovation at project level.

The four main parameters (Task, Team, Time and Transition) as they impact on innovation process are used through the process of this research design. Based on the results developed in previous chapters, this thesis discussed the effective parameters in innovation management process for each of the four phases. The following diagram shows the research design for this objective, showing the process followed and the outcomes expected.
A comprehensive and multiple-view research was targeted, in order to cover the innovation process in construction from different angles. An access to variety of different types of information was tracked as a major prerequisite for this thesis. Addressing this need, both qualitative and quantitative information have been collected through the four research designs. (table 3.2).

Figure 3-6. Fifth Research Design (Innovation framework)

3.5.6. Conclusion
## Quantitative research

- **Information:**
  - +500 construction innovations were reported by SCIRT.

- **Analyses:**
  - Classifying +500 innovations based on six ‘Types’, four levels of ‘Novelty’, six ‘Benefits’ and three classified ‘Phases’ of SCIRT project.

- **Results:**
  - Trends toward classified innovation Types, Novelities and Benefits.
  - Lifecycle models for six classified ‘Types’ of innovation, Four classified levels of ‘Novelty’ and six classified ‘Benefits’.
  - Identifying a failure through SCIRT innovation incentive system (Majority of SCIRT innovations have been classified in simple, problem-solving type).

## Qualitative research

- **Information:**
  - 11 interviews have been organized with SCIRT staffs;
    - 4 interviews with top managers.
    - 5 interviews with technician and staffs in project construction sites.
    - 2 interviews with value manager and facility manager.
  - An independent assurance report about a performance audit has been analyzed as a valuable SCIRT documentation. (‘Effectiveness and efficiency of arrangements to repair pipes and roads in Christchurch’).

- **Analyses:**
  - Applying a multiple-view innovation model (developed in Manufacturing industry) on SCIRT temporary organization;
    - The innovation model includes six classified views, that developed more than 39 organizational factors.
  - Assess the capability of the proposed innovation model by analyzing the interviews’ transcripts and the SCIRT document’s information.

- **Results:**
  - A proof of success of the proposed innovation model on assessing the SCIRT temporary organization;
    - Six tables of result have been developed in order to illustrate the organizational condition of SCIRT project in innovation process.

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Table 3-3. Qualitative vs. Quantitative research designs
Chapter 4. Innovation Classification for Construction Infrastructure Projects

This chapter has been extracted from:


4.1. Introduction

This chapter aims to further understanding of innovation classification. The chapter develops an understanding of the relationship between project’s ‘Tasks’ and innovation process. The relationship between types of construction tasks and innovation behaviour is studied at this chapter. In the first part of this chapter, a definition will be developed for innovation in the construction industry. Different classified types of innovation with variety levels of novelty and benefits are defined using a multidimensional innovation classification model.

The second part of this chapter focuses on the effect of different types of innovation on the productivity improvement in an infrastructure project. By applying the developed innovation classification model on SCIRT innovation database, trends in the three main elements of the innovation classification model (Type, Novelty and Benefit) can be assessed. The chapter finishes with conclusions on the innovation classification model as a comprehensive definition of innovation in the construction industry.

4.2. Build a shared understanding for innovation

A shared understanding of the “innovation” concept between different project partners has been identified as a key success factor in multiparty and uncertain conditions (Dundon, 2002; A. Pattakos &
Dundon, 2008). “It’s one thing for a leader to stand up and ask for innovation, but quite another if everyone in the room has a different viewpoint as to what the leader is asking for!” (D. A. Pattakos, 2011). In support of Innovating with Meaning, we argue that it is important to define and build a common understanding of what it means by the term "innovation," instead of simply stating it as an objective or corporate mantra. A comprehensive and holistic definition has been identified as a key factor for the success of an innovation strategy through the huge infrastructure project (Dundon, 2002).

A shared understanding of innovation as a complex phenomenon among different project partners plays as a foundation for a firm innovation strategy through the project lifecycle. The “simplicity” and “practicality” as the key factors for the innovation definition is required in order to develop an easy-to-use concept among diverse project teams and partners. The success of benchmarking as one of the performance drivers in the construction industry is also related to the capacity of definition for innovation as one the performance criteria (Shahbazpour, Noktehdan, & Wilkinson, 2015). Innovation as one of the key performance indicators (KPI) plays a key role in the benchmarking process throughout the construction industry (Wilkinson et al., 2012). The importance of the comprehensive innovation definition is revealed when the performance measurement system would be able to motivate project teams to innovate in different types, with various levels of novelty and benefits. Prioritizing as a strong managerial mechanism could be optimized by using a classification model covering all types of innovation. An innovation definition would be considered as a tool for the project manager to apply the best management policy that would fit a specific type of innovation. In summary, the project manager would be able to make the best decision for the best type of innovation at the right time and through the right motivation mechanism.

**4.2.1. Innovation Classification System**

Classification methods as a way of organising diversity have been widely used by researchers in complex research areas. Innovation as a complex research area has been defined through diverse types of classification models with multi-dimensional views.

● (Lim & Ofori, 2007): “Innovation that consumers are willing to pay for that”, “Innovation that reduce contractors’ construction cost”, and “Innovation that provides contractors with sustainable competitive advantage”

● (Garcia & Calantone, 2002): Radical, New, Discontinuous, Incremental, Imitative


After a review of the literature, it was found that the most commonly accepted innovation classifications have mainly been developed by analysing innovation within the manufacturing and services context. As mentioned previously, there are significant differences between construction and other industries. Consequently, in order to develop an appropriate innovation classification system for the construction industry, modifications were made to these classification systems and where appropriate new categories were developed.

The innovation “Type”, “Novelty” and “Benefit” are the three main effective factors for defining innovation through the literatures. A multidimensional innovation classification model would be able to cover these three factors. The research developed an innovation classification model in order to address a lack of shared understanding about innovation among different parties in the construction industry. A multidimensional innovation classification model develops six different types of construction innovation with four levels of novelty and six benefits (Table 4.1).
This section will briefly outline each dimension and provide a definition for each classification category.

**Innovation Type:** The authors found it necessary to distinguish between development or utilisation of innovative construction materials or componentry and the development of innovative designs and features for buildings or infrastructures. Therefore, the product innovation category was limited to cover new materials or products used in the construction phase, and a new category was added, called Design, to account for the innovative design features introduced at the design phase of the project. Furthermore, guided by the construction technology classification system developed by C. B. Tatum (1988), the process innovation category was divided into two sub-categories of Tools and Function.

**Product:** Product Innovation involves all new construction materials and products developed in the project or introduced to the project and used within the construction process.

**Design:** Design Innovation is related to new and innovative plans, designs, sketches or concepts for the final building or infrastructure that is being developed in the project.

**Tool:** The Tool Innovation involves the development or implementation of novel construction machinery equipment or tools in the construction project.
**Function:** The Functional innovation refers to new tasks developed or introduced in the construction project and associated management processes.

After further consultation with industry experts two other categories were added where a combination of the previous sub-categories could exist:

**Technology (Design + Product):** The new technology refers to the new design that is coupled with a new material or product.

- **Method (Tool + Function):** The Method innovation is the combination of the Tool and Function innovation that involve both a new tool or equipment and new tasks that are usually related to the new tool.

**Innovation Novelty:** Typically the innovation literature distinguishes between incremental and radical innovations. However, Slaughter [15] provides a more detailed categorisation of novelty within construction innovation context. These categories are Incremental, Modular, Architectural, System and Critical.

- **Incremental:** Incremental innovation is a small change, based upon current knowledge and experience. It is often the result of continuous improvement initiatives and on-the-job problem solving.

- **Modular:** Modular innovation entails a significant level of novelty in one area of a system, but without impacting the other components of the system. Modular innovations may be developed within an organization and implemented without much negotiation with parties involved in the development or selection of other components.

- **Architectural:** Architectural innovation involves a small change within a component of a system, which results in major changes in the links to other components and systems. The distinction between modular and architectural innovations is made on the region of the change and, specifically, the degree of interaction with other components of the system.
- **System:** System innovations are identified through their integration of multiple independent innovations that must work together to perform new functions or improve the facility performance as a whole.

- **Critical:** Critical innovation is a breakthrough in science or technology that often changes the character and nature of an industry. While incremental innovations occur constantly, critical innovations are rare and unpredictable in their appearance and in their impacts.

**Innovation Benefit:** This dimension of the classification system deals with the type of performance improvement that is achieved through implementation of the new innovative ideas. As mentioned previously, the following performance indicators will be used to distinguish between the types of benefits that are delivered by the given innovations.

- **Cost:** Direct cost savings or better utilisation of resources.

- **Time:** Reduction in lead-times or increasing speed for the project or sub-tasks.

- **Quality:** Improvements in degree of conformance with specifications and/or satisfaction of stakeholders with the outputs of the construction project.

- **Safety:** Improving safety, health and wellbeing of the employees and public during and after the construction project.

- **Environment:** Reducing adverse impact of the construction processes as well as the final building or infrastructure on the natural environment.

- **Community:** Reducing adverse impact on communities affected by the construction project and improving communication with the stakeholders.
4.3. Driving productivity in infrastructure projects

This chapter examines the relationship between innovation and productivity improvement in the construction industry at the second part. It is argued that this relationship is not well understood due to lack of understanding of innovation in construction. To overcome this obstacle, the authors present the multi-dimensional innovation classification system which aims at better defining and classifying what is meant by innovation in construction. The use of this classification system is demonstrated by applying it to a database of 500 innovations reported by the construction alliance, the Stronger Christchurch Infrastructure Rebuild Team. The results clearly demonstrate the diversity of types, degree of novelty and performance improvement benefits among construction innovations. Such diversity means that the
impact of the reported innovations on productivity and performance are of different levels of significance. The classification system developed in this study can be used by construction organisations and alliances in the future to develop more detailed methods of calculating innovation performance indicators, based on the innovation type, novelty and benefits factors. By using this system, they can also put in place mechanisms to influence the types of innovation developed in their projects with the aim of maximising their productivity performance.

4.3.1. Productivity stance in New Zealand construction industry

The Construction industry is critical to the functioning of a domestic economy in many countries (Murray et al., 2003). In New Zealand, the construction industry is one of the largest sectors of the economy accounting for 8% of total employment in the country (Bill, 2011). However, in spite of its importance to the national economy in terms of size, the construction industry seems to be lagging other sectors in terms of productivity (Wilkinson et al., 2012). In 2010, the construction industry in New Zealand established the Building and Construction Sector Productivity Partnership to actively address the issue of low productivity in the sector. Although the early focus was on identifying and quantifying the problems that lead to low productivity, over the recent years the focus has shifted to problem solving and addressing the cultural and mechanistic change that is needed to resolve the well documented issue (Wilkinson et al., 2012). One of the areas that the partnership has identified as critical for achieving significant improvements in the sector’s productivity is innovation. The ultimate goal of 20% productivity improvement by 2020 cannot be achieved by repeating the old ways of doing things. New innovative approaches are required in order to significantly improve performance at the same cost or maintain the same level of performance at much lower cost.

4.3.2. Relationship between ‘Innovation’ and ‘Productivity’

It appears that the link between innovation and productivity in construction is not well understood. Loosemore (2014) observes that despite many recent developments in the field of construction innovation, none of these studies feature in the mainstream construction productivity literature.
In contrast, the link between productivity and innovation has been well researched and explored in the manufacturing literature (Huergo & Jaumandreu, 2004). However, while certain parallels can be drawn from the manufacturing literature, it is generally agreed that there are significant differences between manufacturing and construction. Koskela and Vrijhoef (2001) identified the one-of-a-kind nature of construction project, site production, temporary multi organization and regulatory intervention, as differentiating characteristics of the construction industry accounting for lower innovation. Reichstein et al. (2005) also identified a number of “liabilities” which sets construction industry apart from other innovative industries such as manufacturing. These are Immobility, Project-based, Uncertainty of demand, Smallness, Separation and Assembly.

There is a need for more construction specific research to explore the relationship between innovation and productivity. The authors contend that while productivity is a well-defined term, innovation in contrast is poorly defined for the construction industry and is only understood in abstract terms. This is a major obstacle in the attempt to clarify the relationship between innovation and productivity in the construction industry. The study presented in this paper, aims to make a contribution in this area by demonstrating the diversity of various types of innovation present in a construction project and the varying degrees of impact these innovations have on productivity indicators.

**Defining innovation;**

Productivity is generally defined as a ratio between output produced and input used (H.-S. Park, Thomas, & Tucker, 2005). For instance, labour productivity can be calculated as a ratio of hours of labour worked (input) and units produced (output). More holistic definitions of productivity include a number of performance dimensions for units of input and output, such as quality, cost, time and safety. Innovation on the other hand is more ambiguous in its definition. Brown (1994) provides a broad definition of innovation as “doing things differently or better across products, processes or procedures for added value and/or performance”. (Shahbazpour, 2010, p. 17; West & Altink, 1996) provide a similar, but perhaps more complete, definition of innovation as the “intentional introduction and application within a role, group or organisation of ideas, processes, products or procedures, new to the relevant unit of
adoption, designed to significantly benefit the individual, the group, the organisation or the wider society”.

When comparing the above definitions and other popular definitions of innovation in the literature, three key defining elements of innovation can be identified. First is the type of innovative idea or invention. The Oslo Manual on collecting and interpreting innovation data (OECD, 2005) outlines four types of innovations: product, process, marketing and organisational. Second is novelty. The minimum entry level for an innovation is that it must be novel or “new to the firm” (OECD, 2005). Degree of novelty or “newness” can be defined as the extent of uncertainty associated with the implementation of the innovative idea within the context of its application (Shahbazpour, 2010). E. Sarah Slaughter (1998) divided the Novelty of the construction innovation in five different levels of Incremental, Modular, Architectural, System and Critical. The third is benefit or improvements in performance. In construction, traditionally performance has been measured in terms of cost, time, quality and safety (Bassioni, Price, & Hassan, 2004). Recently, environmental measures have also become an important performance indicator in construction projects (EPA, 2007).

Each of these elements (type, novelty, and benefit) can alter the significance and type of the impact that a given innovation has on productivity. In terms of type, whether the innovative ideas are a product, process or an organisational method results in different type of impact on productivity. For instance, process and organisational innovations are mainly concerned with the construction phase and thus will have a direct impact on the project’s productivity performance. On the other hand, product innovation may have much less significant impact on the production phase but much larger impact once the building or infrastructure is in operation. In terms of novelty, the degree of novelty determines the significance of the impact the given innovation may have on productivity. For instance, an incremental change results in much less significant impact on performance than a more radical and disruptive change. Finally, different innovations would improve different set of performance indicators, thus having very different impacts on productivity.

It is therefore proposed that in order to better determine the impact and nature of the relationship between given innovations and overall project productivity, types of innovation, novelty and the
specific performance indicators being improved must first be determined. This requires an innovation classification system, which can be used to categorise the innovations implemented in a project.

4.3.3. Applying the Innovation classification model

The chapter will use the innovation classification system by applying it to a database of 500 innovations reported by the construction alliance, the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), responsible for rebuilding the horizontal infrastructure after the earthquakes in Christchurch. SCIRT is an organisation who put innovation as one of the main key performance indicators (KPIs) for its construction project delivery team. The results will highlight the diversity of innovation types that have been reported by the alliance group, and the classification system used in the paper makes sense of these innovations, and suggests ways of improving productivity through innovation use in construction. Innovation was given a special consideration from the outset, when the SCIRT alliance was formed. In fact, members of the alliance were encouraged to innovate and report on their innovations monthly as one of their KPIs. These KPIs were linked directly to the pay/reward aspect of the contract. As a result, the alliance members had ample motivation to report their innovations. To date more than 500 innovations have been reported by SCIRT. This has provided a unique opportunity to analyse and better understand the relationship between construction innovation and productivity improvements. The authors were given full access to SCIRT’s innovation database. For each reported innovation, the database contained a unique identification number, description of the innovative idea, its potential benefits and information regarding which member organisation had initiated the innovation. Some of the reported innovations were also accompanied by pictures or sketches to better describe the innovation. Each of the reported innovations were analysed and categorised based on the innovation classification system outlined in the previous section. The categorisation process was carried out mainly by one researcher to ensure consistency of interpretation across the data set. Once completed, 20 innovations were selected randomly and categorised by two other researchers using the classification system. This was done to make sure the classification system was being applied appropriately. Any uncertainty around the definition was clarified through this process.
4.3.4. Results

In order to better understand the spread of various categorisations of innovations developed by SCIRT, the data was analysed using pivot-table functionality of MS Excel. A pairwise analysis was also conducted to identify any potential trends which may lead to insights about the nature of innovation activity at SCIRT. The following section presents the summary of the results from this analysis.

4.3.5. Spread of Innovation

Figures 4-2 to 4-4 represent the spread of innovation categories in each dimension of the classification system: type, novelty and benefit. Most innovations in the SCIRT database seem to be made up of tools or functions in terms of innovation type, and modular or architectural in terms of novelty. They also appear to deliver a wide spread of performance benefits, mainly dominated by quality, time and cost.
4.3.6. Pairwise Analysis

The data was also analysed to identify emerging trends that would provide more insight into the relationship between the three dimensions of the innovation classification system. When looking at the spread of innovation based on a pair of two dimensions of benefit and novelty, an interesting trend emerged. As illustrated in Figure 4-5, it appears that architectural and modular categories of innovation are more focused on delivering a single benefit. On the other hand, system category of innovation seems to be the one that mostly delivers a combination of quality, time and cost benefits (Figure 4-6). Modular innovation also appears to be the most prevalent category which focused on the indirect productivity improvements through safety, environment and community (see Figure 4-7).
When looking at the pair of innovation types and benefits similar trends appear. As illustrated in Figure 4-8, the majority of innovations are delivering a combination of direct productivity improvement benefits such as quality, time and cost, were from the two categories of design and method. On the other hand, function and tool categories seem to be more focused on delivering a single benefit (see Figure 4-9). Tools also appear to be the most prevalent type of innovation that delivers either safety, environment or community benefits (see Figure 4-10).

Analysis of the pair of type and novelty also reveals some interesting trends. As illustrated in Figure 4-11, design innovation was dominated by architectural level of novelty, while product
innovation was split between modular and architectural. Technology innovation (design + product) on the other hand was mainly dominated by system level of novelty. Modular and architectural innovations made up the majority of the tools and functions, while those innovations classified as method were mainly system or architectural innovations. Figure 4-12 also illustrates that the system level of novelty was mainly prevalent in methods, while modular innovations were mostly found under the tool and function categories. Architectural innovations were spread amongst tools, designs, functions and methods. Also, it was found that most incremental innovations were under the tools category.

![Figure 4-8. Innovation types that delivered a combination of quality-time-cost benefit.](image)

![Figure 4-9. Innovation types that focused on delivering a single benefit.](image)
Figure 4-10. Innovation types that focused on either sustainability, safety or community.

Figure 4-11. Degree of novelty of various types of innovation.
4.3.7. Discussions

The results of the analysis of 500 reported innovations by the alliance group, SCIRT, clearly demonstrate the diversity of types, degree of novelty and performance improvement benefits among construction innovations. The trends presented in the previous section have all emerged naturally based on the organisational dynamics and culture present among the member organisations as well as within the virtual alliance organisation. Given that innovation KPI reporting was linked to pay/reward system for the member organisations, there was motivation for all parties to look for opportunities to innovate. However, the data shows that most of the reported innovations were tools or functions that were developed to overcome immediate problems facing the operational teams. As a result, most of these innovations were modular or architectural in terms of novelty. This indicates that most reported innovative solutions were developed to either solve localised problems or issues arising at the interface of operational sub-systems. The data also shows that when architectural and modular innovations were dominant, the reported innovations were mainly focused on a single aspect of performance improvement. In contrast, the results show that when more sophisticated types of innovation such as technology and methods were developed, the impact was more widespread and significant, delivering benefits along multiple dimensions of performance such quality, time and cost.

Given that the reported innovations in the SCIRT database were developed without consideration given to the types of innovation, degrees of novelty or performance improvement benefits, they were all treated the same. The KPI associated with innovation simply counted the number of innovations reported by the member organisations. The main reason for this equal treatment of the reported innovations is lack of understanding of various categorisations of innovation by the SCIRT management team. Consequently, they missed the opportunity to guide and direct the innovation efforts of the alliance member organisations towards specific types of innovation which could lead to specific aspects of productivity and performance improvement.
One important point with respect to future application of the classification system to other construction projects is the uncertainty associated with matching the definitions of the various categories of the classification system with the information provided about the particular innovation. Although this was not a major issue in the case of innovations in the SCIRT database, it is still a notable concern for future applications. While applying the classification system in the case study, it was clearly evident that this uncertainty was directly related to the amount and quality of information provided about the innovation. Given that in this case the classification system was applied retrospectively, the research did not have any influence over how data about the innovations was collected and reported. It is therefore suggested that if the proposed classification system is used for development of a KPI system, a data collection template is designed based on the definitions of the various categories. This could for instance take the form of a questionnaire with specific questions around novelty, benefits and type of innovation, which would ensure that adequate information is available for classifying the particular innovation.

4.3.8. Conclusions

In conclusion, the results of the analysis illustrate the need for a better understanding of innovation in construction. The innovation classification system presented in this study provides a practical tool for research and practitioners in the field of construction management, to not only better understand the relationship between innovation and productivity, but to also put in place mechanisms to influence the types of innovation developed in their projects with the aim of maximising their productivity performance. This classification system can be used by construction organisations and alliances in the future. The chapter concludes the first part of the study to understand innovation classifications and to develop an innovation classification model as a comprehensive definition of innovation in the construction industry.

4.4. References


Chapter 5. Incentivising Innovation in Construction Teams

Working paper to be submitted to:


5.1. Introduction

This chapter aims to develop an understanding of SCIRT’s innovation rewarding structure and its capability to incentivise teams and individual through the project’s lifecycle. The relationship between innovation incentive systems and innovation behaviour is also studied at this chapter. At the first part of this chapter, an understanding will be developed for incentive systems in integrated delivery systems in construction. Two main elements of an innovation incentive system (performance measurement system and pain/gain commercial models) will be discussed at first part of this chapter.

The second part of this chapter focuses on the effect of SCIRT innovation incentive system on the ‘types’ and the ‘novelty levels’ of developed +500 innovations. By applying the developed innovation classification model on SCIRT innovation database, the research discusses the way that SCIRT innovation incentive system has affected the process of innovation. Finally, an optimization innovation performance indicator will be proposed research in order to improve the efficiency of the innovation incentive system in the infrastructure project. In doing so, the research objective 3, to develop an innovation incentive system for construction infrastructure projects based on the SCIRT KPI will have been achieved.

5.1.1. Incentivizing innovation in construction projects

As mentioned by Lundin and Söderholm (1995) the “team”, as one of the main elements of a project, plays a key role on innovation process in construction. The creative ideas as the first initiative for every
kind of innovation are humankind’s only capability. This means that innovation is strongly dependent on that capability of the individual through a team, organisation or project. The key role in innovation of a capable project team is such an important issues that many researchers focused on this in various types of literatures (Blayse & Manley, 2004; M. Park, Nepal, & Dulaimi, 2004). G. Winch (1998, p. 274) stated this role as; “Ideas are carried by people, and ideas are the rallying point around which collective action mobilizes”. Mumford (2000, p. 314) states “While management practices can enhance the likelihood of innovation, ultimately, it is the individual who is the source of a new idea.” ‘Innovation champion’ is one of the key research areas that address one kind of individual role in the process of innovation through a construction project (Nam & Tatum, 1997). ‘Knowledge management’ as a tool for individual learning process, introduces knowledge ‘creation’, ‘sharing’ and ‘implementation’ as the key elements for empowering teams to innovate more through the organisation, firms and projects (Carrillo, Egbu, & Anumba, 2005; Lin, Seidel, Shekar, Shahbazpour, & Howell, 2012).

The multi-party, complex and fragmented condition of construction projects makes the role of teams and individuals much more complicated through the innovation process. Teams with different types of tasks and responsibilities develop a combination of knowledge and experience in construction projects. This variety of people could be considered as either an opportunity or an obstacle to the innovation process throughout the construction industry. Either a ‘conservative, risk averse’ or ‘adventurist, innovative’ team would be developed based on the management capability throughout a construction project. A capable performance management system supports the project individual through the innovation development phases, from an innovative idea creation to the final successful innovation.

Incentive systems have been identified as a tool for empowering project teams to perform better through the project lifestyle. In the absence of strong market forces driving innovation in the construction industry, the role of the client or project owner becomes critical for creating the motivation to introduce or develop innovative solutions. Incentives with targeting the teams’ performance have been considered as one of the main policy through the big construction infrastructure projects along the world. In order to entice construction companies to be more innovative, some clients (especially local or national
governments) have started to incentivise firms by incorporating innovation-related performance indicators as part of the construction contract. ‘Crossrail’, ‘Heathrow Terminal 5’, ‘London Olympic Park’ and ‘SCIRT’ are the successful infrastructure projects around the world that introduced an innovation strategic plan in order to incentivize innovation.

The success of an incentive system to improve the performance of the project team is related to appropriate management of effective factors throughout the process of application. Various types of effective criteria have been identified by literatures that could make an incentive process successful. Robbins and Finley (1995) contend that outdated reward structures are a common reason teams fail in organizations. They note that rewards and evaluations are still functionally determined: Teams and individual members are often rewarded for the wrong things. The importance of effective factors in the success of an incentive system was identified by Sarin and Mahajan (2001) as:

- When teams are rewarded (that is, the timing of rewards) had a significant effect on team performance (i.e., process- and outcome-based rewards).

- Team performance was also affected by how the rewards were distributed among the members of the team (i.e., equal and position-based rewards).

- The effects of these reward structures were contextual and depended on the characteristics of the project and industry consideration.

In conclusion, the success of an incentive system to improve the performance of project teams is related to an understanding of the structure of the effective factors and the way they affect the success of the application process.

‘Bench marking’ (performance measurement system) is one of the key elements that play a primary role in the success of an incentive system. The transparency and accuracy of the performance measurement system is one of the most important factors for the success of a fair incentive system. The key performance indicators (KPIs) play a key role on defining fair judgement criteria based on which performance of the project teams is being measured. The importance of the KPI for the performance measurement system has been stated by Chan and Chan (2004) as, “Based on earlier research, a set of
KPIs is developed to measure project performance”. Definitions of the KPIs that were developed by the measurement system are supposed to be an agreed reference for assessing the project team’s performance. The success of an innovation incentive system in construction projects is directly related to the comprehensively and practicality of the definition that has been developed for innovation. A shared understanding of innovation as a complex phenomenon should be developed through a comprehensive definition as an overall reference to assess an individual’s innovative performance.

A comprehensive definition has two main benefits for the incentive process. The first advantage is the opportunity that definition provides for innovation as a complex phenomenon to be completely understood by all people in the project. The next and probably more important advantage is that a competitive environment could be developed as a result of comprehensive innovation definition that motivates different types of innovation through different level of incentive throughout the project. The competition as a result of the different levels of incentive has been identified as a key driver of performance.

However, research indicates that there is a lack of systematic definition of what innovation means. Innovation is basically understood in abstract terms and very little attention is paid to the various types and categories of innovation. Consequently, the performance indicators used to incentivise innovation are mainly one-dimensional and simply count the number of innovative ideas that firms introduce. The importance of a fair and transparent innovation measurement system is revealed when an unfair judgement of an individual’s innovation would disrupt the competitiveness of the incentive system. “Therefore, when the ease of individual evaluation is low, a perception of unfairness may persist in the distribution of rewards” (Sarin & Mahajan, 2001, p. 38). Despite the success of incentive systems on developing the quantity (numbers) of innovations, the quality of innovation has not been well addressed through innovation strategies in large construction projects. Site-based problem-solving solutions with low levels of novelty have constituted most construction innovation but this could be addressed by improving quality of innovations. The capability of innovation incentive system is assessed by current research using the SCIRT innovation incentive system as a case study.
5.2. Performance in SCIRT

“SCIRT is delivering more than construction work. It is aiming to lift the capability of the construction sector workforce, improve the resilience of infrastructure, and foster innovation” (Auditor, 2013, p. 6). The issues around people, including ‘safety’, ‘satisfaction’, ‘skill & knowledge’ and ‘learning structure’ have become the main principles from the early stages of the SCIRT project. Addressing the performance of the individual through SCIRT is a complex project requiring a strategic plan by the project owners from the start of the project. A performance measurement system has to be instituted to assess how effectively and efficiently project teams and individuals are performing throughout the life of the project.

5.2.1. Key Result Areas (KRAs) in SCIRT performance measurement system

Key Result Areas (KRAs) are defined by the SCIRT performance measurement system to develop a classified understanding of the performance as a shared understanding. Five key performance indicators have been developed as the main result of the SCIRT performance measurement system. The KRA framework covers the following service-related areas: safety, value, our team, customer satisfaction, and environment. Auditor (2013) identified the KRAs in SCIRT as:

Safety;

SCIRT considers safety to be very important. It is considered as a separate factor in the second part of project allocation, which is why the safety KRA carries a weighting of 0. By considering safety during the second part of the allocation model, SCIRT can stop allocating work to a delivery team that has a poor safety record. If it were included as part of the DPS, it would have less effect.

Value;

The value KRA includes measures for productivity, quality, and innovation. It is one of the few KRAs that measure performance of IST, rather than of delivery teams. Delivery teams contribute to the design process through early contractor involvement.

Our Team;
The ‘Our Team’ KRA is a measure unique to SCIRT. This measure comes from an understanding of the stress and hardship that staff experience from being affected by circumstances in Christchurch while continuing to work as professionals in the rebuild. This measure indicates that SCIRT values staff wellness. The ‘Our Team’ KRA also includes up-skilling the workforce, with a focus on numbers completing NZQA qualifications, to support the higher objective of “lifting the capability of the sector-wide workforce”. Good performance in this KRA can help to address labour shortages by improving the capability of those already working with SCIRT and attracting others.

**Customer satisfaction;**

SCIRT measures customer satisfaction for both the product and communication. SCIRT states: The results to date show excellent levels of satisfaction that have been due to a focussed effort in engaging affected members of the community with the programme.

**Environment;**

The final KRA is a measure of environmental awareness and waste minimisation. The KRAs are designed to encourage desirable behaviours, not just on the particular element measured but also for general matters relating to the KRA. For example, measuring the number of initiatives to improve environmental performance is intended to make environmental matters “front of mind” more generally. This is an assumption that should be tested through compliance audits on other aspects of environmental performance.

**5.2.2. Key productivity Indicator (KPIs) in SCIRT performance measurement system**

The KRAs are broken down further into key performance indicators (KPIs) and measures against which delivery teams are assessed. 12 Key performance indicators have been developed in order to be used for define different aspect of the performance through the SCIRT performance measurement system (Table 5.1):
(Wilkinson et al., 2012) stated the differences between KPIs and KRAs by developing a separate statement for each of them as:

- **Key Result Indicators (KRIs)** are used to understand how a project or organisation has done in a key area. Measures such as customer satisfaction and profitability are good examples of a KRI, as they summarise how successful a particular project has been.

- **Key Performance Indicators (KPIs)** drive improvement. They tell us what a project manager or organisation must do to achieve successful outcome. An example of a KPI might be how many times a site must be inspected each week, or an employee’s weekly utilisation.
An understanding could be identified about the current level of performance using the SCIRT performance measurement system. Making decisions to improve areas on SCIRT performance could be through improvements in the measurement system. Identifying the Key Result Areas (KRAs) and the key performance indicators (KPIs) as the project owner’s expectations on performance would develop a shared understanding between every SCIRT project team. An early agreement on the team performance criteria develops transparent measures of the performance through different project partners with various tasks and responsibilities.

Benchmarking as a technique for comparing the performance of the project team to an agreed level of performance would be available by scoring each of the KPIs. The performance scores are developed by using assessment structures that provide numbers because of the project team’s performance. The structures for calculating the performance scores are identified by developing mathematical formulae in the performance measurement system. The performance measurement formulae are developed as the shared structures between different teams in SCIRT project. The performance score developed because of the performance measurement system gives an opportunity to apply an incentive system based on the quantitative database of different project team’s performances.

5.2.3. SCIRT commercial framework

The performance scores of different project teams are used by a commercial framework comprising a system of penalties and rewards. Addressing the performance incentive system, a novel commercial model identifies a flexible pain/gain payment structure for each of the project team. Based on the calculated performance scores, the commercial framework develops penalties or rewards for each of the project teams. The fee structure consists of three components called “limbs” (Auditor, 2013):

• Limb 1 – a reimbursement of actual costs,
• Limb 2 – a fixed margin for profit and overhead, and
• Limb 3 – a performance-based incentive payment or penalty shared among owner and non-owner participants.
Limb 1 is the total of the actual costs of the project claimed by the delivery team. It includes costs such as labour, plant, materials, transport, site facilities, communication, and advertising. Limb 2 is paid as a fixed lump sum to cover profit and corporate overheads. It is a set margin. For projects, this is calculated by applying the margin to the Limb 1 costs of the target cost (not the actual costs) incurred by the delivery team under Limb 1 for the project. Limb 3 is the key element of the pain/gain commercial model through the process of incentivizing the performance. Through this limb of payment, a flexible level of pain or gain is identified for the project team just based on the performance score they have been developed through the performance measurement system. The Limb 3 incentivizes the project team to improve their performance score in order to gain more financial benefit through the project lifestyle (Figure 5.2).
5.2.4. SCIRT competitive work allocation model

A competitive work allocation model as the second incentive structure has been used by SCIRT incentive system. Project allocation is part of the system of penalties and incentives that fosters desirable behaviours and constrains cost inflation. Relative performance between delivery teams fluctuates. “The system allows for poorer performing delivery teams to improve their performance and increase their share of work accordingly” (Auditor, 2013, p. 53). The share of work for each of five project teams has been calculated based on the performance scores they developed through the SCIRT performance measurement system. A ‘collaborative-competitive’ environment has been developed through the SCIRT project because of using a job allocation system. Different project teams compete for the bigger share of work by improving their performance score that is calculated by the SCIRT performance measurement system. This competition between project teams for the higher share of work causes a sudden jump in their performance scores since the start of the job allocation system (Figure 5.3).

Figure 5-3. Delivery Performance Scores for delivery teams, from November 2011 to March 2013
5.3. Innovation in SCIRT

Innovation as one of the key performance indicators (KPI) has been specially focused upon by the SCIRT project owners and top managers. This special attention has been followed by an innovation strategic plan that supports creative ideas through the project lifecycle. An innovation strategic plan in SCIRT initiated a supportive culture through the project teams and individuals for improving innovation as one of the project’s first priorities. “Innovations are captured in the value register, are reviewed by IST management, and are costed by the Resource Co-ordinator. Innovations count towards the DPS only when they have been approved and taken up by other delivery teams” (Auditor, 2013, p. 55). The importance of a supportive culture of innovation in SCIRT project is stated by one of the SICRT manager as: “we really worked on the leadership capability and we did that through a series of cultures”.

‘Value register’ as a mechanism to register a novel idea developed by a project team has been used in the SCIRT performance measurement system. This mechanism is supposed to register, assess and support any novel idea from the SCIRT teams through the project lifecycle. The novel ideas are supported through an innovation strategic plan until they become a successful innovation. After the novel idea is reported to the “value register” the mechanism assesses the liability of the reported new idea based on an agreed definition for innovation. “Innovation is defined as “a feature of system, operation or built work that gives better performance at the same cost of the same performance at less cost “. This is the innovation definition that was used by SCIRT. The innovation score is calculated by the SCIRT measurement system based on these structures:

- MCOS (minimum condition of satisfaction) – 2 innovations a month
- Stretch – 3 innovations a month
- Outstanding – 5 innovations a month

The number of the registered innovation per month by each of the SCIRT project teams used was the only criterion for categorizing them in one of the above groups. Finally, an innovation score is developed for each project team based on the following structure:
“The DPS and OPS are grouped into levels of 0-50 unsatisfactory, 50-65 minimum condition of satisfaction, 65-80 stretch, and 80-100 outstanding. The scores themselves are meaningless without context and should not be viewed as an overall measure of SCIRT’s performance” (Auditor, 2013, p. 56)

The incentive for developing more innovation caused project teams to develop more innovations through the project lifecycle. More than 500 construction innovations have been developed through the SCIRT project lifecycle as a result of special attention to the innovation process by the project owners. This success has been stated by Building Back Better (BBB) as, “Innovation is one of the key performance indicators, where contractors and designers are incentivized to innovate through the scoring process. Over 400 innovations to processes and products have been through the stage-gate process to date” (Scott Miles, 2014, p. 13).

5.3.1. Improving the innovation incentive system

Despite a breakthrough achievement of the SCIRT measurement system through developing a huge number of innovations, the quality of the innovations has been questioned by the research. Is a same achievement through the SCIRT innovation incentive system developed for both quantitative and qualitative purposes?

Answering this question, the research referred to the application result of the innovation classification model on SCIRT innovation database (Chapter 4). Referring to the result of this application, the trend of 500 construction innovations to six different classified innovation types with four level of novelty was assessed. The spread of +500 innovations to different types of innovation with various levels of novelty and benefit could reveal the effect of the innovation incentive system on the innovative behaviour of the project teams and individuals. Two important trends are obvious throughout the SCIRT innovation database. More than 50% of SCIRT innovations have been categorized on the innovation type of Tool and Function (Noktehdan et al., 2015), (Figure 5-4);
More than 80% of SCIRT innovations have been categorized in the level of Architectural and Modular and Incremental levels of novelty:

These two obvious trends throughout the SCIRT innovation database reveal an interest through the SCIRT project team to develop an innovation with a lower level of importance. These innovations have been developed in order to address the site-base problems with the lowest level of time and cost.
assumptions for the developers. The SCIRT team’s interest in the less important types of innovation is not actually a unique characteristic for the SCIRT project only, but is a common problem for the whole of the industry. The trend of construction innovation to simple problem-solving types was a common failing throughout the construction industry and has been discussed in recent literatures (Shahbazpour et al., 2015). Improvements to the innovation incentive system to motivate project teams for developing more important innovations is discussed throughout this chapter of the current thesis. Addressing improvements through the innovation incentive system could have a wide advantage for the whole construction industry as it has lagged in innovation.

5.3.2. Innovation definition

Innovation definition as one of the most important elements of an incentive system plays the role of references for motivating innovation through a multiparty complex project. The way a comprehensive innovation definition affects the success of an innovation incentive system is assessed from three main project partners’ viewpoints:

Owners: The key role of the project owners on developing a strategic vision on innovation is directly dependent on an understanding about the innovation concept at a very early stage of the project. In fact, an understanding of innovating provides an opportunity for the owners to develop an effective innovation strategy. A surface knowledge about innovation because of an incomplete definition would limit the owner’s expectations for bigger innovations as the main driver of breakthrough innovation throughout a project. Then, simple and small types of innovation would become common because of the owner’s limited expectation of the innovation concept.

Managers: The role of the project managers as the agent of formal and informal relationships between the project owners and the contractors is affected by the transparent environment throughout the project lifecycle. Applying the process of an innovation incentive system is one of the key responsibilities of the project managers and is dependent on a shared understanding of the innovation concept through the different project parties. An innovation definition as a tool is used by the project manager to develop a shared understanding through different project partners as a foundation for a successful incentive
system. A clear and easy to understand innovation definition provides a shared reference for project partners with different level of knowledge and expertise. The comprehensive innovation definition would help the project manager to deal with the incentive system appropriately. The project owner’s expectations would be smoothly circulated through the different project partners using a completed innovation definition by the managers. A misunderstanding of the innovation concept through different project teams could be addressed by the project manager using a comprehensive innovation definition.

*Contractors:* The role of project contractors as the implementers of innovation processes would be also affected by the capability of the innovation definition. The high-pressure condition of construction projects, with a high level of unknowns and risks, makes innovation as the second priority for the project contractors throughout the project lifecycle. A comprehensive and easy-to-understand innovation definition could make innovation easy to understand for the contractor of even the busiest teams. Innovation could become the priority of the contractors by saving the time and energy they need to put in to understand the owner’s expectations for the innovation concept. An incomplete innovation definition at the best could only encourage the contractors to develop a simple and small type of innovation rather than important innovations with higher levels of novelty.

The incomplete definition the SCIRT incentive system developed for innovation as references has been focused by the research at this stage. “Innovation defined a feature of system, operation or built work that gives better performance at same cost of same performance at less cost)” (Auditor, 2013, p. 56). The SCIRT innovation definition is not comprehensive enough to present knowledge of the innovation concept. The urgency conditions of the SCIRT project as a response to the natural hazard (2011 Christchurch earthquake) left minimum time, money and energy for developing innovation throughout the project. The innovation definition was not capable enough to convince conservative people to develop breakthrough innovations, with much cost, risk and uncertainty. A lack of categorisation of different types of innovation with variety levels of novelty and outcomes limited the SCIRT incentive system to developing a competitive environment for more important innovation. Different level of incentives could be applied by the SCIRT incentive system using classified types of innovation as the innovation definition. This importance of categorisation on the performance incentive system has been
identified by Sarin and Mahajan (2001, p. 38) as; “Therefore, when evaluating individual performance in a group setting is difficult, an equal reward structure is expected to be more effective”. The one-dimensional and incomplete innovation definition by the SCIRT incentive system caused a same incentive system that identified a same level of encouragement for every type of innovation with variety level of novelty and benefit. Consequently, developing more simple innovations (number) instead of a few more important innovations (quality) was rewarded more through the SCIRT performance measurement system. The low level of expectation of the SCIRT incentive system made it meaningless for the project teams to develop important types of innovation with higher levels of novelty.

5.3.3. Innovation classification model

The innovation classification model is proposed by the research as a replacement for the SCIRT innovation definition. A holistic picture of different types of innovation with a variety of levels of novelty and benefits would develop an easy-to-understand definition of innovation. A shared understanding of the innovation concept as a complex phenomenon could be developed through a multiparty project as the biggest advantage of the innovation classification model. (Figure 5-6);
A fair and transparent format would be developed using this innovation classification model as a reference for measuring the innovation in the SCIRT incentive system. Applying different levels of incentive is available by using the innovation classification model. The classified definition for different types of innovation with a variety of levels of novelty and benefits by the innovation classification model develops an opportunity to incentivize more important innovations by applying more reward to them (Shahbazpour et al., 2015). Applying different levels of rewards for six classified types of innovation, four levels of novelty and six benefits would be available by the innovation classification model.

Identifying the special value of different classified types of innovation by the incentive system would help the project partners to make the best decision based on a transparent and understanding of the...
innovation concept. Different levels of the project team would achieve rewards as a consequence of different types of innovation which would be understood clearly by using the innovation classification model. Project owners would be the first party to take advantage of an innovation classification model near the start of the project. An understanding of classified types of innovation with a variety of levels of novelty and benefit would empower the owners to make the best decisions early. The special attention of conservative owners to important types of innovation could become available by using the innovation classification model.

5.4. Discussion

Separating different types of innovation with a variety of levels of novelty and benefit allows the project manager to be able to identify different values for different classes of innovation through the incentive process. The innovation score of the project team would be calculated based on both the numbers of innovations per month and the value of the innovations developed (quantitative and qualitative assessment). The innovation measurement system would be applied in a competitive environment by the manager, using the innovation classification model. Project managers would be able to apply a flexible incentive system by using a shared understanding about different values of classified types of innovation through project teams. Through this flexible innovation incentive system, more important types of innovation with a higher level of novelty and benefit would be incentivized with higher level of rewards. Conservative project contractors would also be empowered to make the best decisions about the type and number of innovations. Developing more important innovations would be rewarded more based on a flexible incentive system using the innovation classification model. The categorisation of different types of innovation through an incentive system would develop an opportunity for the contractors to manage time, cost and energy in a fraught environment at the construction sites. A shared understanding about different types of innovation as a result of the innovation classification model could help the contractors to understand the owner’s expectations more clearly.
5.4.1. Recommending an optimization on SCIRT incentive system

An optimization is proposed by the research on the SCIRT innovation incentive system regarding a knowledge that have been developed through the result of the ‘chapter 5’. Different weighting factors (w) could be identified for each of the classified types of innovation with various levels of novelty and benefits. An optimized innovation scoring formula could be proposed as a tool in order to accounting the numbers, Types, levels of novelty and benefits of innovation. The optimized innovation scoring formulae develops an opportunity for the innovation incentive system to consider both the ‘quality’ and ‘quantity’ of innovations. Innovation would be scored based on the numbers of different types of innovation with variety levels of novelty and benefit. Each of the six classified ‘Types’ of innovation, four levels of ‘Novelty’ and six ‘Benefits’ would be weighed through the optimized innovation scoring formula (table 5.2- 5.4), a formula for optimising could be developed and might look like this (Figure 5-7);

\[ f(x) = \sum_{i=1}^{n} (a_i * b_i * c_i) \]

Figure 5-7. An optimized formula for innovation scoring in incentive system

<table>
<thead>
<tr>
<th>Tool</th>
<th>Function</th>
<th>Design</th>
<th>Product</th>
<th>Method</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a_i)</td>
<td>Tw</td>
<td>Fw</td>
<td>Dw</td>
<td>Pw</td>
<td>Mw</td>
</tr>
</tbody>
</table>

Table 5-2. Innovation type indicator

<table>
<thead>
<tr>
<th>Incremental</th>
<th>Modular</th>
<th>Architectural</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b_i)</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 5-3. Innovation Novelty indicator

<table>
<thead>
<tr>
<th>Cost</th>
<th>Time</th>
<th>Quality</th>
<th>Environment</th>
<th>Community</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c)</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>1</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table 5-4. Innovation Benefit indicator
$a_i$: The weighting factor based on the types of innovation (the proposed weighting could be identified as an agreement at the early stage of the innovation incentive system).

$b_i$: The weighting factor based on the levels of novelty (the proposed weighting could be identified as an agreement at the early stage of the innovation incentive system).

$c_i$: The weighting factor based on the types of benefit developed by innovation (the proposed weighting could be identified as an agreement at the early stage of the innovation incentive system).

*Note:* the proposed optimization has not been validated by the research at the time of this writing. This optimized formula is required to be validated through future researches. Future tests and weighting development would form the basis of future work but is beyond the scope of this thesis.

### 5.4.2. Conclusion

SCIRT used an innovation rewarding structure and its capability to incentivise teams and individual through the project’s lifecycle was discussed in this chapter. The chapter showed that there were different ways of rewarding innovation, and incentivising to innovate. The SCIRT innovation KPI was one option, and the research proposed alternative options which considered a wider classification of innovation, the chapter concluded with a developed innovation model which could be of use to incentivise innovation in future infrastructure projects.

### 5.5. References


Chapter 6. Project Lifecycle model for innovation

Working paper to be submitted to:
Noktehdan, M., & Wilkinson, S. Shahbazpour, M. “Project Lifecycle model for innovation”. Journal of Construction Engineering and Management,

The fourth aim of this thesis is to understand where innovations can be developed throughout the project lifecycle. An initial assessment of SCIRT innovations and the impact of ‘Time’ on the innovation process revealed a relationship between SCIRT innovation and the project lifecycle. A constant changing environment in the project team, priority, activities and resources resulted from the dynamic nature of SCIRT illustrated the changing behaviour of different types of innovation through different phases of the project. Hence, this chapter assesses the construction lifecycle to determine where different types of innovation occur across a variety level of innovation novelty and benefits.

6.1. Introduction

The construction industry is seen internationally as a traditional or low-technology sector with low levels of expenditure on activities associated with innovation. Reichstein et al. (2005), comprehensive survey of UK construction firms indicates that many construction firms do not have the motivation to innovate in order to remain competitive. They can sustain themselves by meeting local needs of their undemanding customers. As the scale and complexities of construction projects increase, so does the consequences of failure with regards to public safety and loss of investment. This increases the tendency of the client as well as the companies involved in the project delivery to continue with the previously tried and tested methods and designs, thus resulting in low levels of innovation (Tawiah & Russell, 2008). However, Loosemore (2015b) recently observed that although many researchers indicate that construction industry is not very innovative, companies involved throughout the lifecycle of a
construction project do in fact engage in a lot of day-to-day problem solving activities. He refers to these as “Hidden Innovation” (Loosemore, 2015b) that are often opportunistic and unplanned in response to situations that arise when dealing with limitation of resources, changing working conditions and facing unplanned challenges and events during the construction phase of the project.

Loosemore and Richard (2015) observation indicates that there are certain types of innovations that occur in a construction project that are perhaps not reported or seen as innovations. This highlights two major issues in construction innovation research that needs further clarification. Firstly, the notion of innovation is often understood in abstract terms among researchers and practitioners in the construction industry (Noktehdan et al., 2015). This has been an ongoing challenge in the wider innovation research literature. Zairi (1994, p. 27) made reference to this when he wrote, “what makes innovation challenging is the fact that it is very difficult to agree on a common definition”. Over the years many researchers have proposed various definitions and classifications of innovation in order to overcome this challenge.

In the construction innovation literature, a number of researchers have also offered various ways to classify construction innovation (Noktehdan et al., 2015; E. Sarah Slaughter, 1998). The second issue highlighted by Loosemore (2015a)’s observation is the significance of the project nature of construction process (Ozorhon, 2012). Innovation research in the construction industry has mainly focused on the systemic factors related to how various entities in the construction project cooperate (Blayse & Manley, 2004; Dickinson, Cooper, McDermott, & Eaton, 2005; Sexton & Barrett, 2003b; Clyde B Tatum, 1987) or on organizational factors related to the individual entities involved in the construction project (Nam & Tatum, 1997; C. B. Tatum, 1989; Toole, Hallowell, & Chinowsky, 2013). However, construction process is project based by nature and in order to better understand the dynamics of innovation in the construction industry, innovation needs to be studied throughout the lifecycle of a project (G. Winch, 1998).

The above discussion implies that innovation varies throughout various phases of a construction project. Anecdotal observations by research and practitioners in the construction industry indicates that such variation does exist, however to date this has not been tested through empirical research. This is an important question because if research findings verify such variations in innovation behavior it
strengthens the argument for developing an innovation management approach in the construction industry that is contingent on the phase of the project.

This research aims to empirically verify the variations in the innovation behavior throughout the construction project lifecycle, by analyzing over 500 innovations reported in a large infrastructure rebuild project in New Zealand.

6.2. Innovation in project-based industry

The innovation management process in construction as a project-based industry is widely related to the project management capability. Brady and Hobday (2011, p. 283) identified the uniqueness of the innovation process in project-based industries as: “These characteristics mean the way innovation takes place, in projects, differs substantially from the way it occurs in mass-produced goods where much of the conventional wisdom about innovation and, indeed, business management has been derived”.

The relationship between the two concepts of “innovation” and “project management” has become one of the main research areas in recent literatures (Brady & Hobday, 2011, p. 284). “Later on, research on innovation and CoPS began to integrate elements of both project management and innovation studies, to which we now turn” (Brady & Hobday, 2011). Brady and Hobday (2011, p. 273) identified their main research aim as “the historical and practical relationship between projects and innovation and the connections between the two, often separate, fields of research “. Actually, there is a two-way relationship between the concept of project and innovation. Critical projects have been developed in order to produce critical change as they respond to the community requirements in the construction industry. “Our research shows that, in CoPS, a radical innovation is often a “base moving” project which fundamentally alters the underlying technological base of the business via changes in the core product or system”. On the other hand, incremental innovation has been developed through the project lifecycle, in order to address the technical difficulties of the construction process. “An incremental innovation in CoPS is an innovation which results in a new product or service within the existing technological base (e.g. a new generation of digital flight simulators or aircraft engines)” (Brady & Hobday, 2011, p. 286).
The obvious fact about innovation in the construction industry is that it could not be separated from the concept of a project and then it is dependent on the capability of the project management system. “Project management is the engine for implementing new ideas and there are a host of tools and techniques that make this process more effective” (Wycoff, 2003).

Despite a secure environment of mass-production industries for the innovation process, a lack of R&D opportunity in the construction industry makes projects as the only opportunity for introducing innovation through the industry (Koskela, 1992). An opportunistic management approach is required for archiving more innovation in the construction industry. Innovation in the construction industry would only be available through a unique temporary opportunity developed by a project. In conclusion, the success of the innovation process in the construction industry is directly dependent on the capability of the project management system. Missing the innovative potential of a project by the management system means killing an opportunity that developed temporarily throughout the industry. Project critical elements and their impact on innovation should be understood as the first stage of empowering the project management system to achieve more innovation. A ‘project’ has been defined as; “a temporary endeavour undertaken to create a unique product or service” (Guide, 2001). Projects’ main characteristics have been described as, “Performed by people”, “Constrained by limited resources” “Planned, executed, and controlled”. “Time, “Team”, “Task” and “Transition” are the four main elements identified by Lundin and Söderholm (1995) for projects as temporary organisation. The key role that these four project elements would play in the project management process makes them as effective factors for the innovation process as well. Considering the importance of the project context, the way each of these project element affects the innovation process has become the main aim of this thesis. Time as one of the main project related parameters, and its effect on innovation process will be studied by this chapter.

6.2.1. Project lifecycle

G. Winch (1998, p. 273) argues that “unlike other industries, innovations in construction are typically not implemented within the firm itself, but on the projects upon which the firms are engaged”. This is supported by Bygballe and Ingemansson (2014, p. 519) illustrating that “projects are considered an
invaluable arena for innovation”. In the construction industry, projects manifest as temporary organizations consisting of a coalition of firms chartered by the client. The temporary nature of this organization, means that it moves through distinctive lifecycle phases starting with the inception of the project, and ending with project termination and handover of the physical assets to the client (Lundin & Söderholm, 1995).

G. M. Winch (2010) contends that the project organization is not only temporary but also dynamic in its nature with respect to the project lifecycle. He observes that levels of uncertainty and project organization’s size, and specialization of the people involved with the project vary significantly through the lifecycle of a project. This dynamic nature of the project organization and the project requirements is well understood by the large body of researchers and practitioners in the construction management field. This is evident in the fact that almost all project delivery systems provide phased-base strategies and advice for better management of the projects (AIA California Council, 2007; Department of Treasury and Finance 2006; Rose, 2013).

Table 6-1 lists a number of project lifecycle phases identified in the literature. The variety observed in the project phase classifications confirms the fact that “there is no single best way to define an ideal project life cycle” (Guide, 2001). Typically, projects lifecycle is divided into phases based on the transfer of major deliverables (e.g. requirements to design, construction to operations, etc.) and the specializations involved in the project (e.g. architects, designers, sub-contractors, etc.).
<table>
<thead>
<tr>
<th>Source</th>
<th>Phases in Project Lifecycle</th>
</tr>
</thead>
</table>
| (Pinto & Prescott, 1988) | Conceptualization  
Planning  
Execution  
Termination |
| (E Sarah Slaughter, 2000) | Conceptual design  
Conceptual development  
Design  
Construction |
| (Khang & Moe, 2008) | Conceptualization  
Planning  
Implementing  
Closing/completing  
Overall project success |
| PMBOK (Rose, 2013) | Starting the project  
Organising and preparing  
Carrying out the work  
Closing the project |
| (J. Liu, Love, Smith, Regan, & Davis, 2014a) | Initiation and planning  
Procurement  
Partnership (construction, operation and maintenance) |

Table 6-1. Project Lifecycle Phases

Typically, projects go through four generic phases (Guide, 2001): Starting the project, organizing and preparing, carrying out the work and closing the project. However, regardless of the classification
system used, a number of observations can be made about the changing characteristics of the project throughout the lifecycle (Guide, 2001; J. Liu et al., 2014a; J. Liu, Love, Smith, Regan, & Davis, 2014b):

- The starting phase of the project are characterised by the smaller size of the project organisation (in terms of costs and staffing levels), high levels of risk and uncertainty and the greater influence of project stakeholders on the overall costs and outcomes of the project. Project aims assessment, feasibility study and concept design have been identified as the critical activities in this phase.

- The next phase of the project is concerned with organising and preparing details of the construction work. This involves detailed design, planning and tender process preparation, selection of contractors and allocation of construction work.

- The third phase of the project is characterised by significant increase in the size of the project organisation, increasing costs of change and incremental reduction of risk and uncertainty. The bulk of work on the project is carried out in these phases. Management of time, cost, safety, staffing, conflicts and communication are some of the most important critical project success factors through these phases.

- The final phase of the project is characterised by rapid drop in the size of the project organisation, significant reduction in risk and uncertainty and increasing probability of successful project completion, as well as much greater costs related to change and alterations.

6.2.2. Project lifecycle models by ‘PMBOK’

A behaviour analysis approach has been widely used by PMBOK (Project Management Body of Knowledge) for the main Management Knowledge Areas. Project lifecycle models have been developed for, ‘Cost’, ‘Risk’, ‘Uncertainty’ and ‘Level of activities’ as the main project knowledge areas (Guide, 2001; Rose, 2013). A behaviour curve as a useful conceptual model could shows the trends of project areas through different phases of a project (figure 6.1).
The constant changes of the project elements (Team, Task and Transition) develop such a dynamic condition through the project lifecycle that they affect the innovation behaviour as well. Understanding innovation behaviour through the project lifecycle provides an opportunity for the project manager to apply the best management practice at the right time of the project.

Innovation as one of the key performance indicators requires an identified behaviour curve through the project lifecycle as well. To address this knowledge, the research analysed the SCIRT innovation trend through three classified phases of the SCIRT project. These provided a classified environment for the project practitioner to apply the best management advice for each phase separately. The project manager’s advice would be developed based on the behaviour of each of six classified types of innovation through the project lifecycle. An understanding about innovation has been developed as a result of analysing the behaviour of +500 construction innovations through the SCIRT project lifecycle.

Innovation, like other project performance indicators (e.g. cost, uncertainty, level of activity and risk etc.) behaves differently through different phases of the project lifecycle. A continuous change of the project ‘teams’, ‘tasks’ and ‘transition’ shapes a unique behaviour curve for different types of
innovation through the project’s lifecycle. A lifecycle model for innovation behaviour is required for an innovation strategic plan through the project lifecycle.

6.2.3. Innovation behaviour in production-based industry

Outside the construction industry, the lifestyle model for innovation behaviour had been developed for mass production industries a long time ago (Utterback & Abernathy, 1975). A need for the behaviour analyses of innovation process has been identified by Utterback and Abernathy (1975) as a foundation for creating knowledge on an innovation management research area. “The essence of our argument is that characteristics of the innovative process and of a firm’s innovation attempts will vary systematically with differences in the firm's environment and its strategy for competition and growth, and with the state of development of process technology used by a firm and by its competitors”.

Two completely opposite patterns when two different types of innovation (Product and Process) are followed reveals the important role the innovation lifecycle model would play on the innovation management process (Figure 6.2).

![Figure 6-2. An innovation lifecycle model in production industry](image)
As can be seen from the figure 6-2, the uncoordinated nature of a project at the earlier stage is stimulated by the need of novel project outcomes which are called ‘Product innovation’. The novel methods are stimulated at the middle stage of the project by using the cooperation of both knowledgeable engineers and experienced contractors before the execution phase. Finally, by entering the project to the execution phase, the problem-solving innovation (Process innovation) is used through the strictly controlled and systemic project environment to address the cost to be remained at the lowest level.

The four different simulated regions (figure 6-2) through the project life cycle developed a changing environment for different phases of the project in order to deal with different requirements. The dynamic nature of the project causes an opposite development pattern for Product innovation and Process innovation through project phases. Different definition that has been developed for these two types of innovation by previous research could explain the trend they follow through the project’s different phases.

6.3. Innovation behaviour in SCIRT project lifecycle

6.3.1. Introduction

Current research has aimed to address the lack of a lifecycle model for innovation through the construction industry by shaping the behaviour of different types of innovation through the SCIRT project’s lifecycle. Six classified types of SCIRT innovation have been analysed based on the time they occurred through the project’s lifestyle. The innovation classification model, SCIRT’s innovation database and the SCIRT timing database are the main elements of this analysis. In order to address this, aim the +500 SCIRT innovations have been analysed based on both the innovation classification model and the time they occurred through the project lifecycle. The spread percentage of six types of SCIRT innovation through three classified phases of the SCIRT project was used in order to shape the innovation behaviour.
6.3.2. Research process

Noktehdan et al. (2015) offered a multidimensional classification system, building on the previous research. They identify three dimensions of innovation definition and use that as a basis for developing their classification system. These are innovation type, novelty and benefits (Figure 6-3).

In order to understand project life cycles and innovations, a second database was provided to the researchers which contained information regarding the projects including the start and completion dates of various phases of each project. This information was used to determine which of the four generic project phases can be associated with a given innovation. The following four phases were used:

- Phase 1 “Starting the project”: Project definition, Project allocation and Concept design
Phase 2 “Organising and preparing”: detail design, TOC, Construction allocation.

Phase 3 “Carrying out the work”: Construction and Handover

Phase 4 “Closing the project”: Project Completion

The categorisation process was carried out mainly by one researcher to ensure consistency of interpretation across the data set. Once completed, 20 innovations were selected randomly and categorised by two other researchers using the classification system. This was done to make sure the classification system was being applied appropriately. Any uncertainty around the definition was clarified through this process.

6.3.3. Research result

In order to gain more insights about the changing nature of innovation activity throughout the project lifecycle, the data was analysed from two perspectives. Firstly, for each category of innovation (Type, Novelty, and Benefit) we looked at how the quantity of reported innovations varied in each phase of the project. Secondly, for each phase of the project we looked at the percentage composition of the various categories of innovation. Figures 6-4, 6-5 and 6-6 demonstrate the changing trends of innovation through the lifecycle of the projects. Please note, since there were no innovations reported in the 4th and final phase of the projects, phase 4 is not shown in the results.

The data shows that innovation types of tools and functions had a similar trend with significant increase in the construction phase of the project (phase 3). Product, design and method innovations showed a marked increase from the start of the project to the organizing and planning phase of the project, with a decline in the construction phase of the project. The technology type of innovations showed a descending trend as project moved to the planning and construction phases.
From a novelty perspective, the results show two types of trends. The more novel types of innovation (System and Architectural) showed a dipping trend, with the number of reported innovations increasing significantly in the organizing and planning phase of the project and dropping off as the project moves in the construction phase. Modular and Incremental innovations had an increasing trend throughout the project lifecycle, with the peak occurring in the construction phase.

In terms of benefit, those innovations delivering benefits in areas of Time, Cost and Quality showed very similar trend, of significant increase in the organizing and planning phase of the project, followed by a decrease as the project moved to the construction phase. On the other hand, safety and community related innovations showed a steady increase as the project progressed through its lifecycle.
Environmental innovations showed a marked increase in the second phase of the project and stayed flat as it went to the construction phase of the project. Please note, there were numerous innovations with multiple benefits. For this analysis, if an innovation had benefits in multiple areas, it shows in the sum for each benefit category.

Figure 6-6. Changing trend of the number of reported innovations categorized by Benefit

Figures 6-7, 6-8 and 6-9 demonstrate the composition of innovation types, novelty and benefits for each phase of the project. As illustrated, in starting phase of the project, Technology and Method innovations are the most prevalent in the type category, System and Architectural innovations are the most common in the novelty category and Quality, Time, Cost are the most common from the benefits perspective.

6.3.4. Discussion

The main aim of this chapter was to empirically verify the changing dynamics and behaviours associated with innovation activities throughout the construction project lifecycle. The results clearly demonstrate that characteristics of the various phases of a project provide for situations and environments where certain types of innovation become more prevalent.

The starting phase of the project characterised by involvement of smaller yet more influential team of stakeholders. If attitudes of this smaller group towards risk and uncertainty is favourable towards innovation (as was the case in the SCIRT project), this phase provides a lot of opportunity for
development and implementation of systemic technology and method innovations with large impact in areas of cost, quality, time and safety.

The next phase of the project is concerned with organising and preparing details of the construction work. This typically involves a substantial increase in collaborative design and planning activities among numerous entities with expertise required for detailed design, planning and tender process preparation, selection of contractors and allocation of construction work. If the climate of the temporary project organisation encourages communication, collaboration and innovation, this phase can lead to a large increase in innovation behaviour. Development of innovative designs as well as introduction of novel construction products and methods were found to be the most prevalent types of innovation focusing on quality, time and cost benefits. Furthermore, in this phase, the tendency is to focus on more system and architectural levels of novelty, as critical decisions are being made with regards to the details of the construction work.

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The third phase of the project is characterised by significant increase in the size of the project organisation, increasing costs of change and incremental reduction of risk and uncertainty. This creates an environment where it becomes much more difficult to introduce systemic and large impact change and instead the focus is shifted towards localised problem solving. This is evident in the large shift towards tool and function types of innovation. As the emphasise in this phase is on-time and on-budget delivery of the project, the reported innovations will have lower levels of novelty and have a large variety of benefits in terms of quality, time, cost, safety, community and the environment.

The final phase of the project is focused on project completion. Costs and risks associated with introduction of new change and alterations, are significantly high and as such there is almost no innovation activity in this phase.

These changes in characteristics and dynamics of the innovation behaviour throughout the project lifecycle clearly points towards the need for a contingent approach to management of innovation in construction project. Figure 6-10 provides a suggested construct for a phase-based approach to management of innovation based on the results of this study. The researchers are currently working on development of a comprehensive framework for phase-based management of innovation in a project lifecycle based on this construct.
6.4. SCIRT innovation examples

6.4.1. Pressure wastewater system;

The pressure wastewater system was one of the breakthrough innovations developed by SCIRT project. The ‘resiliency’ of the underground wastewater systems as one the SCIRT project key targets was identified as the main driver of this innovation at the early stage of the project. This system had been proposed at the early stage of the project as a breakthrough innovation in order to address the critical risk of earthquake failure in the red zone area in Christchurch (SCIRT, 2014). The important role the owner’s played at the early stage of project was identified as a key factor for the ‘pressure waste water’ system to be a huge innovation. ” Back in late 2012 SCIRT checked the damage to the wastewater system in the Parklands and North New Brighton area. Based on the damage found, SCIRT made a recommendation to our clients (Christchurch City Council, New Zealand Transport Authority, and Canterbury Earthquake Recovery Authority) to replace the existing gravity wastewater system with a pressure wastewater system” (SCIRT, 2014).
6.4.2. Pipe bursting;

The mid phase of the SCIRT project has hosted most of the novel methods of construction. The contractibility of the developed designs has been discussed by the designers and contractors at the middle stage, when the detailed designs were ready. This novel method of construction had been developed as a result of early contractor involvement (ECI) at the design stage of project. The ECI had identified it as one the main drivers of the novel methods. As one of the interviewers said: “I think it was a learning process for both side to understand in terms of ECI, would you really want to know what I mean, what really impact you in design or vice versa “. Pipe bursting was one of the novel methods that were used by SCIRT in order to replace the conventional method of repairing damaged pipes. A trenchless technique for replacing damaged pipes is an opportunity developed by the pipe bursting method. ‘Time’, ‘cost’ and ‘safety’ are the benefits that have been achieved as a result of using this novel method.
6.4.3. Sheet piling;

Finally, the construction phase of the SCIRT project was identified as the best time for the problem-solving types of innovation with lower levels of novelty. The strictly controlled conditions of this project phase required the practitioners to avoid innovations with higher levels of change and risk. However, the problem-solving solutions had been developed by the different SCIRT teams in order to address the construction’s technical difficulties at the project sites.

A new way of trenching is one the interesting novel functions that was developed by the SCIRT teams in order to address the site-based technical difficulties. Sheet piles are long sections of steel or metal that interlock to form a continuous wall. Several sheets link together, creating a barrier between the soil and a trench. This wall helps to keep the trench free of soil and water and ensures the trench is stable at all times.

(L. SCIRT, 2016a); “When SCIRT’s Fulton Hogan team moved into Blue Gum Place, it wasn’t long before the usually sleepy street evolved into a bustling hive of activity. Their job was to install an underground wastewater pump station, a high impact task that involved digging two large holes up to five metres deep. When digging this deep, sheet piling is a popular method used to create a temporary wall in a trench. The downside of this technique is the ground-borne noise and vibration felt by residents when the piling rig vibrates the sheets into the ground. Although these vibrations are well below the level that can cause damage to homes or properties, some residents may detect a vibration level in the home that could rattle a window or crockery on shelves. The team was installing an underground pump station only centimetres away from a property boundary, so steps needed to be taken to mitigate the
vibrations and the impact on the residents”. SCIRT’s Fulton Hogan team decided a slide rail shoring system would be used instead of sheet piling to minimize the impact of vibrations on the nearby residents. Supervisor ‘Kevin Scovell’ describes it as a ‘dig and push’ system. ” As contractors dig the hole an excavator pushes the system down into place.”

“Figure 6-13. The slide rail shoring system at work (SCIRT 25 May 2016).

“The result is a large space where a foundation could be poured and a manhole structure inserted to house the pump station machinery,” ‘Scovell’ said. The dig and push approach means less vibration than sheet piling, making life easier for the nearby residents. “A slide rail shoring system is one of the safest methods of trench shoring,” Safety Advisor, Steve Smith, said. “It eliminates any risk of trenches or pits collapsing while crews are inside.” “As well as being easy and safe to install and remove, edge protection is easy to retro-fit to the shoring system to prevent crew falling into the pit,” Mr Smith said.

6.5. Conclusion

Innovation in construction mainly occurs within the context of a temporary project organisation. Given that the project organization is dynamic in its nature and its build up, activities and characteristics change throughout the lifecycle of the project, the innovation behaviour also changes depending on the phase of the project. The analysis presented in this chapter provides empirical evidence and insight about this changing dynamics of innovation behaviour throughout the project lifecycle. The findings
point to the need for development of a phase-based approach to innovation management in construction projects in doing so, a better understanding of how innovations can be developed throughout the project lifecycle can be achieved.

6.6. References


Chapter 7. An innovation model for assessing the organisational capability of infrastructure projects

Working paper to be submitted to:


The main aim of this chapter is to investigate the organisational capability and its effect on the innovation process. The literature review of construction innovation models showed incomplete knowledge of organisational factors and their effect on the innovation process. The ability of a temporary organisation (such as SCIRT) in driving innovations in infrastructure project is explored. The current chapter has been structured in two main parts: the first part of this chapter will outline the literature-review on innovation models. The second part will apply the proposed innovation model on SCIRT temporary organisation.

7.1. Introduction

Transition has been defined by Lundin and Söderholm (1995, p. 443) as, “perceptions of causal relationships, ideas about how to proceed from the present state to the final outcome and conclusion of the project”. A project transition is supposed to provide an appropriate context for innovation through the project’s lifecycle. Innovation, as a complex phenomenon with a high level of unknowns and risks requires a supportive environment that provides an organisational context through the project’s lifecycle. A supportive project transition for innovation requires a capable project-temporary organisation that addresses the organisational context through the project lifecycle. The temporary organisation as a response to this requirement should be developed by novel delivery systems
through infrastructure projects. The temporary organisation would act in the role of an artificial intelligence for driving the innovation strategy through the project lifecycle. Innovation strategy as a tool for driving the project teams requires an organisational context for it to be applied appropriately. An innovation strategy which includes managerial advisers would target diverse aspects of a project organisation in order to empower that through the innovation process. The project organisation as a temporary context for applying the management strategies provides an opportunity for incentivising, managing and marketing a novel idea to become a successful real innovation.

The main aim of the current chapter is to investigate an innovation model as a tool for assessing the innovation capability of a project temporary organisation. The key innovation potential of the infrastructure projects in the construction industry, revealing the important role of organisational capability through the project’s lifestyle. The innovation model as a tool for analysing the innovation potential and the limitations of a project organisation are targeted through this chapter. In order to address this aim current research has been structured as follows: a literature review on innovation process on infrastructure projects has been made as the first phase of this research. A project (temporary) organisation, as the core of an Integrated Project Delivery (PID) system, is analysed as the next stage of this chapter using a conceptual model by G. M. Winch (2014). Literatures about innovation models in the construction industry have been reviewed as the next phase of this chapter. An infancy level of construction literatures on innovation models resulted in research proposing a successful achievement in the manufacturing industry. An innovation model developed by Shahbazpour (2010) was tested as a comprehensive multiple-views model for assessing construction project organisation at the final stage. SCIRT (Stronger Christchurch Infrastructure Rebuilt Team) as a successful construction project organisation has been used as a case study for analysing the proposed model. The SCIRT organisation has been analysed by a database that includes data of more than 600 classified innovations, interviews with executive managers and formal and informal project reports. Being involved with the project environment provided a clear vision about the alliancing agreement used by SCIRT organisation and the way a temporary organisation could affect the innovation management through the project. The result of the proposed model application reveals a success through assessing different aspects of the
SCIRT organisation. In the end, the research propose Shahbazpour (2010)’s innovation model as a tool for assessing the innovation capability of a project (temporary) organisation.

7.2. Innovation strategy in infrastructure projects

Infrastructure projects, as the most innovative contexts in the construction industry, have been studied in many innovation literatures (Tawiah & Russell, 2008; G. Winch, 1998). The huge infrastructure projects play a key role in innovation development in this industry. The need for a strategic plan for innovation has been identified by various innovative infrastructure projects around the world. Crossrail is an innovative infrastructure project that introduced an innovation strategy as a practical plan intended to improve innovation potential through an integrated project delivery system. “Crossrail”, as a partnering infrastructure project (building the biggest tunnel in London) is one infrastructure project that developed a successful innovation strategy (Davies et al., 2014). “Innovation has been defined as one of the visions in different layers of our organisation”(L. Crossrail, 2013). The London Olympic Park is another successful mega-project that formally managed innovation by employing a strategic plan throughout the project (Davies et al., 2014). SCIRT, our research case study, is another successful infrastructure project, defining an innovation strategic plan throughout the project’s life.

Partnering, as a response to the complexity, risks and uncertainty of infrastructure projects, develops a virtual organisation as a context for managing performance through the project’s lifecycle. Integrated Project Delivery (IPD) systems identify the temporary organisation with an independent branding as the first stage of the project. Dynamic of project delivery systems in infrastructure project has been studied through many literatures because of their high level of innovation potential (Pellicer, Yepes, Correa, & Alarcón, 2014; Pries* & Janszen, 1995; Tawiah & Russell, 2008; Toole et al., 2013; G. Winch, 1998). “A34 Newbury Bypass”, “Heathrow Express Cofferdam” and “London Underground Earth Structures” are three innovative infrastructure projects that identified the integrated project delivery system as a driver of performance improvement (Thoms, 2000). The virtual organisation of IPDs could be considered as a context for applying innovation strategy through the project lifecycle.
An innovation strategy is required in order to empower a project (temporary) organisation through the innovation process. Studying world-class innovation companies such as “Apple”, “Toyota” and “Software” reveals the role of an innovation strategic vision among different layers of their organisation as the main success factor (Davies et al., 2014). Despite others, the construction industry applied an ad hoc innovation management that resulted in most construction innovations being in small problem-solving (Loosemore, 2015b). A lack of defined innovation strategy left the construction industry the last among others like the manufacturing and service industries. The lack of a firm organisation capability in construction projects caused most of the innovation to disappear at the end of the project (‘Hidden innovation’) (Loosemore & Richard, 2015). The opportunistic nature of the innovation, as stated by Blayse and Manley (2004) is a definition for the construction project that requires innovation to think only about the project’s problems in order to find their solutions. A lack of a demanding context in the construction industry has been identified as the biggest reason that construction was categorized by a survey in UK as the last among four industries (Reichstein et al., 2005).

Project context was considered as the last opportunity for innovation development, based on the conceptual model developed by Loosemore and Richard (2015). However, (Bygballe & Ingemansson, 2014) indicated that “the projects clearly has not been a suitable environment for innovation”. Despite the importance of a project’s environment on the innovation development process, almost all academic efforts throughout the construction innovation literatures on innovation strategy have focused on the firm’s level. A survey in Germany of construction firms focused on the contribution of the two business strategies, knowledge and relationship, to innovation (Drejer & Vinding, 2006). Another similar survey in Australia has focused on the 335 project-based dynamic and resultant strategies on employment (Manley & McFallan, 2006). Another Canadian survey considered project-based companies in order to develop a commercial strategy based on the limitations and potentials they come up with through the industry (Seaden et al., 2003).
7.3. Project temporary organisation

The Project Management Institute in the 5th Edition of its Project Management Body of Knowledge defined the temporary organisation concept as, “a temporary endeavour undertaken to create a unique product, service or result” (G. M. Winch, 2014, p. 722). Action has been stated as the core of a temporary organisation by Lundin and Söderholm (1995). A temporary organisation provides an organisational environment for the multiparty condition of construction projects in order to achieve a unique target. The virtual independent organisation developed by IPDs, brings project partners together closely as a unique entity in order to achieve the project target. Having access to an organized context as a result of a temporary organisation developed an opportunity for the project managers to apply strategic plans.

An understanding of a temporary organisation’s elements is required as the first step of current research. To address this need the research referred to the conceptual model developed by G. M. Winch (2014) for the temporary organisation. ‘Project owners’ and ‘project-based firms’ as two Permanent organisations and the ‘project’ as the temporary organisation are the three main elements based on the conceptual model (Figure 7-1):
Interactive areas between two different types of permanent organisations with completely different responsibilities have been identified as an important issue through a temporary organisation. A big innovative opportunity could be developed through interactive areas between three elements of a temporary organisation. Making this opportunity clearer, the innovation potential of the temporary organisation is assessed for each of the three interactive environments by the research as:

**Governance**: the interactive environment between ‘project owners’ and ‘governments’ has a special effect on the innovation process. The project owners as the main financial supplier of the project play a key role in the innovation potential of the temporary organisation. The culture throughout the project is the most important effect of project owners as it would affect the innovation process through an effective project portfolio of the project’s temporary organisation. An appropriate budgeting management through an effective project portfolio has been addressed by G. M. Winch (2014) as one of the most important responsibilities of the project owners. A safe and stable financial environment could be guaranteed by using an effective insurance mechanism as the other effect of the project owners through the temporary organisation. Conservative owners of a complex and risky infrastructure project could accept more innovations as a result of an innovation strategic plan through a capable project temporary organisation.

**Commercial**: The business of earning money creates such a large aspect of a project’s context that was called ‘commercial’ by G. M. Winch (2014). Commercial models are the main driver through the interactive environment between owners and project-based firms, as they play a key role on improving the innovation potential of the temporary organisation. ‘Tendering’, ‘Contractor selection’, ‘Contracts’, ‘Compensation methods’, ‘knowledge management’ etc. are some of the key activities through an interactive environment between owners and project-based firms. Project managers are the key drivers of smooth collaboration and relationships between different project partners. ‘Benchmarking’, ‘Performance measurement’ and ‘Rewarding system’ are tools that could be used by the project manager in order to motivate innovation through the project lifecycle. IT (Information Technology) as a tool for managing relationships between different parties, has become one of the main issues through the interactive environment between the Permanent organisations involved in a project. BIM (Building
Information Modelling) as an IT-related technology is supposed to connect different project partners through the project lifecycle.

**Resources:** Contractors’ and designers’ commitment to a high performance through the project lifecycle would develop a perfect interactive environment between projects-based firms and project. A safe and timely human workforce, with tools and materials supplement, throughout the project lifecycle is the main concern in this interactive environment. Project-based firms are the main and last parties who are involved through an innovation development process. The Implementation as the last stage of an innovation process should be done at the construction phase of a temporary organisation. The big role of project-based firms on implementing innovations at the construction sites reveals the importance of this interactive environment for improving the innovation potential of the temporary organisation.

A capable project organisation as a context for managing these three-main interactive environment is required for the successful management of innovation. This necessity has been mentioned in many innovation literatures in the construction industry (Pellicer et al., 2014; Sexton & Barrett, 2003b; Toole et al., 2013). The organisational capability for innovation development is defined as “the comprehensive set of characteristics of an organisation that facilitate and support innovation strategies”. Sexton and Barrett (2003b) categorised capability into two distinct but complementary groups as “cognitive” (or taught) and “organisation” (or function). C. Tatum (1989) indicated four organisational structure as effective areas on innovation as supportive: policies, flexibility in unit size, inter- and intra-organisational coordination, and staffing to satisfy requirements. Toole et al. (2013) identified five main organisational characteristics as effective in the innovation development process as: “Culture”, “Learning”, “Collaboration”, “Customer focus” and “Network”. Pellicer et al. (2014) has a statement about organisational capability. he said that “an innovation management system transfer driver into special asset and benefit, the system is influenced by the business environment and organisation capability of the project”. Organisational capability and its effect on innovation have been studied by research from other industries as well. Shahbazpour (2010, p. 139) defined organisational capability in his innovation framework as, “The aim of Phase II of the framework is to assess the current situation and become aware of the elements within the organisation that significantly affect the innovation
process”. He also stated that, “Organisation is the context within which the teams and individuals carry out innovation. It plays a role of creating the motive for initiating innovation, as well as directing and enabling its further development and implementation”. Despite the importance of organisational capability for innovation construction, there is still a lack of understanding about the project organisation, how to assess its condition and, finally, how to improve the capability of the project’s construction for innovation.

### 7.4. Applying the innovation model on the SCIRT organisation

Having involvement with SCIRT, the current researcher had an opportunity to assess the organisational capability of SCIRT by using the innovation model developed by Shahbazpour (2010) (figure 7-2).

![Multiple-viewpoint modelling process (Shahbazpour, 2010)](image-url)
**Process:** Shahbazpour (2010, p. 38) defined this view of the model as: “The process view of innovation is concerned about the sequence of activities through which inventive ideas are materialised into benefits for the innovators and the recipients of the innovation.”. The process view of Mehdi’s model considers three main activities that start with “problem solving”, followed by “Internal diffusion” and finally ending with “Project management”. A systematic approach is required for identifying the problems through a construction phase. The best solution for identified problem is developed in construction projects as a result of a systematic problem-solving process. The problem should be analysed based on a transparent information database which is used for managing a systematic design making. Innovation diffusion includes a transparent communication and collaboration channel between different project participants which is supposed to share knowledge appropriately. Transferring a novel idea to a real innovation has been introduced as a set of project management activities by Mehdi’s innovation model. The project-based firms (Contractors, Consultants, Supplier) are targeted by this view of Mehdi’s innovation model because of the functional nature the ‘process view’.

**Control:** This view has been identified by Shahbazpour (2010, p. 58) as; “Control view of innovation is considered with innovation decision, the factors influencing them and the mechanism employed to meet them”. ‘Style’, ‘Flexibility’ and ‘Autonomy’ as the three main areas through ‘Control’ view is used to show the best mechanism for controlling projects in order to improve their innovation potential. Two main control styles, “cognitive” and “Interacting” were introduced by the innovation model based on how the management of the organisation uses the control mechanisms. ‘Cognitive’ style as a traditional controlling mechanism includes three main parts as; ‘Monitoring’, ‘Assessing’ and ‘Rewarding/Punishing’. The interactive style of control on the other hand considers an active involvement of top managers in the controlling process. ‘Flexibility’ as the second effective factor on control view, includes ‘Rigid’ and ‘Rigidity as the beneficial factors for driving efficiency at the later stage of innovation development and an inhibiting factor for the initial stage of the innovation development, by banning creativity from the project team. ‘Centralisation’ (spread of organisational decision making) as a factor for the autonomy of the controlling system is considered an inhibitor at the
initial stage and an effective factor at the later stage, when efficiency is more important for a successful innovation.

**Structure**: “The structure view of innovation is concerned with the arrangement of entities internal and external to the organisation and their relationship to one another with respect to flow of information and resources” (Shahbazpour, 2010, p. 48). The relationship between two different permanent organisations in an alliancing project organisation (Owner and Non-owner) could be analysed by the structure view of Mehdi’s model. “Network” as one of the two main factors of the structure view could be used in order to address the relationship between permanent organisations that are working under an alliancing contract. The three organisational factors (network ties, boundary openness and cohesiveness) are for assessing the network efficiency of a partnering through diverse viewpoints. ‘Boundary openness’ as one of the main aims of an alliance contract in construction projects has been focused upon as one of network factors in the innovation model. Sharing the knowledge and resources between different parties as the main argument in boundary openness, has been tracked by alliancing project under the “win-win” concept as a common language through the project organisation. A ‘collaborative–competitive’ environment as a result of employing a novel commercial model by the partnering project develops an opportunity for the project participants to open their boundary and share more in order or gain more.” Network ties” as one of the main factors, introduces the number of the ties for project participants as a benefit of the innovation process. More innovation potential would be available for the project participants that increase the number of their ties through the project as a result of more opportunity that is provided by a large number of ties. An alliance between diverse types of project-based companies (contractors, consultants and suppliers) and the owner-participant is the best opportunity to develop the number of ties through the project. A long-term relationship, an alliancing contract would develop on infrastructure projects providing an opportunity to develop firm ties between project participants. “Cohesiveness, also as known as ‘network cohesiveness’ is an indication of how much a firm's alliance partners are interconnected among each other”. Team creation, as one of the main step of alliancing development process reveals another opportunity; partnering organisations would provide for increasing cohesiveness between project partners based on a trust, collaboration and team climate.
**Knowledge**: “From the knowledge viewpoint, innovation is a process of knowledge creation”. Knowledge management has been categorized by Shahbazpour (2010, p. 53) into three main areas as ‘knowledge acquisition’, ‘knowledge diffusion’ and ‘responsive to knowledge’. Two main types of knowledge (‘tacit’ and ‘explicit’) were introduced as the most effective factors in knowledge acquisition. Both types of knowledge (tacit and explicit) are required for managing complex infrastructure projects with high levels of uncertainty. The knowledge acquisition capability of an organisation was identified as a factor dependent on the current knowledge condition throughout an organisation (Shahbazpour, 2010). Knowledge and experience integration, as a result of an alliance between people and teams with diverse skills and knowledge, would develop an opportunity for increasing the knowledge acquisition through a project lifecycle. ‘Knowledge diffusion’, the second effective factor, referred to the advantage of alliance projects that integrate different project participants to share more through the project lifecycle. Regular meetings, an innovation champion, a talented project manager, communication technologies, and project standards and frameworks are among the activities that foster the knowledge disseminating through partnering projects. IT (information technology), as one of the most important drivers of knowledge dissemination, has developed a separate researcher area in construction management named ‘BIM’ (building Information Modelling). An online network through-project organisation (like ‘High VIZ’ in SCIRT) is one of the IT development efforts in the partnering project. Every project’s activities and performance information should become able to be shared between different project parties by using BIM. “Responsiveness to knowledge“ is the last effective factor in this view that considers the agility level as a driver that help organisations to adopt an innovation faster. The high level of risk and uncertainty of the infrastructure projects requires project organisations to be very responsive to the innovations and solutions through all the project lifecycle.

**Culture**: Culture is concerned with norms, values, meaning, symbols and rituals shared by members of the organisation, describing how things are done. Four types of cultural context (Clan, Adhocracy, Market and Hierarchy) have been classified based on the degree to which the organisation focused inwardly or outwardly. Collaborative long-term innovation as the main characteristic of the ‘Clan’ culture would suit a project-alliancing organisation. Experimentation, tolerance of mistakes and
embracing change are three main cultural norms and values that foster innovation in a construction project organisation. ‘Climate’ as the main area in a supportive culture would consider the trust, challenges involved, freedom, idea time, conflict, idea support and risk taking as the most important factors for a capable organisation. ‘Leadership’, the last and most important driver, would develop an innovative culture. A capable leadership would introduce the best behaviour, traits and style throughout the project lifecycle. Leadership, by developing different level of leadership in order to maintain a high level of integration between different parts of the project, is one of the main target areas in a project-partnering organisation.

**Resource:** Resources are essential for successful innovation. Resources must be ‘valuable’, ‘rare imperfectly’, ‘imitable’ and ‘un-substitutable’ in order to lead an organisation to a competitive advance. The collective advantage of diverse knowledge, skills and experience, integrated by an alliancing in construction project would develop an ideal resource for the innovation development process. “Tangible resources such as time, labour, coded knowledge, skill, patience, brands, technology and money are required for successful innovation”. ‘Resource availability’ as one of the key resource area has been focused in ‘Slack and Scarcity’ by Shahbazpour (2010). ‘Slack’ has been defined as the excessive level of available and recoverable resources. ‘Slack’ has an inverse U-shape relationship with innovation. Both too much and too little slack have been identified as inimical to innovation. Slacks have been perfectly managed through a novel commercial model in alliancing the delivery system. A pain/gain method includes three different limbs under which the project compensations are managed in a collaborative competitive environment. Limb 3 is considered as a kind of slack that incentivises project teams to the higher level of performance in order to gain bigger share of work and profit through the project lifecycle. ‘Dynamic capability’ as the last effective factor considers the ability of the organisation to integrate and reconfigure the current resources as a key factor for improving innovation. Knowledge creation and learning, networking, and strategic alignment are the main factors in increasing the dynamic capability in an organisation. The alliancing project organisation’s ability to synthesize a diverse type of knowledge and skill in a single entity should be considered as a dynamic capability for the innovation development process.
The research assessed the organisational capability of SCIRT from six different views. Interviews with SCIRT senior managers were conducted and organised through a research contract between the University of Auckland, the University of Canterbury and SCIRT. Spending around one year in Christchurch city, the researcher became more aware of the organisational condition of the SCIRT project.

The results of the application of an innovation model on the SCIRT organisation is presented for each of the six views through more than +30 organisational Factors. Discussing the result for all of the organisational factors through the next part of this chapter will provide an opportunity to have a broad view of different aspects of SCIRT’s organisational capability.

**7.5. Discussion of the result of the application**

The organisational capability of the SCIRT project as one of the main drivers of the innovation strategy has been assessed using a comprehensive multiple view innovation model. The classified environment of Mehdi’s innovation model develops a clear and complete vision of what the innovation factors are and how the SCIRT organisation has met them through the innovation process.

**7.5.1. SCIRT organized process**

“As performance is important to SCRT, SCIRT management prepared a peak performance plan that is reviewed annually” (Auditor, 2013, p. 31). High-level strategic planning was employed by SCIRT in order to ensure that the horizontal infrastructure rebuild programme was linked with the wider Canterbury recovery and was repairing the right things, in the right place, at the right time, to the right standard. A large scale of projects (148 project) was managed by SCIRT through a consistent approach to pricing, sound risk management, and use of its collective experience and learning. The network interdependences in the SCIRT project reveal the need for a prioritization process that was prepared in order to outline the principle and methodology for the scoping project. “Individual lengths of pipe cannot be replaced in isolation because of the widespread ground settlement caused by the earthquakes” (Auditor, 2013, p. 36). The ground condition after the earthquake has been identified as the root of
many problems that have had a significant effect on prices. A pain/gain commercial model was used by SCIRT as a system of penalties and rewards that were considered as drivers to foster certain behaviour. Delivery teams competed to increase their share of work based on work allocation system rules that considered the KPI (Key Performance Indicator) as a reference to indicate the share of work for each of SCIRT teams. “SCIRT manages risks early, rather than transferring them to the delivery teams” (Auditor, 2013, p. 49).
<table>
<thead>
<tr>
<th>Areas factors</th>
<th>SCIRT organisation condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process</strong></td>
<td></td>
</tr>
<tr>
<td>Problem Solving</td>
<td>“Network interdependencies are considered first to define hydraulic catchments boundaries.”</td>
</tr>
<tr>
<td>Analyses (Root cause)</td>
<td>“That is really challenging ground conditions so the poor soils and obviously solve the liquefaction”</td>
</tr>
<tr>
<td>Communication (transparency)</td>
<td>“SCIRT is transparent in its scheduling, making the information publicly available.”</td>
</tr>
<tr>
<td>Collaboration (diversity)</td>
<td>One of the main challenges for SCIRT is to bring together a mixture of staff from different organisations to work together as a team</td>
</tr>
<tr>
<td>Politics Political (tactics)</td>
<td>“The IST maintains plans and procedures to manage all important aspects of SCIRT’s work”</td>
</tr>
<tr>
<td>Project management</td>
<td>“we used to learn technical working groups for design phase”</td>
</tr>
<tr>
<td>Multiple projects</td>
<td>“SCIRT was established, it took on 148 projects”.</td>
</tr>
<tr>
<td>Scanning (Active scanning)</td>
<td>“The SCIRT Management Team is part of the IST and provides SCIRT’s everyday management”</td>
</tr>
</tbody>
</table>

Table 7-1. SCIRT organisational condition (Process)
7.5.2. SCIRT organized Control

A large number of continuous independent estimator reviews, independent audits, internal and external performance reviews and consistent inspection and testing developed an organized control system. This was a necessity for a large-scale recovery project costing more than two billion dollars to the tax-paying public. The SCIRT organisation addressed this need by employing both two types of the ‘interactive’ and ‘cognitive’ control system throughout the project. A KRA (Key Result Area) as a set of defined outcomes (Safety, Environment, Quality, Consistency and community and stakeholder relationship) was used through a cognitive controlling system throughout the SCIRT organisation. The interactive controlling system was addressed through a set of ‘monthly developed reports to the general alliancing managers’, ‘weekly data collection about the workers trade and skills’ and ‘continual manager capability and equipment reviews’. Several layers of internal and external reviews and audit in the SCIRT organisation revealed a high level of rigidity throughout the control system. “The auditor examines the claims in detail and produces a monthly progress report to the three public entities that includes comment on any issues arising”. Centralisation has been managed by employing a voting system throughout the decision-making process. “The SCIRT Board’s decisions are made through voting by all participants (owner and non-owner), with a requirement that all decisions must be unanimous” (Auditor, 2013, p. 22).

<table>
<thead>
<tr>
<th>Areas factors</th>
<th>SCIRT organisation condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td></td>
</tr>
<tr>
<td>Style</td>
<td>Diagnostic</td>
</tr>
<tr>
<td></td>
<td>“we set the challenging goals and we allow people to achieve them”</td>
</tr>
<tr>
<td></td>
<td>Interactive</td>
</tr>
<tr>
<td></td>
<td>“we just navigated through that change very well but other time we do that intentionally”</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Rigidity</td>
</tr>
<tr>
<td></td>
<td>“early on there was a lot more freedom to add the value to the project I think there is lot less opportunity”</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Centralisation</td>
</tr>
<tr>
<td></td>
<td>“everything we do it is going through the approval process with asset owner because they accept the risk”</td>
</tr>
</tbody>
</table>

Table 7-2. SCIRT organisational condition (Control)
7.5.3. SCIRT organized knowledge

Both ‘Tacit’ and ‘Explicit’ types of knowledge were required to address the high level of uncertainty that was caused as a result of massive damage to roads and pipes after the earthquake. Diverse types of knowledge, skills and experiences were synthesised in an alliancing project organisation, as a unique opportunity for SCIRT to access a valuable source of tacit knowledge through the project. The Infrastructure Recovery Technical Standards and Guidelines (IRTSG) has valuable explicit knowledge that has been used as a reference by SCIRT organisation. The SCIRT organisation deployed an integrated information technology in order to address knowledge management as one of the effective factors on innovation. The competitive work allocation system and the early contractor involvement process, two important SCIRT mechanisms, have been developed as a perfect condition for project teams to share knowledge. “SCIRT is capitalising on its collective experiences and learning” (Auditor, 2013, p. 49). SCIRT’s project learning legacy was a defined formal plan for addressing the learning process in the SCIRT organisation. It revealed a high level of organisational agility as an effective factor that empowers, then respond to new knowledge.
### Table 7-3. SCIRT organisational condition (Knowledge)

<table>
<thead>
<tr>
<th>Areas factors</th>
<th>SCIRT organisation condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacit Type</td>
<td>“different functional groups came together and basically facilitate made to get people to talk”, “all around the SCIRT we have got lots of story people kind of story”,” The first is the person who knows , I would say as a massive range of people”</td>
</tr>
<tr>
<td>Explicit Type</td>
<td>“Infrastructure Recovery Technical Standards and Guidelines (IRTSG)”</td>
</tr>
<tr>
<td>Absorptive capacity</td>
<td>“the value register and the way that people reported on innovation”, “did lunch and learn so this is about creating that whole learning kind of cultural environment”</td>
</tr>
<tr>
<td>Integration</td>
<td>“a professional coacher came out and bring people together”, “Early contractor involvement allocation is done early in the process to gain construction expertise and advice”</td>
</tr>
<tr>
<td>Collaboration</td>
<td>“we have a blue-sky network”, “when we log on every day the high viz system flashes everything for us”</td>
</tr>
<tr>
<td>Knowledge management Technology</td>
<td>“we heard that someone did something else, so quickly have a look”, “we take on ECI document really and really quickly and then implement on the new project disaster of relief or an emergency response tool”</td>
</tr>
</tbody>
</table>

#### 7.5.4. SCIRT organized structure

The alliance of the New Zealand government and the private sectors (project-based companies) developed valuable networking for the SCIRT project. An effective structure became available in order to address the huge scale of infrastructure reinstatement and rebuild activities. “Networks and alliances
of customers, suppliers, competitors and other non-market participants, such as financial institutes and universities are key enablers of innovation” (Lawson & Samson, 2001, p. 383). Three functional layers of SCIRT structure (SCIRT governance, the Integrated Services Team (IST) and the delivery teams) would be considered as an opportunity for the project participants to increase their network ties throughout the project. “Alliance Agreement requires non-owner participants to subcontract a minimum of 40% of the work, which gives opportunities to other contractors. SCIRT as an integrated delivery system had tried to follow the teaming approach as a cohesive structure. By working collaboratively, SCIRT encourages its staff to leverage their collective skills and knowledge” (Auditor, 2013, p. 38). Network interdependency in the SCIRT project require a boundary-open relationship with other Canterbury recovery projects in order to address the consistency through the recovery of pipe and roads.
<table>
<thead>
<tr>
<th>Areas factors</th>
<th>SCIRT organisation condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td></td>
</tr>
<tr>
<td>Boundary openness</td>
<td>“CERA, through the CGG, needs to facilitate better connections between SCIRT and other government agencies”</td>
</tr>
<tr>
<td>Number of ties</td>
<td>“Alliance Agreement requires non-owner participants to subcontract a minimum of 40% of the work”</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>“By working collaboratively, SCIRT encourages its staff to leverage their collective skills and knowledge.”</td>
</tr>
<tr>
<td><strong>Internal</strong></td>
<td></td>
</tr>
<tr>
<td>Centralisation</td>
<td>“SCIRT is organised into three functional layers”</td>
</tr>
<tr>
<td>Complexity</td>
<td>“SCIRT is more complex than a usual alliance because it involves multiple owners and non-owners”</td>
</tr>
</tbody>
</table>

Table 7-4. SCIRT organisational condition (Structure)

### 7.5.5. SCIRT Organized resource

SCIRT as a two billion recovery project can itself be considered as a rare, imperfectly imitable and valuable resource in order to develop innovation and increase infrastructure resilience. A collective of diverse skills, knowledge, experts, finance and human resources as a result of the alliance project was considered as an innovation advantage from the resource view of the innovation model (Shahbazpour, 2010). Resource sharing happened using a competitive collaborative environment as a result of a Pain/gain commercial model. The slack as an effective resource factor has been managed through excessive money (Limb 3 of pain/gain commercial model). Better performance was rewarded through a rewarding system. Variation as an effective factor on innovation was allowed if there had been an increase or decrease in the scope of the works. The resource reconfiguration was addressed by employing an effective project-prioritizing process. “Projects are of an appropriate size and configuration to optimise resources and where there is an effective prioritisation method” (Auditor, 2013, p. 13). SCIRT addressed dynamic capability as a last effective factor by developing a wide vision.
based on the values of “lifting the capability of the sector-wide workforce improve the resilience of infrastructure”, and “foster innovation” (Auditor, 2013, p. 55).

<table>
<thead>
<tr>
<th>Resource</th>
<th>Dynamic Capability</th>
<th>SCIRT organisation condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute</td>
<td>Rare/Imperfectly imitable</td>
<td>“typical project that was not a rebuild these opportunity may not come in more business as usual” “seven hundred and fifty thousand dollar structure just to keep a way the risk of a tsunami”</td>
</tr>
<tr>
<td>Availability</td>
<td>Knowledge/Skills/Expertise</td>
<td>“we had a mixture of people in a team, “having so many people in so much knowledge in a room or in an organisation”</td>
</tr>
<tr>
<td></td>
<td>Slack</td>
<td>“we are suggesting the additional work to make something better which is separate funding”, “waiting for the refunding which was hugely DE energizing”,” The target cost can be adjusted by a variation that the SCIRT General Manager approves”</td>
</tr>
<tr>
<td></td>
<td>Resource Reconfiguration</td>
<td>“SCIRT is delivering more than construction work. It is aiming to lift the capability of the construction sector workforce”. “there is an effective prioritisation method”</td>
</tr>
<tr>
<td></td>
<td>Learning and Sense–making</td>
<td>“I think there was a chance to really understand let call it each other industry” “you always going to learn”</td>
</tr>
</tbody>
</table>

Table 7-5. SCIRT organisational condition (Resource)

### 7.5.6. SCIRT organized Culture

Five Key Result Areas (Quality, Safety, Community and Stockholder relationship and Consistency) provided a clear vision of the SCIRT project’s values in order to incentivise desirable behaviour. “SCIRT is best described as an organisation that despite operating in a complex and uncertain environment has a clear sense of purpose, an outcome focus and a team of aligned and committed members” (Auditor, 2013, p. 31). Mistakes were tolerated as long as the mistakes have not been hidden and lessons were learned from that through the report. Change as a basic need in such an uncertain and
high-risk environment recovery project has been managed by employing a peak performance framework. Challenge involvement, idea time, idea support, conflict and debate as the main factor of a strong culture has been addressed through the regular feedback collection surveys, negation, discussion forums, a no-blame culture and regular meetings. The “SCIRT project team work together in good faith, with trust, mutual respect, and a ‘no blame’ culture” (Auditor, 2013, p. 72). SCIRT as a project with a long-term benefit for the Christchurch community require a culture that guarantee the high level of community engagement, trust and honesty. “The results to date show excellent levels of satisfaction that have been due to a focussed effort in engaging affected members of the community with the programme” (Auditor, 2013, p. 55). “We now are being honest and then one of our main principal and subject is about being honest with the community”. Successful leadership of SCIRT was one of the most important and effective factors that have been identified as the most cultural advantageous by the interview senior manager. The SCIRT project manager (interviewee) stated this as, “We established the seven-leadership wave which is a key leader that is known across the project to come together in the regular bases developed there.”
<table>
<thead>
<tr>
<th>Areas factors</th>
<th>SCIRT organisation condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clan/ Collaborative long-term innovation</td>
<td>“SCIRT demonstrates many of the good practice characteristics of alliance contracts”, “wellbeing engagement culture and I called that incorporate responsibility culture”, “you need to be aligned to SCIRT and it need to aligned to the other team and working collaborate together”</td>
</tr>
<tr>
<td>Tolerance for mistakes</td>
<td>“tolerance for mistakes, we used to have them rubber check”, “is OK to make mistakes as long as you don’t you hide tell people we could fix” “The team works together in good faith with a “no disputes” arrangement, fostering a “no blame” culture”</td>
</tr>
<tr>
<td>Embracing change</td>
<td>“we talked about continual improvement and creating intentions”</td>
</tr>
<tr>
<td>Challenge/Involvement</td>
<td>“as a company we spent a lot of money to try to involve everyone”</td>
</tr>
<tr>
<td>Trust/Openness</td>
<td>“one of our guideline principle and subject is about being honest with the community”</td>
</tr>
<tr>
<td>Risk taking</td>
<td>“one of the most significant aspects of alliancing is the treatment of risk”</td>
</tr>
<tr>
<td>Debate</td>
<td>“The discussion forums generated a wide range of concerns, such as wanting more opportunity to participate in early contractor involvement, wanting more work, rates being too low”</td>
</tr>
<tr>
<td>Leadership traits</td>
<td>“we really worked on the leadership capability and we did that through a series of cultures”</td>
</tr>
<tr>
<td>Leadership styles</td>
<td>“the capability for leaders to deal with uncertainty and being uncomfortable basely whether that was through conflict or through sharing amount of volume of work”</td>
</tr>
<tr>
<td>Leadership behaviour</td>
<td>“language shapes behaviours and the collective behaviours make culture” “the leaders intentionally had created this language”, “The KRAs are used to influence behaviours, to identify trends, and to differentiate performance between delivery teams”</td>
</tr>
</tbody>
</table>

Table 7-6. SCIRT organisationnel condition (culture)
7.6. Conclusion

This chapter has shown the organisational capability and its effect on the innovation process. The level of innovation potential of infrastructure project revealed the important role the alliance organisation played in improving innovation. The innovation model as an effective tool to assess capability was developed for manufacturing as a world class industry. The result of the innovation model application on a real recovery project (SCIRT) in Christchurch revealed the benefits of this model to construction. The success of the SCIRT alliancing organisation, with more than 600 construction innovations, was identified as a result of the innovation strategy developed by the project. The innovation capability of the SCIRT organisation was assessed based on six different views of the innovation model and the results showed well-organized Process, Control, Structure, Knowledge, Culture and Resource throughout the project. In the end, the current research recommends the innovation model as a tool for managers in construction in order to assess their project organisation’s capability for innovation and then to develop the best innovation strategy.

7.7. References


Shahbazpour, M. (2010). *Strategic manufacturing system and process innovation: a framework for small and medium sized enterprises.* ResearchSpace@ Auckland.


Thoms, G. (2000). *innovation at the cutting edge: The experience of three major infrastructure project: CIRIA.*


Chapter 8. Phase-based Innovation Framework

An innovation framework is required for managing innovation at project level. The strategic plan for managing innovation in construction projects is addressed as a critical knowledge gap through the literatures. This chapter develops a phase-based innovation framework for construction infrastructure projects. The research provides draft best-practice guidelines for managing innovation at project level. The research findings of previous chapters are used through the development of this chapter.

8.1. Introduction

Innovation is a complex phenomenon that requires a strategic plan through an infrastructure project’s lifecycle. The success of innovation management in construction is dependent on the innovation capacity of projects as a project-based industry. A gap in the knowledge of strategic planning for innovation in projects has caused many construction innovations to be developed as problem solvers and then despaired of by the end of the project. ‘Hidden innovation’ is a phrase that was used in order to illustrate the innovation condition in construction (Loosemore, 2015b). Loosemore (2015b) identified innovation management in construction as an ad-hoc process that developed innovation in simple and small formats. Addressing this lack of strategic plan, the research proposed an innovation framework for construction infrastructure project, based on the results that were developed through this thesis. Four main parameters and their impact on innovation process have been studied by the research through the previous chapters. This multiple-view comprehensive research has been developed by this thesis in order to develop knowledge of the innovation process in the construction industry. Four separate yet related researches have been developed in order to address a gap of knowledge about managing
innovation at the project level in construction as a project-based industry. Using this information, the research has been able to develop an innovation framework that addresses managerial advice through each phase of an infrastructure project.

8.2. Innovation framework

A phased-based innovation framework is required as a strategic plan in order to manage innovation through a project’s lifecycle. The project was identified (refer to Chapter Six) as a dynamic phenomenon that develops a constant changing environment through different phases of the lifecycle. This dynamicity of projects requires an innovation strategic plan that addresses the changing pattern of innovation behaviour in every phase of its lifecycle. An innovation framework should be developed based on the specific characteristics of project in different phases of lifecycle. Phased-based managerial frameworks have been followed by many project management standards and guidelines in order to address the changing conditions of the critical parameters through different phases of the projects (Department of Treasury and Finance 2006; Guide, 2001). ‘Value for money’, ‘cost’, ‘uncertainty’ and ‘safety’ are some of the main managerial parameters that have their own phase-based management framework through standards and guideline. Addressing a gap of knowledge in the innovation framework, current research developed a phase-based framework. The thesis results in each of the four chapters developed an understanding for innovation stance in consecution infrastructure projects. This knowledge has been used for monitoring the changing behaviour of key project parameters (Team, Task and Transition) through different phases of an infrastructure project. A changing behaviour of innovation through the project lifecycle has already been confirmed by the results of Chapter Six of this thesis.

Four classified phases of a standard lifecycle model were based on the proposed phase-based innovation framework. A constant changing environment through different phases of project lifecycle caused totally different condition in each of the four-different phase’s innovation management. Addressing this change, the research developed the best practical and managerial advice by using a comprehensive discussion about effective parameters (Team, Task and Transition). Based on the results developed in
previous chapters, this thesis discussed the effective parameters in innovation management process for each of the four phases. The innovation management strategy should be flexible enough through the project lifecycle in order to address this changing and dynamic nature of innovation behaviour through the four phases. The unique condition of the four phases will be discussed step by step by the research in order to develop a clear picture about innovation behaviour. At the end, practical advice is developed for each of the four phases in order to manage innovation through the four classified phases of a project lifecycle.

8.3. First phase; Starting the project

Defining an ambitious project at the start of its lifecycle is the key innovation driver that is followed in the first phase of the projects. A firm start for the projects would guarantee the success of innovation though the rest of its lifecycle. An ambitious project is defined based on an innovative and breakthrough concept and technological targets at the very early stage of projects. An understanding of stakeholders’ expectations and needs is required at the first phase. The key role of the project in developing more
important innovation (e.g. Technology) has been proved by Chapter Six of this thesis, where 41% of SCIRT innovations at first project phase have been classified as technological innovations.

8.3.1. ‘Conservative Owners’ and ‘Ordinary Stakeholders’

The high level of risk, unknowns and uncertainty at the first phase make the owners and stakeholders very conservative about the project outcomes. The concern about financial sources that are mostly developed from the taxpayer’s money forced the project owners to follow very restricted approach in defining the project targets and size. ‘Technological innovation’ is only available on the owners’ demand in the first phase of the projects. Owners and stakeholders are required to be incentivized for demanding more breakthrough and technological innovations at the earlier stage of projects. A high level of financial and legal supports is required for the technological innovation. This supportive condition reveals the key role of a ‘risk-taking’ and ‘open-minded’ owners at the earlier phase of projects. Keeping risk, uncertainty and unknowns as low as possible would help the conservative owners to be convinced of breakthrough innovations.

8.3.2. ‘Project opportunities’, ‘Feasibility study’ and ‘Project justification’

An understanding of worldwide markets, similar projects and technological innovations around the world provides infrastructure an opportunity to propose breakthrough innovations in the early phase. Research into project targets, owners’ expectations and needs develops an understanding about the innovation opportunity that would be available for addressing the needs. This understanding about the project targets could help the owners to make the key decisions based on such comprehensive knowledge. A broad knowledge about innovative opportunities would be developed as a result of a ‘project justification’. This justification reports on the technological innovation that decreases the level of risk and uncertainty as the main barrier at the first phase of project. The ‘feasibility study’ is a mechanism that decreases risks of the proposed innovations through a technical and engineering study in the first phase.
8.3.3. ‘An agile organisation’

The smallest size of a project’s temporary organisation happens at the first phase of the lifecycle. This small size of the project’s temporary organisation improves the agility to address the high level of risk and uncertainty at the beginning. The decision-making capacity of the temporary organisation would be affected by the high level of agility at that time. Flexibility of the project at this phase would allow project owners to adjust the level of project funding and budgets based on the proposed new technological innovation requirements. The information and knowledge flow smoothly through the agile temporary organisation at this time.

8.3.4. Recommendation

Considering the key role of the first phase of the project on technological innovation, the current thesis proposes practical advice for innovation management as:

► Project owners and stakeholders should be convinced for breakthrough innovations;

- Defining ambitious project targets that develop value for money through the project.
- Running research into similar successful innovations through national and international markets.
- Decreasing the owners’ concerns by developing a project portfolio that supports enough funding for breakthrough innovation.

► Support innovation proposals until becoming a real target for the project;

- Developing a feasibility study that supports the proposed innovation through technical and engineering approval through the development process.
- Developing a justification for research that supports the proposed innovation through the benefits and values that are discovered.
- Requesting government support for the proposed innovation that provides enough funding and legal foundation for development process.
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Increase the capacity of project organisation for making key decisions;

- Keep the size of an organisation as low as possible in order to improve the agility for making key decisions.

- Develop democratic mechanisms to achieve feedbacks from the entire stakeholders.

- Keep it simple and easy to change the developed decisions based on new developed opportunity by breakthrough innovations.

8.4. Second phase: Designing, Organising, Tendering and Preparing

The developed conceptual decisions are referred to the second phase by the project teams in order to develop details on plans and schedules and processes. The second phase of the project acts as ‘Phase-Transfer Catalysis’ that transfers the ‘rhetorical’ nature of the project at the first phase to a functional nature at the construction phase. The risks and uncertainties start to decrease while more detailed information becomes available throughout the second phase of the project. Regarding the availability of people with a variety of types of knowledge and skills at this phase, innovations in the architectural level of novelty would be common at this time. The SCIRT innovations have been classified as ‘Design’, ‘Product’ and ‘Method’ types, more than others at the second phase of the project (Chapter 6 of the current thesis). The important role of teams with different roles and responsibility in innovation should be considered through an innovation framework. Considering this important role, the researcher will discuss the way the key project parameters (Team, Task and Transition) would affect innovation in the second phase.

8.4.1. Variety of teams with variety types of skills, and background

A variety of different types of teams and individuals with skills, backgrounds and responsibilities are added to the project organisation at the start of the second phase. This diversity of skill and knowledge
in the second phase of the project provides an opportunity to share as much information that is required for architectural plans, project time schedule, project budgeting plan and the tendering process. A mixture of owners’ financial and decision-making power, consultants’ engineering and technical knowledge and contractors’ first-hand experience provides the best condition for innovating at this phase. While this fragmentation of the second phase could be considered as an opportunity for innovation, it could also cause much chaos in the case of inefficient information and communication management. Information flow should be managed efficiently in order to avoid a distraction through project organisation discipline. Communication management plays a key role in increasing the capacity of the project organisation to achieve the maximum benefit from this mixture of skills and knowledge. Information Technology (IT) is a tool has been recently focused on by research in the construction industry in order to be used for managing communications and information flow through huge infrastructure projects.

8.4.2. A Competitive-Collaborative approach for achieving the best

Using the advantage of both completion and collaboration through achieving the higher level of productivity, integrated project delivery (IPD) systems have been developed for infrastructure projects. The last updated format of project delivery systems (IPD) have introduced novel mechanisms for managing projects by approaching integration of main project parties. Integration of project parties (Owners and Non-owners) by an independent project entity (virtual organisation) is the main advantage of IPDs. Competition is also pursued by IPDs in order to motivate project participants to compete with each other for achieving better performance. The second phase of a project considered competition as a key mechanism for developing detailed designs. Inviting competitive design submissions through an architectural competition event can be a productive way for clients to explore for full extent of a project and to evaluate the quality of the design responds. The tendering process is also a key step of the project at this phase that would be followed by a competitive-collaborative approach. Early contractor involvement (ECI) is a new concept that has been followed by the integrated delivery system in the construction industry. Providing tendering documents based on both the competitive cost and performance-based criteria would motivate the contractors to compete based on key performance
indicators (KPI) and cost. Innovation is identified as one of the KPIs in order to shift the attention of the constructors to the importance of innovation as one of the owners’ expectations through tendering documents. Detailed design, detailed time schedules, a detailed budget plan of the tendering process and as-built documents are all produced during the second phase of projects.

### 8.4.3. Fragmentation for Commitment-building

The huge diversity of the project teams and individuals at this phase of the project, require clear structural and managerial positions. The responsibilities are required to be defined for each of the project parties in a detailed manner at this stage of the project. Shaping the project-temporary organisation requires each of the project teams and individuals to identify their roles and responsibilities through the whole project lifecycle. The ‘compensation method’ as one of the main tools for paying project participants is identified and confirmed at this phase. Performance-based compensation models and performance measurement systems are the two main elements of an incentive system for a project that should be mentioned through the project’s legal agreement documents during the second phase. Every single organisational role and responsibility must be clearly demonstrated before heading to construction as the next phase.

### 8.4.4. Recommendation

Considering the importance of the second phase on innovation, current research recommends practical advice for managing the innovation process at the second phase of project as follows:

► **A collaborative approach is required in order to take advantage of a variety of types of people with diverse skills and knowledge**

- Inviting a wide range of engineering designers and contractors from national and international construction industry through submissions such as architectural competition events.

- Incentivising project practitioners to innovate more by using mechanisms such as rewards.
Using IT such as Building Information Modelling (BIM) as a mechanism to drive and manage communication and information flow through different parties.

A competitive approach is required in order to motivate project different parties to compete with each other for better performance

Using competition in design and architectural plans by using formal mechanisms such as architectural competition.

Developed tendering process as a competitive mechanism based on both cost and performance criteria.

Define innovation as one of the key performance indicators (KPI) in order to incentivise contractors to compete for more innovation through project lifecycle.

Identifying the roles and responsibilities for different project parties

Shaping the project temporary organisation by identifying a virtual organisation with an independent entity.

Identifying the method of compensation for the project temporary organisation based on both ‘performance measurement system’ and a ‘Pain/gain commercial model’.

Identifying ‘slacks’ for time and funding in order to support the probable innovations through the project lifecycle.

8.5. Third Phase: Carrying out the work

The start of the construction activities at the site of the project is considered as a milestone in an infrastructure project’s lifecycle. The flexible and open-mind organisation at the previous phase of the project becomes more hierarchical and closely organised at the start of this phase. A complex environment in the third phase is a response to the biggest size of the project temporary organisation that would have happened through the third phase of projects. A large number of small to medium
enterprises (SME) work at construction sites in order to cover huge amount of work and activities. Very strict roles and terms are identified in order to control the construction’s high-pressure conditions. ‘Cost’, ‘time’, safety and ‘environment’ are the major concerns in the construction phase due to covering a huge amount of dangerous, costly and timely activities with potential harm for the environment. This pressure-cooker environment could make a big innovation a headache for a project temporary organisation. However, innovation with minor influences on their environment such as ‘functions’ and ‘tools’ constitute most of the innovations in this phase. SCIRT innovations have been classified mostly as lower levels of novelty, referring to the results of Chapter Six of this thesis.

8.5.1. Contractors are very busy

The largest size of a project temporary organisation would happen in the construction phase where a large number of small to medium enterprise (SME) are in charge of different types of construction activities. Following this dramatic size increase, funding, time and safety concerns are increased dramatically at the construction phase. Lots of technicians, subcontractors, builders, site managers and labourers work in different parts of a construction site in order to address different activities in this phase. Financial struggling as one of the main characteristics of the SMEs reveals the prompt money fluency. Delays on funding approvals are considered as one of the biggest concerns at this phase of the project. Lagging the time schedule is another common issue in this phase, as it develops an emergent and rushed condition to fulfil the time shortages. Problem-solving kinds of innovation as an answer to probable technical and site-based difficulties are most common in this phase. Contractors preferred innovation with lower level of novelty in order to solve their urgent problems with minor influences on others’ work at a construction site. ‘Tool’ and ‘function’ types of innovation have been classified as the problem-solving innovations with the lowest level of novelty that have happened mostly at the construction phase of the SCIRT project.

8.5.2. Labour, Material and Equipment utilisation

Good project management in construction project mostly pursues the effective use of labour, materials and equipment. The productivity improvement is the major concern of project management at this phase
through controlling time, cost and safety concerns. The factors that are affecting site-based job productivity such as ‘job size and complexity’, ‘job site accessibility’, ‘labour availability’, ‘equipment utilization’, ‘contractual agreement’, ‘local climate’ and ‘local cultural characteristics’ should all be considered through the construction phase. Material procurement and delivery is one of the main successful factors in this phase of the project. The use of novel equipment (e.g. machineries, tools and facilities) and novel methods of work would improve the productivity at the construction phase of projects.

8.5.3. A hierarchical organisation for constructing well

Regarding the historical increase in the size of the project temporary organisation, the construction must behave in a hierarchical way in order to maintain the organisational harmony. A large number of SMEs with a variety of types of skills and responsibilities, develop huge concerns about the safety, time and cost and environment at this phase. The project temporary organisation is required to control the main managerial parameters (Time, Money, Safety and Quality) through very tough and strict roles and conditions. Supply chain management is one of the main tasks in the construction phase, as it is required to make timely and safe material supplements on the project site. Measuring the performance of the project teams is considered as one of the main aim of the project organisation at this phase. This measurement process is supposed to be handled through an identified set of key performance indicators (KPIs). The performance scores are developed for each team in order to be used by the pain/gain commercial model. Construction teams are paid based on the performance scores they come up with through the construction phase. Innovation as one of the key performance indicators (KPIs) would be incentivized through a performance-based payment system.

8.5.4. Recommendation

Considering the huge impact of the construction phase on the innovative potentials of a project, the researcher proposes practical advice for managing the innovation process at this phase:

► SMEs are required to be supported through time and money slacks for developing innovation;
■ An innovation champion should be employed in order to monitor the innovative activities.

■ Identify enough time and money slacks through the construction phase in order to make it possible for busy contractors to relax and drive innovative thinking through the project.

■ Rewards and celebrations should be held throughout construction in order to incentivize the construction teams to drive innovative thinking through a calmer environment.

► Equipping the project site well in order to support innovative ideas;

■ Provide a free space at the construction site for teams to sit around a table and discuss technical difficulties, share knowledge and develop novel ideas.

■ Develop an internal network as an online portal in order to make it easy for construction teams to report on and share new ideas, and receive as much practical feedback as possible.

■ Employ a capable management mechanism in order to make sure of the timely procurement, delivery and inventory control of novel materials and equipment on site.

► Develop a culture of innovation, tolerance for mistakes and support;

■ An innovation registration mechanism should be developed in order to make it easy for busy contractors to report a novel idea and receive enough support through an organized process.

■ Use an incentive system that motivates construction teams to innovate more by being paid more.

■ Accept any failure as a result of innovation, assess and record the cause and effect for future avoidance.
8.6. Fourth phase: Closing the project

Approaching the end of construction, the size of the project temporary organisation starts to decrease. The pressure-cooker environment of the construction phase cools down by the start of the fourth phase of the project. This more calm condition of the fourth phase provides an opportunity to run research on the project performance database. First-hand knowledge, lessons learnt and experiences of projects’ teams and parties should be collected, analysed and reported for future use in the closing phase. Access to the key project teams and individuals enables the research to have the first-hand information about the project performance database and knowledge through the last phase. The importance of this research in the last phase of project is revealed by Loosemore (2015b) where ‘hidden innovation’ has been identified for the lost innovations in construction projects by the end of its lifecycle. Loosemore (2015b) stated that, while innovations in the construction industry are very common, the lost and missed information at the end of project caused this pocket of innovative practices to be ignored by researchers. This lack of a loop of knowledge in the construction industry caused the industry to lag behind production-based industries where innovations are looped through the industry constantly. Addressing this gap, recent successful infrastructure projects around the world have started to mention the knowledge, experience and lessons learned through their project by initiating a formal ‘learning legacy’ project in the closing phase. ‘Crossrail’, ‘London 2012 Olympics Park, and ‘SCIRT’ are three successful infrastructure projects that have initiated this learning legacy project.

8.6.1. ‘Research Capacity’ of universities plus ‘First-hand Information’ of infrastructure projects

The research capacity of universities and the unique knowledge and experiences of an infrastructure project provide the best opportunity for developing a learning partnership between these two parties at the closing phase of a project. Full access to the project information and learnings could be guaranteed for the PhD students and their supervisors through this learning project as an independent yet partnering
project. Key project teams and individuals as the main source of the learning and project information, would be available for interviews and meetings. This learning legacy project should make sure of an identified systematic access of the researchers to the project site. This systematic access would be guaranteed through regular, formal project site visits, meetings, interviews and project documents. Ethical issues are the main concern through the research due to the project teams’ rights and welfare. The researchers are required to guarantee the project people’s rights through signing off formal approval before heading to project sites and databases.

8.6.2. Put lessons learned online for public use

‘Collecting the project information’, ‘analysing the results’ and ‘presenting the lessons learned’ are the main targets of developing a learning legacy project. An easy to use and understand set of results are required to be developed by the learning legacy project. A ‘friendly user interface’ is also developed through an independent online portal. Classified research themes are used for presenting the learning in order to make it easy for the users to track research results.

8.6.3. An independent entity for the learning legacy project

An independent organisation’s roles and responsibilities should be defined in order to lead the partnership project smoothly. ‘Human ethical approval’, ‘access to confidential database’ and ‘copyrights for published results’ are supposed to be addressed through an independent learning legacy project. The human ethical issue is one the most concerns that a learning legacy project should address through a formal approval mechanism. Access to a confidential consultancy database is usually a big challenge through the learning process. This challenge has been one of the major barriers for creating a loop of knowledge throughout the construction industry. Addressing this challenge, a learning legacy project requires to develop enough of a legal and powerful foundation for accessing as much of the performance database as possible. Project team and individuals should be convinced that the result of the learning project would not harm them and their businesses at the end of the day. The independence of the learning legacy project develops a foundation to develop a unique web-based portal that presents all result through classified research themes. A separate way of funding would also be available by
developing an independent entity that covers funding that is required for the research. The government plays a key role in developing and supporting this partnership between universities and huge infrastructure project as they are two organisations with a public interest.

8.6.4. Recommendation

Considering the important role that the closing phase of a project would play on learning the project’s lessons and knowledge, the research developed practical advice for running a project learning legacy at this time:

► Full access to project information should be guaranteed for authorized researchers
   ■ A warm welcoming culture is required for getting as many researchers as possible involved in a project learning legacy.
   ■ Regular meetings should be scheduled for project teams and individuals in order to share with the researcher’s knowledge, experiences and lessons learned.
   ■ The human ethical issues should be pursued through an organized approval process through the learning project.

► An easy to understand result should be developed for public use
   ■ Developing an independent web-based portal page as a user-friendly interface that present all the learnings through a classified manner.
   ■ The results of the learning project should reserve publishing rights by presenting through journal papers, formal reports, books and PhD & Masters theses.
   ■ The potential top innovations should be listed as opportunities for future use in the construction industry through the commercialisation process.

► An independent entity should be developing as an ‘industry-university’ partnership project
   ■ An independent organisation of the learning project should be developed with separate funding, structure and roles.
■ ‘Commercialisation’ of the selected top innovations should be followed throughout the learning project organisation.

■ The developed result of the learning project should be presented to stakeholders and public through publishing rights.
Chapter 9. Conclusion and Recommendations

9.1. Introduction

There is a key role of infrastructure projects in improving the innovative potential of the construction industry. Developing the innovation potential of these types of projects would help construction. The current thesis applied a multiple-view analysis onto an innovative infrastructure project in order to assess key areas of success through innovation by SCIRT. SCIRT is an innovative alliancing (with more than 500 innovation) between NZ government (the owners) and private construction companies (project-based firms) for rebuilding of Christchurch’s damaged infrastructure after the 2011 earthquakes. The most important development of this study is an innovation management framework which was developed for infrastructure projects. This framework develops innovation practical advices based on the four phases of project’s lifecycle. The temporary organisation concept has been analysed by researchers as an initial step for understanding the way integrated delivery systems (such as alliancing) would affect the innovation potential of infrastructure projects. An understanding of the structure of a temporary organisation has been developed by the research as a foundation for the thesis. One of the best theories about the temporary organisation has been chosen by the research as a multiple-view tool that consider four effective parameters as ‘Time, Task, Team and Transition’. A classified multiple-view context of the chosen model for temporary organisation developed an opportunity for this thesis to assess the ways of affecting an innovation process from four different views. The research analysed innovation potentials and limitations of SCIRT as an innovative temporary organisation. The four different viewpoints were analysed and discussed separately through the support of full access to different types of SCIRT information (interviews, reports, and spreadsheets). With the lack of an understanding about the role of temporary organisation on innovation process though the construction literatures, the current research results would contribute to knowledge by developing a comprehensive assessment. An infrastructure project’s effect on the innovation process has been analysed and discussed.
from four different views. Future researches on innovation in the construction industry would be able to focus on each of the four developed researches in order to assess their effect on the innovation process. Using the developed innovation framework, the construction practitioners would also be able to manage through a supportive transition the right types of innovation at the right time of the project with the help of an incentivized team.

9.2. Review of Objectives

9.2.1. A multiple-view approach for innovation

‘Time’, ‘Team’, ‘Task’ and ‘Transition,’ as the four main parameters of a temporary organisation, shaped the foundation of this thesis in order to assess the innovation process through an infrastructure project. The effect of ‘temporary organisations’ as one of the key words of this thesis, on the innovation process has been analysed from four separate views by this thesis. Responding to this an understanding of the theory of temporary organisation was developed by the research as one of the key steps of the research. The innovation management framework as the main development of this thesis (chapter 8) was developed based on the developed knowledge of the four parameters (Task, Team, Time and Transition) through chapters 4 to 7. A comprehensive, multiple-view theory about the temporary organisation was selected by the research as a research foundation after a literature review. An innovation multiple-view assessment illustrates the anatomy of a temporary organisation by the four classified parameters (Time, Team, Task and Transition). Innovation process in an infrastructure project was chased by employing a multiple-view approach that covers the effects of a temporary organisation from different angels. This chapter provides the final conclusions to the thesis, showing where the key learnings have been made and discussing research limitations and future research directions.

9.2.2. First research aim (Innovation framework)

The first and most important aim of this thesis was to fill the knowledge gap of innovation management at project level in the construction industry. The corresponding objective was to develop a phase-based innovation framework for construction infrastructure projects. Addressing this, the knowledge acquired
in the four parts of the thesis have been used to develop a phased-based innovation framework for managing innovation through the infrastructure project lifecycle.

Research Objective 1: **Develop a phase-based innovation framework for construction infrastructure projects which can be used to guide innovation at project level.**

- **A phased-based innovation framework has been developed;** using the results of innovation lifecycle models (developed as the fourth research objectives), the research developed a best practice guideline for managing innovation in project level. Four classified phases of an infrastructure project were used as a foundation for developing managerial advice. The changing behaviour of different types of innovation through different phases of a project, have been considered as the required knowledge for developing relevant advices.

- **Innovation stance have been discussed for each of the four phases;** with regards to the main project parameters (Team, Task and Transition), the innovation stance would change through the four phases of the project. This changing context of project was considered as the fundamental knowledge in order to develop the best managerial advice by the innovation framework.

- **Innovation management practical advice have been developed for each of the four phases;** Practical and easy-to-understanding advice have been developed for each of the four phases of the project by the innovation framework. The phased-based nature of the managerial best practices, develop an opportunity to address the gap of knowledge of innovation management in project level in the construction industry. The project owners, designers, engineers, managers and practitioners are all be able to use this innovation framework.

- **Contribution to knowledge and practice;** the knowledge gap of innovation management at project level in construction has been addressed by this thesis. The bias of researchers towards innovation at firms/company level caused the innovation left behind throughout the project level literatures in construction. The multi-view approach of this thesis in developing knowledge of innovation process at project level resulted an innovation management framework. The lack of a practical innovation guideline at projects level makes the development of this thesis as a contribution to both knowledge and practice. The gap of knowledge of managing innovation in infrastructure projects could be filled by using the developed innovation framework as the main development of this thesis.
9.2.3. Second research aim (Task)

Research Aim 2, was to further understand of the impact of ‘Task’ as one of the four project-related factors on innovation process. Undertaking this aim, the research set the research objective to develop a comprehensive and multiple-view definition for innovation with variety of types, novelty and benefit in construction.

Research Objective 2: Develop an innovation classification model as a comprehensive definition of innovation in the construction industry.

● An innovation classification model developed; an innovation classification model has been developed as the first academic achievement of the research. After a literature review of the previous innovation definition and classification model, a multidimensional innovation classification model was developed. Tasks and activities in an infrastructure project are supposed to host different type of innovations with variety levels of novelty and benefits. Having an understanding about different types of innovation is considered as a required knowledge for managing other effective factors through the innovation management process. Having a shared understanding about the concept of innovation was identified as a priority for innovation management in a construction project. Without a clear definition, it would be impossible to incentivise teams to develop right type of innovation at the right time of project and with right transition support.

● +500 SCIRT innovations have been classified based on the developed model; A full access of the researchers to +500 construction innovation that reported by SCIRT developed the best opportunity for validating the developed innovation classification model. Addressing this opportunity, the innovation classification model was applied to the SCIRT innovation database. This application process was supported by enough information about the +500 innovations that presented by spreadsheets.

● Trends through the innovation database have been analysed and discussed; the results of the innovation classification model application have been presented by a published journal paper. The result illustrated important trends through the innovation classified types, classified levels of novelty and classified benefits. The most important trend through the SCIRT innovations is about the single types of innovation (Tool and Function) that constituted most of the +500 innovations. The trend of
most of the SCIRT innovations to the ‘problem-solving’, supported an approved theory about the construction innovations.

- **Contribution to knowledge and practice:** A lack of comprehensive definition for innovation in construction literatures was addressed by the developed innovation classification model as the main contribution to knowledge at this part of the thesis. The multiple-view approach of developed model would be considered as an opportunity for using that as a practical tool by project practitioners at project level. The trend of SCIRT innovation towards simpler innovations supported the recent theory of ‘hidden innovation’ in the construction industry.

**9.2.4. Third research objective (Team)**

Research Aim 3 was to understand the impact of the ‘Team’ on innovation process in construction as the second project-related parameters. Assessing the SCIRT’s innovation rewarding structure and its capability to incentivise teams and individual was the corresponding objective.. In undertaking this aim, the research set the following research objective.

Research Objective 3: Assess the SCIRT innovation incentive system and develop an optimisation in SCIRT’s innovation scoring formulate.

- **The SCIRT rewarding structure has been discussed comprehensively:** the importance of incentivized teams and individuals for innovation success in infrastructure project was discussed as the second objective of this thesis. ‘Performance measurement system’ and ‘Pain/gain commercial models’ are the two main elements of a rewarding structure in infrastructure project that were studied at first. SCIRT rewarding structure and its effects on innovation process was focused by using the + 500 innovations.

- **An improvement was found in the innovation incentive system:** +500 innovations have been classified based on six classified types, four levels of novelty and six benefits. The result of this classification was used in order to analyse the capability of the SCIRT rewarding structures for developing different types of innovation. A trend of most of the SCIRT innovations to the simple and problem-solving type was identified and improved upon for the incentive system. The SCIRT
innovation incentive system was identified unable to motivate project teams to develop innovations with higher level of novelty.

- **The SCIRT incomplete innovation definition was criticized:** the innovation definition was identified as an incomplete reference for incentivizing more important innovations in SCIRT project. Innovation was defined as one of the KPIs in rewarding structure. Innovations had been registered by a defined mechanism in SCIRT rewarding structure. This registration mechanism defined innovation in simple and incomplete manner. Improvements of the SCIRT innovation definition can be made that can drive better innovations from project teams. Most of the reported innovations were classified in a small and simple types as a result of the focus on quantity and not quality. This means that a more ambitious definition is required for advertising, driving and rewarding more important innovation.

- **The innovation classification model has been proposed as a comprehensive innovation definition:** the multidimensional nature of the innovation classification model develops an opportunity for rewarding structure to define different levels of importance for different types of innovations. Six classified ‘types’ of innovation, four levels of ‘novelty’ and six classified ‘benefits’ would be able to be rewarded separately by using this innovation classified model. An optimized innovation scoring formula is proposed by the researches. Both quality and quantity of innovations are considered as the indicator through accounting the innovation score. Different ‘waiting indicators’ were proposed for every classified type of innovation with variety levels of novelty and benefit.

- **Contribution to knowledge and practice:** A comprehensive knowledge was developed about ‘incentive system’, ‘performance measurement system (KPI)’ and ‘pain/gain commercial model’. The optimized innovation scoring formulate could be considered as both knowledge and practical accomplishment. Although this formulate has left untested at this stage, future researches should take the advantage of doing further researches in order to testing its ability at a real construction project.
9.2.5. Fourth research objective (Time)

The fourth aim of this thesis was to understand the impact of third project related parament on innovation process. The corresponding objective is to assess where innovations can be best developed throughout the project lifecycle.

Research Objective 4: Assess the SCIRT’s lifecycle to determine where different types of innovation occur across a variety levels of innovation novelty and benefits.

- **Innovation behaviour was discussed at project level;** project is a dynamic phenomenon that effects the process of innovation throughout the limited lifecycle. This effect has been addressed as the third main objective of this thesis in Chapter six. Despite the importance of project context, most of the innovation literatures were developed based on the organisational and individual level in construction. Addressing this gap of knowledge, the research focused on the project dynamic in order to shape the innovation behaviour at project level. Project lifecycle models as the tool for illustrating the behaviour of main managerial factors (Cost, Risk, Uncertainty, etc.) was used by the researchers.

- **+500 innovations have been classified based on type, novelty, benefit and three phases of SCIRT project;** the changing behaviour of innovation through different phases of a project lifecycle, were addressed by using the SCIRT innovation datable. Behaviour of different classified types of SCIRT innovation were analysed through different phases of project by using the result of the classification. A full access of the researchers to the timing database of every +500 innovations developed the best opportunity to study the effect of ‘time’ on different types of innovation in SCIRT project.

- **Innovation lifecycle models developed for the innovation six classified types, four levels of novelty and six benefits;** using the result of the classification, the research developed lifecycle models for different types of SCIRT innovation. These innovation lifecycle models illustrated a clear relationship between the project dynamic and the patterns of different types of innovation in an infrastructure project. This pattern will be used as required knowledge for developing a phase -based innovation framework. The changing behaviour of innovation through the project lifecycle reveals the fact that construction innovation requires a contingent managerial approach in project level.
**Contribution to knowledge and practice:** There is a clear gap of knowledge of project dynamic and its impact on innovation process through construction literatures. Addressing this gap, the developed innovation lifecycle models would be considered as a real contribution to Knowledge at this field. The changing trend of innovation through the project Lifecycle was focused to develop enough knowledge of where different types of innovation occurs through project Lifecycle. Having this knowledge in hand, the project practitioners would be able to focus on the right type of innovation at the right time through their project Lifecycle.

**9.2.6. Fifth research aim (Transition)**

The fifth aim of this thesis was to describe the importance of the “Transition” on innovation process at project level. The corresponding objective is to assess the ability of an innovation model to explain SCIRT’s temporary organisation in driving innovation.

Therefore, Research objective 5 became: to apply an organisational innovation model on SICRT as a tool for improving innovation for temporary project organisations in the construction industry.

**The key role of temporary organisation on innovation process has been discussed:** an ongoing trend of governments to the integrated project delivery (IPD) systems has developed a gap of knowledge of the role of a capable transition in innovations process. A virtual (temporary) organisation is the main element of the IPD in infrastructure projects. The ability of this temporary organisation in driving innovations in infrastructure project was a focus of the research. The structural differences of the temporary and paramagnet organisation was addressed in order to illustrate innovation process in construction as a project-based industry.

**A literature review on the innovation model in the construction industry:** a lack of practical and comprehensive innovations model was identified as result of a literature review in construction literatures. The existence innovations models have been mostly developed at the industry level instead of project level. A lack of understanding of the organisational factors in project level was identified through innovations models in construction literatures. The innovations models play an important role as a tool for illustrating the organisational factors in project level.
• **An innovation model was proposed for use in the construction industry as a successful achievement from manufacturing literatures;** addressing this gap of knowledge, the research expanded their literature reviews through breakthrough and innovation-leader industries. This approach has been supported by Mr Egan in his construction report. Successful academic achievements of leading industries were recommended by him to be used in the construction industry as well. Addressing this recommendation, the research proposed a multidimensional innovation model that developed in manufacturing literatures. The model required to be validated through a real infrastructure project in the construction industry. Addressing this validation, the research applied the proposed innovations model on SCIRT temporary organisation. Interviews information, official reports and online database are all used through this validation process.

• **The result of the innovation model application on SCIRT’s organisation showed a firm contribution that the model provided for the SCIRT organisational assessment;** the result of the validation was illustrated through separate tables of results. Each of the six separate views of the proposed innovation model have been analysed separately. Interviews and other available information about the SCIRT temporary organisation have been used through the analyses. The developed results validate the innovation model as a tool for assessing the organisational capability of temporary organisation in an infrastructure projects.

• **Contribution to knowledge and practice;** Introduction of a successful innovation model from manufacturing as the leading industry into construction as the lagged behind industry could be considered as a contribution to knowledge. Using this practical and comprehensive innovation model, the project practitioners would be able to empower their project’s temporary organisation for providing more innovation. The multiple-view approach of the introduced innovation model provides an opportunity for the top managers to consider all aspects of the organizational parameters through the development process at earlier stage of the project.
9.3. Original Contributions and Significance of the Research

9.3.1. Classified research themes

The classified context of this thesis develops an opportunity to analyse the four different parameters’ effects on the innovation process though an infrastructure project. The four main elements of temporary organisations have been used by the research in order to develop a holistic picture of how SCIRT’s temporary organisation affected the innovation process through the project’s lifecycle. The results of current research are a contribution to the innovation research as a new knowledge area in the construction industry. The key role of a temporary organisation on an infrastructure project with an integrated delivery system makes the multiple-view assessment results of current research as a contribution for the construction industry. The four classified areas of results (Time, Team, Task and Transition), could also be used by future researchers in order to have a focus on each of them separately. A phase-base innovation framework is the final accomplishment of this thesis that works as a practical tool for driving innovation through a contingent management approach. Using the develop knowledge about the four parameters, the research became able to develop a phase-based innovation framework as the final academic achievement.

9.3.2. Thesis Result

The findings in each of the four main factors (Time, Task, Team and Transition) have been discussed separately in the four chapters of the current thesis. The impacts on the innovation process for each of the four parameters have been discussed based on the analyses of SCIRT as a temporary organisation. Synthesising four separate research areas in an innovation practical framework developed a comprehensive multiple-view result framework that could address the innovation process throughout an infrastructure project. The synthesized innovation framework could illustrate the process of an innovation through a single statement such as, “An innovation process through a temporary organisation is supposed to start by an incentivized team whose focus would be on the right task, at the right time
with a supportive transition”. A holistic and multiple-view result of this thesis developed a practical tool for further research in future. Table 9.1 is intended to develop an abstract of results of all researches in a single and holistic view.
| Task; Chapter 4 | ● An innovation classification model developed.  
● +500 SCIRT innovations have been classified based on the developed model.  
● Trends through the innovation database has been analysed and discussed. |
| Team; Chapter 5 | ● The SCIRT rewarding structure has been discussed comprehensively.  
● An improvement on SCIRT’s innovation incentive system has been made using the result of +500 innovation classification result.  
● An incomplete innovation definition has been identified as one of the main drivers of the false trends though the SCIRT innovation database.  
● The innovation classification model has been proposed as a comprehensive innovation definition. An optimized innovation scoring formula is developed to account for both quality and quantity of innovation by the incentive system. |
| Time; Chapter 6 | ● Innovation lifecycle models developed for the innovation six classified types, four levels of novelty and six benefits.  
● +500 innovations have been classified based on types, novelty, benefit and three phases of project that they occurred on.  
● The behaviour of innovation in different types with verity levels of novelty and benefits have been analyses and discussed through three classified phases of SCIRT project. |
| Transition Chapter 7 | ● The key role of temporary organisation on innovation process has been discussed as one of the main elements of IPDs.  
● A literature review on the innovation model in the construction industry revealed a lack of understanding of the organisational factors on the innovation process.  
● An innovation model has been proposed for use in the construction industry as a successful achievement in manufacturing industry.  
● The result of the innovation model application on SCIRT’s organisation showed a firm contribution that the model provided for the SCIRT organisational assessment. |
| Innovation Framework Chapter 8 | ● Four classified phases of an infrastructure project were used as a foundation for a phase-based innovation framework  
● Innovation stance have been discussed for each of the four phases with regards to the main project parameters (Team, Task and Transition).  
● Innovation management practical advice have been developed for each of the four phases. |

Table 9-1. Table of the Thesis Results
As can be seen from the table the results in all four research areas show a clear effect on the innovation process through the SCIRT temporary organisation. Making these effects clear, the result of each of the four research areas have been used to develop a practical innovation framework for construction industry as the last academic achievement of this thesis.

9.4. Recommendation and opportunities for future research

The classified research approach of current thesis provides an opportunity for future researchers to develop an understanding about each of the four parameters specifically. The infancy level of innovation research in construction literatures requires future research to develop more knowledge about each of the four parameters. The innovation behaviour in an infrastructure project should further be assessed by refereeing to this thesis result in future researches.

9.4.1. Longitudinal aspect of SCIRT as the single case study

Regarding the limitation of time and budget, a longitudinal study was not an appropriate approach for this thesis. Addressing this fact, current thesis undertook a cross-sectional approach through SCIRT as a case study. Based on this approach, the researchers were able to compare many different variables at the same time. This research looked at Task, Team, Time and Transition as the main four variables to assess the effects on innovation through SCIRT project. However, ‘SCIRT’ is the only case-study for the current thesis which would limit the result of this thesis. The result of current research has been developed based on the specific characteristics of an emergency condition of a post disaster rebuilt project (SCIRT). Addressing this limitation, future researches are required to run similar researches based on information from infrastructure projects with business as usual condition. Doing further similar researches provides an opportunity to test the liability of the developed knowledge of this study. The future research opportunities are classified based on the four main parameters. One of the most important research area to be studied is to test the capability of developed innovation framework in future infrastructure projects.
9.4.2. To further test the framework

The innovation phase based framework as the most important development of this thesis requires further testing and improvement through future researches. The limitation of research resources such as time and budget, left the developed innovation framework untested at this point of time. Future infrastructure project should employ an action research approach in order to get involved with a real infrastructure project. Future research would be able to apply the innovation framework on a real project temporary organisation and testing the capability of that for innovation improvement at project level.

9.4.3. Task

Regarding the importance of an innovation shared-understanding in infrastructure projects, an optimisation on the developed innovation classification by this thesis is considered as an opportunity for future projects. Adding more classification views, as extra factors could improve the efficiency and practicality of the developed innovation classification model by this thesis. The innovation classification model should be applied on innovation database form infrastructure projects with ‘business-as-usual’ condition by future researchers. This further application could improve the efficiency of the innovation classification model as a practical tool in the construction industry.

9.4.4. Team

The key role of humankind in the process of innovation, reveals the big opportunity that this parameter (Team) developed for future researches. Rewarding structures as one the main mechanism in managing the individuals and teams attitude, is still in infancy level in construction literatures. More research is require in order to develop broader understanding about the innovation incentive systems in infrastructure projects. The ‘performance measurement systems’ and ‘Pain/gain commercial model’, as the two main elements of an incentive system develop a world of opportunity for future researchers in innovation and construction areas. Further researches should also be done in order to illustrate the ways of optimization on innovation incentive system in infrastructure projects.
9.4.5. Time

Project-based nature of construction industry has shaped the foundation of current research. The phase-based innovation framework was actually developed as a response to the changing environment of projects through the lifecycle. Infrastructure projects as dynamic phenomena follow a constant changing pattern through their lifecycle. Addressing this dynamicity, future researches are required in order to develop more knowledge about the effects of project dynamic on the innovation behaviour. Using the result of the chapter 6, future research would be able to add more phases in project lifecycle. This extra phase would be considered as an opportunity to increase the efficiency of the developed innovation lifecycle models. Future research should also be run with a similar style in order to illustrate the innovation behaviour throughout an infrastructure project lifecycle with ‘business-as-usual’ condition.

9.4.6. Transition

The proposed multiple-view innovation model in chapter 7 is required to be studied through further researches in order to make sure about its capability. Further researches are required in order to assess the capability of the proposed innovation model in different types of project in the construction industry. Regarding the fact that the innovation model has been originally developed for manufacturing industry, the liability of the model required to be assessed further. The proposed innovation model should be tested in further temporary organisation in order to be used as a practical tool in the construction industry. The similarity and differences between manufacturing and construction industry are required to be studied by future researchers. Theses similarities and differences should be considered in order to customize the innovation model for construction industry.

At the end, this research was developed with the hope of developing a tool that could be used for the productivity improvement in construction. Innovation as one of the key driver of productivity improvement plays a key role in future of construction industry.
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Appendices

Appendix A: Participation Information Sheet, Consent Form and Ethical Approval Letter

Appendix B: 50 Innovations chosen from the SCIRT Innovation database for further investigation

Appendix C: Fulton Hogan Top Innovations

Appendix D: Interview Transcription

Appendix E: Learning from Innovation

Appendix F: The SCIRT Innovation Project
Appendix A: Participation Information Sheet,

Consent Form and Ethical Approval Letter
PARTICIPANT INFORMATION SHEET
(Chief Executive Officer)

Title of project: Innovation management in construction infrastructure projects. A framework for Alliance procurement system

Name of researcher: MOHAMMADALI NOKTEHDAN
Degree: PhD in Civil Engineering
Department: Civil and Environmental Engineering
Research supervisor: Prof. Suzanne Wilkinson and Dr. Mehdi Shahbazpour

Purpose of this Participant Information Sheet

The purpose of this Participant Information Sheet (PIS) is to seek your permission/authority to approach employees within your organisation to request their participation in this research. The project is part of the Doctor of Philosophy Degree, Civil Engineering, in which the researcher, Mohammadali Noktehdan, is currently enrolled at The University of Auckland, Civil and Environmental Engineering Department. The aim of the research is to develop an innovation framework as a tool, to improve innovation development potential in the New Zealand construction sector.

Research Background

This research focuses on innovation management process within the New Zealand construction industry. It aims to identify the key innovation indicators in infrastructure projects in the construction sector. The intention is to develop a comprehensive innovation model as the first stage and then develop an innovation framework as a tool for construction organizations to enhance their innovation capabilities while working under the project alliancing delivery systems. Therefore, data collection through interview sessions is crucial in fulfilling the objective of the research.

Data Collection

This phase of the research project involves semi-structured interviews with the engineers involved in the development of a number of innovation projects extracted from the SCIRT
Innovation Database. A copy of the Interview Questions that will be asked from the participants has been attached for your consideration. The results of the interviews will be analysed in order to identify key factors that lead to the development of the selected innovations. These factors will be compared with the factors identified in the Construction Innovation literature and at the end a new model of Construction Innovation will be developed.

Participation

The intention is that employees from your organization will be invited to take part in two interview sessions that would last approximately 30 minutes each. Candidates would be selected on the basis of their knowledge and experience in managing or involvement in the selected SCIRT innovation projects. The interview questions will be sent to the participants in advance, along with a separate Participant Information Sheet and a Consent Form. Your endorsement will also be relayed to the employees who are invited to participate in this research, but they will still retain their right to decide whether or not to participate. Furthermore, participants will retain the right to keep their response transcripts restricted from access/review by other members in your organisation (including yourself). The interview will be made only with the consent of the participants. No commercially sensitive information will be asked from the participants and if any such information is provided in the interview, it will be omitted from the transcript.

Data Management

The interview sessions will be audio recorded upon approval from the participants. Participants are allowed to turn off the recording anytime during the session, without the need to provide any reason. Answers and data from interviews will be transferred to a draft interview information sheet in electronic format. Participants are able to review and withdraw the data provided after undertaking the interviews/survey. Upon request, an electronic document of the draft interview/survey information sheet will be sent by email within two weeks after the interview/survey for approval. The participants will be given a period of two weeks from the receipt of document, to respond and edit the transcribed data in order to comply with the organisation’s confidentiality requirement. If the participants decide to withdraw, all information provided will be deleted immediately. After applying all modifications requested, a final interview and survey information sheet will be released and used for analysis and results presentation.

During the study, all data will be kept in the researcher’s and research supervisor’s computer. Upon completion of the study the data will be transferred to a DVD and stored in a secure manner for a period of six years. After six years, the DVD will be physically destroyed. All hard copies will be immediately destroyed and draft interview/survey information sheets deleted. The results of the research will be presented in the form of written reports, presentations, conference papers, journal articles and PhD Thesis. This will be done in a manner which will not identify any participants, their employer, data source either by name, inference, or implication. Data collected will be coded so that the participant’s identity is protected. All results will appear in a generalized format for interpretational purposes only. The final results
will be made available upon your request, but only after completion of the entire research report.

**Anonymity and confidentiality**

The information collected will only be used for research purposes. All personal data will be de-identified and will not be associated with the answer to the questions.

**Consent**

I seek your assurance that participation, or non-participation, will not affect the employment status of the participants. If you are happy for us to contact your employees regarding their potential participation in this study, please sign the attached Consent Form and return to us.

**Contact / Further Details**

If you have any questions or need to contact us about the interviews, please feel free to phone the researcher, Mohammadali Noktehdan. If you require clarification and any further information (for example; the summary of results), please do not hesitate to contact any of the researchers listed below. An appointment will be arranged later and the researcher will personally handover the results in order to ensure the confidentiality.

**Researcher** : Mohammadali Noktehdan  
**Mobile** : +64 226368385  
**Email** : mnok946@aucklanduni.ac.nz

**Supervisors** :  
Prof. Suzanne Wilkinson  
**Phone** : +64 9 3737599 ext. 88184  
**Email** : s.wilkinson@auckland.ac.nz  
Dr. Mehdi Shahbazpour  
**Phone** : 021 141 4842  
**Email** : m.shahbazpour@auckland.ac.nz

**HOD** : Prof. Pierre Quenneville  
**Phone** : +64 9 3737599 ext. 87920  
**Email** : p.quenneville@auckland.ac.nz

For any queries regarding ethical concerns you may contact:

The Chair, The University of Auckland Human Participants Ethics Committee, The University of Auckland, Office of the Vice Chancellor, Private Bag 92019, Auckland 1142.  
Telephone: 09 373 7599 ext. 87830/83761. Email: humanethics@auckland.ac.nz
APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE

ON ........................... FOR (3) YEARS REFERENCE NUMBER ................../..........................
PARTICIPANT INFORMATION SHEET
(Interviewee)

Title of project : Innovation management in construction infrastructure Projects. A framework for Alliance procurement system

Name of researcher : MOHAMMADALI NOKTEHDAN

Degree : PhD in Civil Engineering

Department : Civil and Environmental Engineering

Research supervisor : Assoc. Prof. Suzanne Wilkinson and Dr. Mehdi Shahbazpour

Purpose of this Participant Information Sheet

The purpose of this Participant Information Sheet (PIS) is to invite you to participation in this research project, and provide you with the information that enables you to make an informed decision as to whether or not to volunteer to participate. The project is part of the Doctor of Philosophy Degree, Civil Engineering, in which the researcher, Mohammadali Noktehdan, is currently enrolled at The University of Auckland, Civil and Environmental Engineering Department.

Your participation is requested to take part in two 30 minute interviews regarding a recent innovation project you have been involved in. This interview is an important element of our research project, which aims to develop a tool to help improve the innovation capabilities of the construction industry in New Zealand. I would like to interview you to obtain your views and experiences regarding a specific innovation project you have been involved in as part of the SCIRT project.

Research Background

This research focuses on innovation management process within the New Zealand construction industry. It aims to identify the key innovation indicators in infrastructure projects in the construction sector. The intention is to develop a comprehensive innovation model as the first stage and then developing an innovation framework as a tool for construction organizations to enhance the innovation ability of construction enterprises.
working under the project alliancing delivery systems. Therefore, data collection through interview sessions is crucial in fulfilling the objectives of this research.

Participation

The intention is that, considering your experience in the development of the innovation project selected from the SCIRT database, you could provide some contextual and background information regarding the factors that led to the development of this particular innovation and its successful implementation.

Your Chief Executive Officer (CEO) has given his permission for you to participate in this interview (see attached written Consent). While your Chief Executive Officer (or other suitably authorized company manager) has given the permission, you still have the right to decide whether or not to participate. Your participation or non-participation will not be disclosed to the CEO. Assurance has also been given that your participation or non-participation will not affect your employment status. Although the report of this research will be available to your employer, your transcript of response will be kept confidential and will not be revealed to anyone else.

Two interviews with expected duration of maximum 30 minutes for each session are expected to be required. The information provided will be used for qualitative analysis and used only to support the objectives defined for the study. No names will be included in this research project. You also have the right to withdraw from participation at any time without any explanation. You are not required to provide any commercially sensitive issues during the interview sessions. If any such information is provided, it will be omitted from the interview transcript.

Data Management

The interview sessions will be audio recorded with your permission. You can ask for the audio recording to be turned off anytime during the session, without giving any reason. Answers and data from interviews will be transferred to a draft interview information sheet in electronic format. You are able to review and withdraw the data you provided after undertaking the interviews. If you request an electronic document of your draft interview information sheet, it will be sent to you by email within two weeks after the interview for your approval. You are given a period of two weeks from the receipt of document, to respond and edit the transcript data in order to comply with the organisation’s confidentiality requirement. If you decide to withdraw, all information provided will be deleted immediately. After applying all modifications requested, a final interview information sheet will be sent to you and used for analysis and results presentation.
During the study, all data will be kept in the researcher’s and research supervisor’s computer. Upon completion of the study the data will be transferred to a DVD and stored in a secure manner for a period of six years. After six years, the DVD will be physically destroyed. All hard copies will be immediately destroyed and draft interview/survey information sheets deleted. The results of the research will be presented in the form of written reports, presentations, conference papers, journal articles and PhD Thesis. This will be done in a manner which will not identify any participants, their employer, data source either by name, inference, or implication. Data collected will be coded so that the participant’s identity is protected. All results will appear in a generalized format for interpretational purposes only. The final results will be made available upon your request, but only after completion of the entire research report.

Anonymity and confidentiality

The information collected will only be used for research purposes. All personal data will be de-identified and will not be associated with the answer to the questions.

Consent

If you are happy to participate in this interview please sign the attached Consent Form and return to us. Upon receipt of your consent, the researcher will contact you to organise an interview time and location that is convenient for you.

Contact / Further Details

If you have any questions or need to contact us about the survey, please feel free to phone the researcher, Mohammadali Noktehdan. If you require clarification and any further information (for example; the summary of results), please do not hesitate to contact the. An appointment will be arranged later and the researcher will personally handover the results in order to ensure the confidentiality.

Researcher : Mohammadali Noktehdan
Mobile : +64 226368385
Email : mnok946@aucklanduni.ac.nz

Supervisors : Prof. Suzanne Wilkinson, Dr. Mehdi Shahbazpour
Phone : +64 9 3737599 ext. 88184, 021 141 4842
Email : s.wilkinson@auckland.ac.nz, m.shahbazpour@auckland.ac.nz

HOD : Prof. Pierre Quenneville
Phone : +64 9 3737599 ext. 87920
Email : p.quenneville@auckland.ac.nz

For any queries regarding ethical concerns you may contact:

The Chair, The University of Auckland Human Participants Ethics Committee, The University of Auckland, Office of the Vice Chancellor, Private Bag 92019, Auckland 1142. Telephone: 09 373 7599 ext. 83761. Email: humanethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE

ON .........................FOR (3) YEARS REFERENCE NUMBER .................../..........................
Consent Form (CF)  
(Chief Executive Officer)

THIS FORM WILL BE HELD FOR A PERIOD OF 6 YEARS

Title of project : Innovation management in construction infrastructure Projects - A framework for Alliance procurement system

Name of researcher : MOHAMMADALI NOKTEHDAN
Degree : PhD in Civil Engineering
Department : Civil and Environmental Engineering
Research supervisor : Prof. Suzanne Wilkinson and Dr. Mehdi Shahbazpour

I have read the Participation Information Sheet and understood the nature of the research and why the participants have been selected. I have also had the opportunity to ask questions and have had them answered to my satisfaction. I confirm that I hold the appropriate authority to provide consent for the following statements:

- I give permission for employees of my organization to take part in the research.
- I give permission for employees of my organization to provide information related to my organization to support this research. I understand that any such information will be treated confidentially and any reported information will be appearing in general form.
- I confirm that the employees’ participation or non-participation in this research will not, in any way, affect their employment in my organization.
- I understand that employees will retain the right to keep their survey response confidential from me and other members of my organization.
- I know that the data will be analysed by the researcher without the assistance of any third party.
- I understand that data will be kept for 6 years, after which they will be destroyed.
- I understand that the data from the participants will be stored securely within the
university premises and only the researcher and supervisors can access it.

• I understand that the participating employees will have the rights to review a draft report related to the information they provide to ensure that the information reported satisfies my organization’s confidentiality requirements.

• I understand that the interview session will be audio recorded upon receiving consent from the participant.

• I understand that the participants will have the right to turn off the recordings anytime during the session, without giving any reason.

• I understand that audio recordings will be transcribed and the participants will be given the permission to edit their transcript, in order to comply with organisation’s confidentiality requirement, if requested by them.

• I understand that the participants will be given two weeks from the receipt of document, to edit the transcript to their satisfaction.

• I understand the participating employees are free to withdraw their participation in this research at any time without giving any reasons.

• I understand that the participating employees are able to withdraw the data they provide.

• I understand that although data the participants provide will be reported, it will be done in a way that does not identify the source either by name, employer or inference.

• I understand that the participants will not be asked to provide any commercially sensitive issues during the interview sessions.

• I assure that my employee’s participation, re-participation or non-participation in this research will not affect their employment status.

• I understand that upon my request a copy of the final research report will be provided by the researcher.

Name : ___________________________ Position: ___________________________

Signature : ___________________________ Date ___________________________

Please include your email address in the following space, if you would like to receive a copy of the final report. ___________________________
MEMORANDUM TO:

Prof Suzanne Wilkinson
Civil & Environmental Engineer

Re: Application for Ethics Approval (Our Ref. 01194 1): Approved with comment

The Committee considered your application for ethics approval for your project entitled
Innovation management in construction infrastructure projects. A framework for
Alliance procurement system.

Ethics approval was given for a period of three years with the following comment(s):

1. Email to CEO:
   a. Please amend the sentence saying "I need access.....'", to say "I am
      requesting access...'.
   b. Please remove the personal email and use only your
      University of Auckland email.
   c. Please add the full UAHPEC approval wording.

2. PIS:
   a. The Committee prefers that personal mobile phone numbers are not used.
   b. Please update the UAHPEC Chair contact details as these have been revised: For any queries
      regarding ethical concerns you may contact the Chair, The University of Auckland Human
      Participants Ethics Committee, The University of Auckland, Research Office, Private Bag
      92019, Auckland 1142. Telephone
      09 373-7599 ext. 83711. Email: ro-ethics@auckland.ac.nz

The expiry date for this approval is 18-Apr-2018.

If the project changes significantly you are required to resubmit a new application to UAHPEC
for further consideration.

In order that an up-to-date record can be maintained, you are requested to notify UAHPEC
once your project is completed.

The Chair and the members of UAHPEC would be happy to discuss general matters relating to
ethics approvals if you wish to do so. Contact should be made through the UAHPEC Ethics
Administrators at ro-ethics@auckland.ac.nz in the first instance.

All communication with the UAHPEC regarding this application should include
this reference number: 011941.
(This is a computer generated letter. No signature required.)

Secretary
University of Auckland Human Participants Ethics Committee

c.c. Head of Department / School, Civil & Environmental Engineer
    Mr Mohammadali Noktehdan
    Dr Mehdi Shahbazpour

Additional information:
1. Should you need to make any changes to the project, write to the Committee giving full details including revised documentation.

2. Should you require an extension, write to the Committee before the expiry date giving full details along with revised documentation. An extension can be granted for up to three years, after which time you must make a new application.

3. At the end of three years, or if the project is completed before the expiry, you are requested to advise the Committee of its completion.

4. Do not forget to fill in the 'approval wording' on the Participant Information Sheets and Consent Forms, giving the dates of approval and the reference number, before you send them out to your participants.

5. Send a copy of this approval letter to the Awards Team at the, Research Office if you have obtained funding other than from UniServices. For UniServices contract, send a copy of the approval letter to: Contract Manager, UniServices.

6. Please note that the Committee may from time to time conduct audits of approved projects to ensure that the research has been carried out according to the approval that was given.
# Appendix B: 50 Innovations chosen from the SCIRT

## Innovation database for further investigation

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Innovation type</th>
<th>Innovation description</th>
<th>Company</th>
<th>Reason of selection</th>
<th>Innovation benefits</th>
<th>Opportunity for wider adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thanks from City Care Sign</td>
<td>Tool</td>
<td>City Care have made a “Thanks from City Care” sign that we get the crew to hold and take a photo of on the site where they have been working.</td>
<td>City Care</td>
<td>This innovation has been chosen as a novel Tool on project productivity.</td>
<td>Improved safety</td>
<td>This innovation has a potential for wider adoption on the project where a high level of community interaction is required.</td>
</tr>
<tr>
<td>Data logging Pipe</td>
<td>Tool</td>
<td>It is important to record these checks, as 3rd parties (ECAn, CCC) may request proof that set-ups are being monitored closely.</td>
<td>Sorner</td>
<td>This innovation has been chosen as a tool in order to assess the effect novel Tool on project productivity.</td>
<td>Improved management process</td>
<td>This tool could be reused in other Piping projects.</td>
</tr>
<tr>
<td>Automated reminder system</td>
<td>Tool</td>
<td>Engineers are often too busy to remember all the expiry dates of their traffic management plans, dig permits etc. To help overcome this we have created a system through Smart Sheet that automatically sends the engineer and the Traffic Co-ordinator an email at least 3 days prior to the date that the TMP expires.</td>
<td>Fletcher 0518</td>
<td>This tool has been chosen in order to assess the effect of tool with high level of novelty on the technical difficulty of a construction project.</td>
<td>Critical</td>
<td>This tool has improved the safety on the project.</td>
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<tr>
<td>Hose Management system</td>
<td>Tool</td>
<td>New 40m deep piles are being constructed to support the new abutments for Bridge St. Bridge. The piles are formed of driven permanent steel casings which will be filled with concrete. A hydraulic clamshell (grab) is used to muck out the casings. At full depth, 60m of hose is needed. We found that when the clamshell is taken up out of the casing to discharge the spoil, the 60m of hose needs to be managed to avoid hose damage and safety issues.</td>
<td>Fulton Hogan</td>
<td>This tool has been chosen in order to assess the effect of tool with high level of novelty on the technical difficulty of a construction project.</td>
<td>Improved efficiency</td>
<td>This innovation could be easily adapted to other construction projects.</td>
</tr>
<tr>
<td>One meter fence on top of a 12 compliant barrier</td>
<td>Tool</td>
<td>This method that we are employing offers no consideration to worker safety as a 1.8 meter high fence is not designed to absorb an impact and is not assigned a deflection rating. Furthermore it is more susceptible to being blown over in stormy weather as there is no sufficient weight to act as a ballast.</td>
<td>Meadow 0540</td>
<td>This tool has been chosen as a helpful solution that could improve the project safety.</td>
<td>Improved safety</td>
<td>This innovation could be used on any construction project that includes trenching activities.</td>
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<tr>
<td>Mobile Skip</td>
<td>Tool</td>
<td>City Care</td>
<td>Thanks from City Care Sign</td>
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<td><strong>Power connection for shared low pressure wastewater tanks</strong></td>
<td><strong>Product</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
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<td><strong>Bridge St Cathodic Protection</strong></td>
<td><strong>Product</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
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<tr>
<td><strong>Mud recycling for PM128</strong></td>
<td><strong>Product</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
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<tr>
<td><strong>Self-compacting concrete</strong></td>
<td><strong>Product</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
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<tr>
<td><strong>Rock anchor spacers/calibrators</strong></td>
<td><strong>Product</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
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<tr>
<td><strong>Caisson methodology for installing lift stations</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<td><strong>Casings for cofferdams</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<tr>
<td><strong>Screw pile frame for cofferdam pump station construction</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<tr>
<td><strong>Pipe bursting the water main in Buckingham</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<tr>
<td><strong>PVC pipe with push camera</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<tr>
<td><strong>Core-drilling displaced joints in pipes</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<td><strong>Lift Station Installation Sequence Review</strong></td>
<td><strong>Method</strong></td>
<td><strong>Description</strong></td>
<td><strong>Aligning innovation</strong></td>
<td><strong>Main benefit</strong></td>
<td><strong>Target of this innovation</strong></td>
<td><strong>Benefit of this innovation</strong></td>
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<tr>
<td>Locating services using GPS</td>
<td>Method</td>
<td>Time and cost are the main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
<td>This innovation could easily adopted to the infrastructure projects</td>
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<td>Barriers for Bridge Pier Assesmen t</td>
<td>Method</td>
<td>The option chosen involves using Geoid sign barriers TM a system imported from Sweden.</td>
<td>Safety and environment are the main benefits of this innovation</td>
<td>This novel method of trenching could be adopted to any construction project that include trenching.</td>
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<tr>
<td>Trenching method</td>
<td>Method</td>
<td>We made four concrete cuts along the trench before starting then left seal in the middle section there until just before re-sealing. Workers take out a narrow bit of seal for the dewatering and then a wider trench for the pipe works. This minimizes dust and means there is no unsterilized area. It also makes the site look a lot tidier. It saves time and money</td>
<td>Time and cost are main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
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<tr>
<td>Site Specific Environment al Risk Assessment</td>
<td>Method</td>
<td>Each construction site has its own specific issues to deal with. Some are business as usual like sediment control around streets and others are more site specific like archaeology, notable trees or sewer over pumping. To help identify and manage these specific issues McConnell Dowell now uses two tools: an environmental section in the Construction Execution Plan (CEP) and the GIS mapping system combined with a descriptive table to clearly define the environmental issues that a site needs to be aware of.</td>
<td>Time and cost are main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
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<tr>
<td>Pipe bursting</td>
<td>Method</td>
<td>Pipe bursting is a method of replacing buried pipes which reduces the need to dig trenches. While some digging is required, it is substantially less than the traditional trenching method. Pipe bursting is our preferred method because it reduces the risk of hitting underground services (power, water, telecommunications lines etc.), as we are not digging through the footpath where most services are laid.</td>
<td>Time and cost are main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
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<td>Integrated pipe/thrust block detail</td>
<td>Method</td>
<td>We are required to construct a thrust block over beams in our PE pipeline. Because concrete developing strength takes time we propose to precast the thrust blocks incorporating an EF coupler with two sections of PE pipe going through it. This will also have some reinforcing steel in it and lifting eyes to enable moving it around.</td>
<td>Time and cost are main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
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<td>Lightweight Localized Storm water Pump Station</td>
<td>Technical</td>
<td>LightweightLocalized Pump Stations utilizes a new innovative design philosophy which focuses on the use of horizontal axial flow pumps which enables shallow and lightweight structures to be used.</td>
<td>Time and cost are main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
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<tr>
<td>New tank design means one day install not four</td>
<td>Technical</td>
<td>The original design (WW4001) had the entire tank encased in concrete. This meant with all the incoming pipes concrete would need to be poured into the pit in three sections. This would take three days per tank as the concrete would need to cure after each pour. the idea for the new oversized concrete lid and chip as backfill around the tank WW4001. This meant we could dig, install and backfill pits to a safe level in one day rather than the three of four days it was taking.</td>
<td>Time and cost are main aim of this innovation</td>
<td>Environment is the main target of this innovation</td>
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<tr>
<td>Pressure Wastewater Technology</td>
<td>Design</td>
<td>During construction City Care suggested that the last 80m of road had only minor shape correction and therefore there was an opportunity to not use the blanket treatment of 100mm AP40 and stabilization and just resurface with minor works to tie into the existing pavement.</td>
<td>City Care 0340</td>
<td>This innovation has been chosen as a change on the prior design.</td>
<td>Time and cost are the main aim push this innovation</td>
<td>Changing on design is completely depended on the project condition and could be happened on every single project design</td>
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<tr>
<td>Baxley Road Resurfacing</td>
<td>Design</td>
<td>During the full dig out it was also noted that there were areas of high quality base course. Instead of automatically excavating CCL decided to beam test the pavement in these areas to see if full excavation was required. The results showed that certain sections of the pavement were still in good condition and excavation and replacement was not required.</td>
<td>City Care 0310</td>
<td>A change on the design has been chosen in order to assess the effect it has had on the project productivity</td>
<td>Time and cost are the main aim push this innovation</td>
<td>Changing on design is completely depended on the project condition and could be happened on every single project design</td>
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<tr>
<td>Moor house Ave Base Reuse</td>
<td>Design</td>
<td>AP40 removed from a 5year old pavement in Sinclair Street, due to road being higher level than the new design, and then reused in Baker Street to top up a road that was to be cement stabilized.</td>
<td>Fulton Hogan0347</td>
<td>An innovation on reading design has been selected in order to have an in depth understanding of design change and it effect on project productivity</td>
<td>Time and cost are the main aim push this innovation</td>
<td>Changing on design is completely depended on the project condition and could be happened on every single project design</td>
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<tr>
<td>Rationalization of waste water pipe in Hawkesbury Ave</td>
<td>Design</td>
<td>When the drawings for Hawkesbury Avenue were reviewed by the Delivery team they identifyed a section of pipe could be removed if one additional manhole was installed at the position of the first lateral. Saving = 30m of pipe ($21000) Add = ($4500).</td>
<td>Nectchers</td>
<td>A design change has been selected which is resulted of a design review process</td>
<td>Time and cost are the main aim push this innovation</td>
<td>Changing on design is completely depended on the project condition and could be happened on every single project design</td>
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<tr>
<td>Additional lift station on Shirley Road</td>
<td>Design</td>
<td>We have experienced very bad ground conditions in the Shirley Road area and the current design requires very deep gravity lines to be installed with super soft raft foundations, dewatering issues, and huge quantities of under cutting. We have proposed that an additional lift station be designed into the area to lift the gravity line out of this poor ground. The cost of the lift station and shallow pipe versus the cost of the deep trench /super soft foundation heavy dewatering is likely to be lower.</td>
<td>Nectchers</td>
<td>This innovation has been chosen in order to assess the effect of change on the first plan on the productivity.</td>
<td>Time and cost are the main aim push this innovation</td>
<td>Changing on design is completely depended on the project condition and could be happened on every single project design</td>
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<tr>
<td>Lift Station relocation</td>
<td>Design</td>
<td>The original lift station located between Innes Road and Weston Road within the public walkway was relocated at our request. This had the effect of swallowing up a considerable length of gravity main from over 3.35 m deep to around 1.5m deep.</td>
<td>Nectchers</td>
<td>A change of a lift station location has been chosen as an innovation.</td>
<td>Sustainability is the main aim of this innovation</td>
<td>Changing on design is completely depended on the project condition and could be happened on every single project design</td>
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<tr>
<td>Using pea metal &amp; plywood in trenches to reduce slumping along the trench line</td>
<td>Function</td>
<td>The sub-contractor chose to use plywood on the inside of the sheet piles before backfilling and to fill these voids with pea gravel.</td>
<td>Fulton Hogan</td>
<td>This innovation has been selected as new function by project team in order to assess the effect on productivity.</td>
<td>Community has been focused by this innovation as their main target</td>
<td>this innovation could be reused in construction project where a noise pollution is considered as the project issue.</td>
</tr>
<tr>
<td>Protection of dewatering pipes</td>
<td>Function</td>
<td>The system consists of a timber/plywood channel that is laid on the road , the pipe is then placed between the timber formed channel and then this is covered with a layer of compacted stone to form a ramp</td>
<td>Nectchers 0380</td>
<td>This new way of pipe protection has been selected as an innovation in order to assess the effect on sustainability of final outcome</td>
<td>Sustainability is the main aim of this innovation</td>
<td>this innovation could be adopted to the future project which involve tight barrier.</td>
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<tr>
<td>Bridge pile cap overlay utilised in total zone of incrusty</td>
<td>Function</td>
<td>Our chosen option was a system of coating the freshly laid concrete with Pleura 5502F, a fast setting plastic that when applied created a water tight barrier to keep salt water from coming into contact with the concrete overlay.</td>
<td>Fulton Hogan0292</td>
<td>A new way of barrier construction has been chosen from the innovation list in order to have an In depth understanding about the novel functions and their effect on productivity.</td>
<td>Sustainability is the main aim of this innovation</td>
<td>this innovation could be adopted to the future project which involve tight barrier.</td>
</tr>
<tr>
<td>Working around a 50 year old 750 diameter pumping</td>
<td>Function</td>
<td>Downer was required to connect 2 new pumping mains to the existing 750 diameter 50 year old ductile iron cement line manifold. Ductile iron is a very brittle material and requires the manifold to be excavated to a depth of 2 meters clear of the underside of the pipe work. This method used standard concrete formwork beams and adjustable props</td>
<td>Downer</td>
<td>A novel function has been chosen as a common solution for the rebuilding project where the new way of doing is required to answer to unique problems.</td>
<td>Sustainability is the main aim of this innovation</td>
<td>this innovation has been developed for a specific technical difficulty. The adoption to a similar projects condition is possible.</td>
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<tr>
<td>Lifting pressure wastewater chambers</td>
<td>Meadow</td>
<td>A novel way of lifting waste water chambers has been selected as a new function that developed the safety of the project. Safety is the main benefit of this innovation. This innovation could be reused for lifting the wastewater chambers in future project.</td>
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<tr>
<td>Scale Model of Pump Station</td>
<td>Fulton Hogan</td>
<td>This innovation has been selected as new function by project team in order to assess the effect on productivity. Time is the main target of this innovation. This innovation seems very useful for future project.</td>
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<tr>
<td>Leader Board</td>
<td>Fulton Hogan</td>
<td>This novel idea has been chosen in order to assess the effect of a simple change on project productivity. Quality is the main target of this innovation. This innovation has been very useful as the main idea in future project.</td>
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<tr>
<td>Heathcoat Odawa Bridge Jacking and Excel Program</td>
<td>Downer</td>
<td>This innovation has been chosen as new function in order to introduce the big change resulted by that on project. Time is the main target of this innovation. This innovation has been developed for a significant issue so it could be adopted to a similar project.</td>
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<tr>
<td>Utilizing Ship Gangways on Horton Bridge</td>
<td>Fulton Hogan</td>
<td>A simple idea has made a big change on project and this is the main reason of selection. Cost is the main benefit of this innovation. This innovation could be adopted to the project that need access by bridge.</td>
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</table>

In order to make sure that the precast shop drawings for the pump house at Mt. Pleasant 3 are correct, we have built a to scale model of the pump house using the drawings. This system includes a concrete base and threads a lifting strap underneath, through purpose built voids, to allow the lifting tackle free movement during extraction. A spreader bar is used to install the chamber, without putting any pressure on the chamber. A novel way of lifting waste water chambers has been selected as a new function that developed the safety of the project. This innovation could be reused for lifting the wastewater chambers in future project.
# Appendix C: Fulton Hogan Top Innovations

<table>
<thead>
<tr>
<th>Project number</th>
<th>Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>10724</td>
<td><strong>Hose Management system</strong></td>
<td>New 40m deep piles are being constructed to support the new abutments for Bridge St. Bridge. The piles are formed of driven permanent steel casings which will be filled with concrete. A hydraulic clamshell (grab) is used to muck out the casings. At full depth 60m of hose is needed. We found that when the clamshell is taken up out of the casing to discharge the spoil, the 60m of hose needs to be managed to avoid hose damage.</td>
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<tr>
<td>10623</td>
<td><strong>Scissor lift</strong></td>
<td>Civil South faced a large scale task in terms of setting up steelwork and preparation for Pump Main 128. Traditionally, the set up for this work has involved scaffolding. Civil South chose to initiate the use of scissor lifts to provide more flexibility at a lower cost.</td>
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<tr>
<td>11110</td>
<td><strong>Power connection for shared low pressure wastewater tanks</strong></td>
<td>We came across the situation where we had multiple dwellings at an address, like in the case of flats, with simply no room to install separate simplex tanks for each unit/property. A shared tank in common ground was the only option. The connection to power supply with a shared tank is a dilemma. How can we connect the tank to one power supply and how do we then separate the cost per property? The final solution is the first of its kind across SCIRT, a great example of where the delivery team input into IST design process.</td>
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<td>10623</td>
<td>Plastic lining to damaged reservoir roof drain</td>
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<td>We identified a fast, cost effective repair for the broken outfall pipes on Worsley Reservoirs #1 and #2 which will save the reservoirs water supply from being contaminated. Jeremy and his team came up with a method of using Sika combiflex bandage and PVC pipe to line the insides of the roof outlet pipes on the reservoirs, which were broken and leaking water into the tanks’ water supplies.</td>
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<thead>
<tr>
<th>10724</th>
<th>Bridge St Cathodic Protection</th>
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<tbody>
<tr>
<td></td>
<td>Whilst working on the repairs to the piers of Bridge St Bridge, we have installed cathode protection to the piers. The sacrificial anodes will prolong the period before corrosion of the reinforcement occurs, potentially increasing the lifespan of the piers by up to 25 years.</td>
</tr>
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<tr>
<th>10926</th>
<th>Mud recycling for PM128</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>As part of the works to install PM128, a significant quantity of Bentonite drilling mud was required. CDS were engaged as part of these projects and as part of their work package provided a mud recycling system with the ability to re-use the drilling fluid, while removing the sand component.</td>
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<tr>
<th>10724</th>
<th>Self-compacting concrete</th>
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<tr>
<td></td>
<td>Bridge St Bridge required concrete pours under the deck. Space was very limited so the initiative was taken to use self-compacting concrete as access was limited.</td>
</tr>
<tr>
<td>Clifton Reservoir Repair specialist Fibre</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
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</table>
| • We repaired the central column, increasing the ductility, therefore making it more resilient for future seismic activity  
• When repairing the central column we used a specialist Fibre Reinforced Plastic wrapping and protective coatings that are potable water compliant.  
This innovative approach to repair the column of the existing tank removed the need for it to be completely demolished and re-built, saving both time and money. |

<table>
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<tr>
<th>Main Road Causeway: Dewatering within western culvert works</th>
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<tr>
<td>Site crew from FH Drainage crew put together a sediment control system that made the most of the local conditions by utilising a verge area as a temporary detention basin, addition of flocculants to assist with settlement of sediments and the use of the seawall as a dissipaton device. The dewatering was highly successful, and both Environmental Canterbury, CCC, Downers and SCIRT IST having praised the team on their actions. This system has now been replicated on the main culvert (works being undertaken by FH Civil South team) and also on the eastern culvert. Use of flocculants is relatively new to SCIRT, and will only work in certain conditions (where we have reduced flows to aid settlement), however its use here will add value at a programme level.</td>
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<tr>
<th>Owles Terrace - Dealing with the tidal surge through a work site</th>
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<tbody>
<tr>
<td>There was a requirement to install a 90mm PE pipe at 900mm in Owles Terrace. It was noted that for most high tide events, the site would be inundated with the incoming high tide as it entered the site through the stormwater network. Investigations were organised by the Project team to limit the requirement to remove surface waters after each high tide event using a sucker truck. After discussion with the Environmental Advisor it was agreed that as the catchment was relatively small in size and capacity, the network could be blocked to limit tidal inundation of the work site. The sumps within the catchment were blocked using a 225mm and 300mm blow up bung, the outlet valve was blocked using a drain test plug, and a rudimentary bund was created using sand bags and plastic lining to limit and surface flows from adjacent catchments entering the work site.</td>
</tr>
</tbody>
</table>
The initiative was highly successful, and the cost savings associated with the reduced hire rates for the sucker truck was approximately $10,000. Delivery of the 90mm PE pipe was completed within program.

10724

**hydro excavated slit trenches Bridge Street Bridge**

Safety to existing services and personnel - Bridge Street Bridge

1) To avoid damaging existing services at bridge street during jet grout works, we hydro excavated slit trenches to expose the services, installed and backfilled ducts - to accommodate the drill stem. This removed the requirement for large excavations, therefore removed the requirement for anyone to be in an open excavation, also protecting existing services.

11130

**Pipe bursting the water main in Beckenham**

The Fulton Hogan team proceeded with pipe bursting the main rather than digging trenches as per the TOC for many Community benefits.

10793

**pipe thrusting under the railway line on Wrights Road**

a successful solution when thrusting the pipe to the steel casing under the railway line on Wrights Road, where we were dealing with elevated water levels. A false wall was welded to the inside face of the sheet-piled thrusting pit and filled with foam/resin to act as a water stop. This enabled us to continue with the pipe thrusting and avoided any settlement of the railway tracks.
## Revised methodology

1. Eliminating need for long term by-pass pumps and 2 Eliminating need for a temporary syphon and
2. Reducing 6 stage benching process to a 2 stage process through the manhole at the intersection of Frosts & Beach Roads.

The original design required a temporary syphon (at a cost of $60K) to be constructed in the process of commissioning Pump Station 128 to maintain existing wastewater flows until the new pump station became live. Fulton Hogan worked with our sub-contractor Barr’s, and reviewed our proposed methodology and developed an alternative process to save on cost. The 6 stage process for the manhole at the intersection of Frosts and Beach Roads would require by-pass pumps for each stage at a cost of $30K each time, plus the cost of removing the temporary syphon structure, or grouting it. This system existed short term for 2 months only.

## Recycling AP40 on roads to be cement stabilised

AP40 removed from a 5 year old pavement in Sinclair Street, due to road being higher level than the new design, and then reused in Baker Street to top up a road that was to be cement stabilised.

## Open ended drill head

This new methodology could well be replicated across the SCIRT programme where horizontal drilling is required.
<table>
<thead>
<tr>
<th>10793</th>
<th>Using pea metal &amp; plywood in trenches</th>
<th>The sub-contractor chose to use plywood on the inside of the sheet piles before backfilling and to fill these voids with pea gravel.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10724</td>
<td>Bridge polyeuro pilecap overlay</td>
<td>Our chosen option was a system of coating the freshly laid concrete with Polyeuro 5502F, a fast setting plastic that when applied created a water tight barrier to keep salt water from coming into contact with the concrete overlay.</td>
</tr>
<tr>
<td>11223</td>
<td>Scale Model of Pump Station</td>
<td>In order to make sure that the precast shop drawings for the pump house at Mt. Pleasant 3 are correct, we have built a to scale model of the pump house using the drawings.</td>
</tr>
</tbody>
</table>
Appendix D: Interview Transcription

Interview transcription number three

Tell us a little about your role? How do you understand the context of Company?

I am one of the two delivery managers so the two of us manage the five delivery teams I look after the tree of the five Team looks after the other two we look after the operational performance we review them regularly we coordinate the all to make sure the compliance function has worked well and the issues we looked after the time, cost, quality people would say those three together but also safety performance environmental performance interaction with community and stockholders all of those thing is important to us

And you review them through the KPI system or?

Yes so we are review that and the important function of their role is the allocation of work so depending of their performance against those different inceptors on their team is allocated different portions of work and also importantly so obviously there is money tied up so there is highly interest there is also money tied up with our work scale change process which their normal language is variation so the variation is the contract so you want more money to do more work you need to put the work scale changes and we have to approved it so we approved the scope changes

And you have been with Company for?

I have been with SCIRT four and half years

And you have done basically this or you are job is evolved and changed?

Yes I have job two jobs here so my first start was sett the my job was setting up safely quality and environment systems and for the last two and half years I have been the delivery manager.

That is when the delivery started so before were engaged with the design?
No the delivery started before at that first role but that was small and is really being in the last two three years.

We are kind of interested in the how the innovative has come out of Company the question that you may have seen here some of our we looked at Innovation from six different angles Process Culture Structure Resources Knowledge and Control and when you are talk about this things we can refer to a specific project that you have been involved or you can talk in general about the Company if you wish but it any of innovation stake out in your mind? Like it is really innovative work and that you can talk about that?

Yes so the innovation around introduction of new technology particularly in waste water materials and use and the important point al may have so the pressure waste water the vacuum system pipe lining what else? There is number of material sites that the PVC which is really new but these the technology around that.

This the pressure water water example

Yes this is an example so what i would say there is a they stand out to me now because they are new technology that has been used on another parts of the world but first time they are being used in Christchurch and in New Zealand and ..

And the delivery of the benefits was promised?

It is probable too early to say in some respect yes so the pressure waste water vacuum they are all resilience the time will tell on those ones with pipe lining yes they have as far as savings the reasons you don’t have to dig up the waste water network you can line through so it is an interesting technologies. And other trenchless technologies directional drilling top thing that have been.

So what would you say as the driver of these ideas and where they come from?

Took with resilience which was important to start with so our resilience discussion was really important about Company but obviously also the value for money.
So in term of the stakeholders would you say the asset owners came up with the pressure to make sure *this is the solutions that you are going to be resilient or innovative…?*

So initially that was the team and it was the resilience was the team and that was what was driving that they probable focuses on the worth damage there is time we are on budget became more and more important and It was value for the money and the client had everything to say about that so it actually changed from a team driven resilience discussion to a client driven budget discussion.

**So this was cheaper?**

That was happen over the life of these program. And most of the projects that have been come out of innovation this program the innovation that come you said the concept similar?

Yes that is right, like if you would said design pressure waste water vacuum catchments now we probably would used the pressure water water and vacuum because they cost more the capital cost is more but at the time we were designing at the different way and now we would gravity system all line the pipe we would dig the all system all.

**In terms of risk associate with any new idea as you said we don’t know how the system are going to perform in the future who owns the risk? Is the asset owner? Or it is the Company?**

No it is the shared risk but some of the shared risk for the period of the time the risk are shared during the construction hand over and the defects period so there is the once the project out of construction there is a three month period before hand over and there is an twelve month defects liability period through out that period there is a shared risk and after this time is the client risk so the idea once you free of the defaces and in to the operational the client will take the risk.

**And do you think not having that risk on Company for the long time do you that freed up people to kind of trying the new things new ideas or?**

I don’t think I don’t know if there was the, I think it was more responding to the next situation the innovation is really around what Christchurch presented to the post earthquake and that is really
challenging ground conditions so the poor soils and obviously solve the liquefaction of what happened so there was a response to that was that drove the early innovation

So the potential there was to innovative, because there was another way?

And it is funny really because it has not taken along for people to go back to the business as usual and immediately post earthquake we were expecting an eminent another earthquake so it was really expected it is not just something In the future maybe next year maybe in next ten years we have another one-off these earthquake so that was design for that. And that was deriving us.

So now more of the infrastructure is done. Do you think people still go back to do the same old stuff? Because you know there are not building other thing do you guys of problems you solved you don’t really facing but they are very innovative problem anymore putting loads or?

Yes I think so yes that is right the innovation around value for money how can you do it more effetely what technologies can you save money with.

And did you see that across the delivery team? They trying to come up with ideas to be more efficient?

Yes that is right to beat the budget that talk cost that is some amount of money that get to deliver job and they don’t get anymore unless they are getting the work scale changed which is quite difficult and they have to delivered it if they deliver that there is seem to cost apparently they incentivized sharing the savings .

Now you over seen the multiple delivery teams. So you see difference of how they approach new ideas and?

Yes sure.

In what way would you say?

I guess it is just the acceptance of our design or the acceptance of the specification so the design are focused of the specific project so they usually but often the specification will point to the wrong
direction the specification is a collection of roles from sometime in the past which it doesn’t ways I the
value to what we are doing and I said either excepting that or sometime challenging that and the
challenging was hard but here is definitely result the savings

So you see the different process or different structure within everything whether they capture
problems capture solutions?

So yes that is right so different delivery team shove different cultures the contractual ones just accepted
and others would challenged to Point and trying value engineer.

What is main drivers for those? Is it just because of not realize very different game?

So two things are design changes so you in count unexpected design ground conditions so you collect
information before constriction and you identify that the waste water network can’t be lined there the
drugged up that is the design change designer change the methodology and then the client was always
in the new scope so we want the street down as well as those are street or we want something else done

So they come back with the score change and you are nock it back do they find that the innovative
way to do it?

That is an idea not always.

So that kind of my drive to that sort of innovation

Yes that is the idea

Is it many about the budget around the scope changes?

Yes and in time so they get extension of time and dollars to do job

Do you think the teams delivery team are getting enough recourse of enough time and budget to
also be innovative and try things or is that you apply that pressure to make them more?

Yes that have got enough resources i think the challenge here has been as a contractor they go yes Mr.
client we will do what you want and we don’t care if we waste the money we don’t care that is typical
contractor or maybe the done contactor any one saying or we are asking to be smart contractor here

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actually work with the client and the designer that to came up with the best solution and that is not easy because we have got people that have come in and they have just come off with just here they used to do and also there is the best interest to fit enough with the budget as much as possible so they can make their margin so culturally that is he challenge.

And for the allocation of the job as the KPI system so is that what is driving them to innovation?

Yes, correct that is right.

How does that work? They get more work if they score higher?

Yes so we have a monthly score, non cost and cost and cost is fifthly percent of the allocation model and non cost is forty percent and schedule, time is ten percent.

So if they beat the old budget not only they save that money but they also might get that more work?

Correct, yes that is right.

And that was all the way from the beginning or?

Yes, all the way from the beginning.

And do you think that had an impact?

Yes

So is that a model that you recommend other construction alliances to do?

Yes the right time and place not for everything but for the big scale would for the scale works for us given the number of small jobs we have so water view tunnel for example another civil job not bad wouldn’t work because it is really one big job I know this is in north or south part of port all in the civil work but it’s not really a hundreds. we are a hundreds of small job so we can shuffle them around and incentivize people through the allocation of those seven hundred small jobs and I think it is a disaster of relief or an emergency response tool I think the model would be really good to make people to work with other people and also give them an incentive to perform and I will get more work
In terms of capturing knowledge obviously you see across the different teams they do the report and they do value register what they, who owns that after Company is gone?

There is three owner participant three clients on that

And they have all the registered reports and stuff like that?and the delivery teams?

They will take lessons out of this absolutely they have already take a lesson from this

Did you have to do anything special to get them to talk i know that in the design stage every one collaborating but delivery team are working they are come different companies?

We employed coaching so we head the alliance coaching so we had a professional coacher come out and bring people together different functional groups came together and basically facilitate made to get people to talk

And that has become the way of doing things done?

No it is always hard work dealing with different team and people getting them to collaborate work together is always hard but that is .

So you put formal structures like meeting that have and also the reports for everybody could see?

That is right

Do they also have a chance of informal meeting and interacting? Or the delivery just their own jobs and get to see other delivery teams?

More certain people collaborate a lot work together a lot and the project staff les so if you are a project manager and you want the job if you are work next to another delivery team you would work with them that would be expectation would be work with them some of the work were really closely but in general if they are not there is in need to really

What do they have access if they need to?

Yes of the lessons yes absolutely yes.
How would you know if you are solving the face with the problem that somebody else solved?

Yes so that value register is available for all and that comes through what I would say is it is hard work and we all worked very well together but there is also the cooperate pool on those people they don’t really want Company people talking to downer people about something that not want that e next job so it is really hard commercially so ask people to work together from different

So in terms of winning of those next jobs do they actually have to get normal tender process?

Within the SCIRT?

Yes

No

Have you get allocate to them?

We allocate them to work based on the monthly report that we get.

And all of them expect the expertise to?

Yes and no. so we have two teams Company and Company are principal project managers professional project manager they have got number of so if you look at the sites they have got the small number of people employees that work there the other three care Company have launch proportional self employs people so that they try to deliver themselves by them as much as they can. so different odel Company and Mac Company do allot of the structures around the country Company do a lot of by marine work and Company an Company do a lot of reading

So you took those into account?

We took those into account.

So just from the KPI?

That’s right.
In terms of decision making where do you get involved in innovative ideal comes. is that part of your job to kind of approve that or?

Yes so the practice the watering guide so that challenges was around dewatering around the city really high grand water table so increased that in post earthquake. We put that best practice guide together on that basically on real work so essential we set around specifications.

And has that become something that some people say that other people have?

Yes that is right. Councils and this Christchurch city council uses two now.

How was that transition to the client do they were they open to that were they, did they have their own standard that was better yours or?

It is not easy dealing with them always but that particular instance was easy because there was an obvious benefit

So you have asset owner’s representatives that work in the team?

Yes that right we work with them in the building

They are basically expertise or provide approval do they have power to make decision?

Yes they can do both.

That is good that must save a lot of time

That is right

They have always been in front of beginning helping you guys?

Yes that is right.

Would they still they are council employees or Company employees?

Good question. it depend who you talk to.

How much of the part of the team do they feel like because the Company is like a?
I think that would consider themselves both

You came from another?

Company, I am employed by Company.

But you feel like you SCIRT?

Yes absolutely.

That what a problem as well as she de branded or something when guys coming here?

Yes that is right.

How do you feel about the decisions making process? How it encourages or discourages innovation? Whether to take the risk whether to do something whether to? Form you observation?

I think early on there was a lot more freedom and we would certainly feel I will to make an innovating on project bad add the value to the project I think there is lot less opportunity so we have really had the change of culture throughout the program and it comes them to dollars and the end of the day because

Money is spent now or allocates less.

Yes that is right.

The opportunity in more on the efficiency rather that?

Correct, there is not the big new technologies coming out and exciting thing anymore but it is more small.

That what we have done as research to know if there is an effect of the time on the project on the types of the innovation which has been developed on the project and we found it that the first phase of the project there was more opportunistic for innovation bigger innovation you know like what you have done
That is right. Later on less chance for that generation and maybe that's also good thing so maybe you think bad thigh but do you really want a lot of changes towards the end of the program you probably don’t, you want the consistency you want to know people meet budget meet time

**And also there is less time to take the risk or less room for to be**

Yes exactly right, you can actually say that talk the budget we have a risk opponent that is why the budget fixed so at the start when they talks developed is actually a fix budget for risk at it could be between two and eight percent of the value

**It was like the contingency?**

Yes that is the contingency that is right. And that is actually reduce over the time

**Because it was spent or it was?**

No no, of project coming out construction the size of that percentage decreased.

**There is lot more certainty of course?**

Correct.

**In terms of culture we were told that (Company) has had an interestingly designed culture that when people who compare Company culture or on post organizations the says that this was very different like meeting people value for other people time the ability to share and collaborate those things but in compares to Company Company or Company the host comply it is all the culture that is being drive for many years and it is very different to SCIRT culture when you go back to Company do you think you will have that culture difference do you see that?**

Yes think so. We are all in pool sit this we out about the vision. If someone displays values and v=behavior that I and we call them on that

**How did that come out? Was that by HR do something magical about?**

No it was a general manager was very strong man so if you need to take a head of the (Company) Opes you need to be focused on the big for Christchurch. And that was easy as a post disaster program
So it not likes any other climate job? You actually rebuild a major new Zealand capture disaster.

That right

What sort of cultural of interesting thing you have seen when you get back to Fletcher? If you go back to Fletcher?

I think that is probable actually have a single vision in making a aliening people to vision make sure that they do the right thing by the if you get vision right you wound make a mistake with other decisions

And really making sure that is everybody from the top to bottom?

Correct was aligned.

Would it be difficult if you go back it has been multiple clients and project probable?

Very difficult yes. but that is Ok that is life we will all dead.

In terms of systems of capturing ideas managing contract and something else anything stand get back the In terms of systems of capturing ideas managing contract and something else anything stand iurt the you get back to continue other actually very nice we are .

Just make it very visible so I don’t know whether you Dave shown you high viz we have got a reporting platform which has everything we need it has got, target, it has got data progress every month

What I was thinking they were very clear they know what they need to do?

Yes that is right so having good systems having sort of IT is really helpful and when we log on every day the high viz system flashes everything for us and we can see so you had a minute I can show you what it looks like.

What I was thinking is that council changed their mind about some design guide or standard?

Yes that what the decreasing budget

How do you that SCIRT dealt with that?
Good, I think we dealt with that well. There is very upset people from team and had redesign a lot of the contractor they were builds a big exciting ten million dollar project and they ended up mid one mid dollar project which as a engineer this exciting but also the delivery team has got less money

The delivery team has got less money out of it too yes.

So was there any sort of issues, did you have to manage this?

Yes at that time we have managing a cash flow people expected cash flow forecasted cash flow so obviously got less so Ok now.

She was saying that they were parole ground then they just said Ok lest get on with the things that shows that the organization resilient if it adjust a new one?

Yes.

..

...

...

...

Let take some for a walk and I will show you.

...

...

...

Roading you might say has the less opportunity for innovation right because you know?

Ask a road engineer but I wouldn’t say so but probably.
So I quickly show you on the system.

What I want to really show you is a visual representation of what we are doing so this is our construction spent over the time this the charismas period what we work drops down here what you can see is big turn over here and reduce the with this design so the innovation has actually been reducing our spend.

The point of the designer actually?

Yes,

But the process innovation is much more than designs one at the end of the project. Maybe because they are costing less.

Yes that of right. So the really visual and you can see eighthly percent though the program based on cost you can see the project that complete to hand over and then what you can do is to have look on each individul project so this all live and I gust this is going to been quite a key to our success I gust I just pick a project so what you can see here so here is the retaining wall fixes road so you can see the different phases so concept design detail design and construction is part of through construction you can see how much is spent off a today so the original talk is bout the same what did I spend is spent about a third of it and I am, it is actually it coming right budget you can see how that money has been spent…so it is actually really great way of displaying everything that we are doing we can see the number of project so we have guile a few so.

And how often do you track on?

Every month, so for me very month everything in construction so there is two hindered projects that we are reviewing and it is expectation so cant go though every project but the project that lost money all something funny what is going on there so you are doing a little bit of investigation.
Is available for everybody to access or just for SCIRT staffs?

It is just for SCIRT.

So it is not an online tool.

No, So there is lot of different information here so I can have a look at...

So with your safety and environmental impact on, how do think obviously role worry about time cost and guilty more how does innovation on safety and cost environment come out?

I think is has been huge innovation in safety and environment and it is just for people working together and I think safety is always really important that was so you here that any meeting people talk about safety first and quality Is a little about the life style getting better innovation around quality but and it is really about documentation and verifying things

But environment I mean if they were trading off of environment for time or cost

We are trying not to we trying to get everything well yes and I think it is a bit of Pelosi really you can have only two or one time cost or quality and environment and safety you actually can’t manage them all the well and that is it is difficult but it is what we are trying to do

One of the ideas we had was if the value register and the way that people reported on innovation obviously you can say safety innovation time innovation and so on but I you do KPI system if you had away of allocating more waiting to lets say safety time or to cost would that happen out into types of behavior

Yes absolutely and we used to that way we change the waiting as we so we didn’t get the lot of safety innovation start with we actuality made a bigger thing

Did that kind of help to shape the type of initiatives that is there any more we talk about to Sherry in Fulton Hogan she was saying the KPI system for them was mainly a way the incentive to capture and report but in reality when we faced with the problem we had to solve the problem so the instant we should go in find this the innovation we are just need to capture the things we are
doing because we were faced with problems so it would be interesting to see how the KPI could have influence the more towards the specific type of innovation

This right

Because they are as the power you can as a project delivery manager to make sure that the adjust and people through.

And that is come back to what I was saying about we were right to share this things

Have you ever experienced any failure of innovation which has been developed through project?

Yes absolutely.

What did you do as?

That was the bigger learning. So pipe lining. A new technology came across the project pretty new for the new Zealand not all the pipe lining has done water view on Auckland has done but not much and when we first started to do it in Christchurch as wet environment because it is fully emerged pipes cold it is cold here and you are looking to have at here is of I mean a sort of the pipe there were failure they were blocked in lines and it caused also the problem so it was just it was ground working out the optimum temperatures they were warming pipes and the perfected that now.

So there was no any consequence for the people who developed the innovation? The people who came up with the idea of pipe lining did they get on with trouble?

Not only if they didn’t learn. So if they didn’t learn yes absolutely,

So they were allowed to take risk?

Yes this is right correct. So they were two business that went out of a business for example and that a pretty big consequence but I would say that those company didn’t that is another step.

Thank you very much for your time.
Appendix E: Learning from Innovation
Learning from Innovation
Appendix F: The SCIRT Innovation Project
The SCIRT Innovation Project

Suzanne Wilkinson, Mehdi Shahbazpour, Robert Finch and Mohammadali Noktehdan

Project LR0453

The University of Canterbury Quake Centre with the University of Auckland, funded by the Building Research Levy
The SCIRT Innovation Project

Project Team

Professor Suzanne Wilkinson, University of Auckland
Dr. Mehdi Shahbazpour, University of Auckland.
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Project duration: 21 months
Project commencement date: July 2014
Project completion date: March 2016
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We would like to acknowledge the funding provided by The Building Research Levy through BRANZ for this project. We would also like to acknowledge the in-kind support from SCIRT, and in particular Rod Cameron. SCIRT support included approved access to SCIRT databases, access to SCIRT data and access to SCIRT staff, and assistance with organising interviews and data collection. Rod Cameron, Value Manager at SCIRT, and David Bain, Utilities Coordinator at SCIRT, committed time to this project, and provided valuable advice and direction throughout the project.
Abstract

Improving innovation in the construction industry has been a continued area of interest for practitioners in the construction industry. However, current understanding of innovation in the construction industry lacks depth. As a result although many organisations know that they should be innovating, they do not have the understanding, and the appropriate tools and methods, to develop and implement processes and structures to foster a culture of innovation in their firms and the wider construction industry. The SCIRT Innovation Project shows how an innovation process was initiated and managed throughout the rebuilding of the horizontal infrastructure after the Canterbury earthquakes. SCIRT placed innovation at the core of its business with innovation measures as one of its key performance indicators. This project shows the innovations produced, the processes used to foster innovation and identifies the key innovations which have the potential for a transformative impact on the building industry.
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Section 1 Introduction

1.1 Background

Improving innovation in the construction industry has been a continued area of interest for practitioners in the construction industry. However, current understanding of innovation in the construction industry lacks depth. As a result, although many organisations know that they should be innovating, they do not have the understanding and the appropriate tools and methods to develop and implement processes and structures to foster a culture of innovation in their firms and beyond. The SCIRT Innovation Project aims to examine innovations being produced by SCIRT and assess whether selected innovations produced by SCIRT are suitable for wider New Zealand construction industry adoption. The Canterbury earthquakes resulted in substantial damage to housing, commercial buildings and infrastructure. In the recovery phase, the scale and immediacy of the need to restore services and repair and replace infrastructure has resulted in significant changes from business as usual activities. Innovative thinking was embedded into the rebuilding of Christchurch infrastructure through SCIRT. This thinking is one of the key areas of interest for the New Zealand construction industry because it could lead to improved performance, decreased costs and improved quality. SCIRT placed innovation at the core of its business with innovation measures as one of its key performance indicators. Some of the key changes to performance are evident in the ways in which SCIRT has been innovating. SCIRT introduced innovation as a performance driver for the purpose of fostering an on-going culture of improvement.

As innovation is a complex phenomenon, the SCIRT Innovation Project first aimed to understand the KPI process adopted by SCIRT as a driver for innovation generation and business improvement. The multiple-view model of innovation, developed for the manufacturing industry by Dr. Shahbazpour, from The University of Auckland, and lead researcher for this project, was modified for the construction industry and used to understand how companies innovate, and how innovative ideas travel through companies. The multiple-view model of innovation incorporates different organisational capabilities such as innovation processes, decision making structures, culture of collaboration and innovation, as
well as knowledge generation and sharing processes. It also takes in to account innovation aspects such as the direction from which the innovation originated, the drivers for innovation, whether innovations are novel, incremental or systemic and the outcome benefits of the innovations. Understanding the multi-views of innovations assists with the development of tools for improving the likelihood that companies will innovate. Understanding the source and drivers in this level of detail also enables paths to be explored through which these innovations and innovation processes, including those used by SCIRT in rebuilding horizontal infrastructure, can be adapted and translated to vertical infrastructure projects.
1.2 Research Objectives

The main purpose of this research was to understand how the innovations from SCIRT have been developed and to assess the applicability of the innovations for wider adoption in the New Zealand construction industry.

The project team’s key objectives were to:

Categorise the innovations being produced by SCIRT (e.g. process, product, organisational).

Assess the impacts of these innovations on different KPI’s (e.g. time, cost, quality, H&S, etc.).

Select the top innovations for assessment for use in the wider New Zealand construction industry including in both vertical and horizontal building projects

Provide recommendations on which of the SCIRT innovations are suitable for wider New Zealand construction industry adoption in both vertical and horizontal construction.

1.3 Research Methods

SCIRT is an organisation established under an alliance agreement and is responsible for rebuilding horizontal infrastructure in Christchurch following the earthquakes of 2010 and 2011. Innovation was given a special consideration from the outset, when the SCIRT alliance was formed. In fact, members of the alliance were encouraged to innovate and report on their innovations on a monthly basis as one of their KPIs. These KPIs were linked directly to the pay/reward aspect of the contract. As a result, the alliance members had ample motivation to report their innovations. More than 500 innovations have been reported by SCIRT. This has provided a unique opportunity to analyse and better understand the relationship between construction innovation and productivity improvements.
The research methods consisted of the following two main stages:

Innovation Classification

The researchers were given full access to SCIRT’s innovation database. The researchers worked through each innovation classifying each into a type and impact classification system developed specifically for this project. The database reported each innovation contained a unique identification number, description of the innovative idea, its potential benefits and information regarding which member organisation had initiated or conceived the innovation. Some of the reported innovations were also accompanied by pictures or sketches to better describe the innovation.

Innovation Assessment

In collaboration with SCIRT team members, a long list of innovations was selected on the basis of those which would have the likelihood of maximum impact for the industry. A series of interviews and a focus group was conducted to further validate the selected list of innovations.
1.4 Layout of the report

This Section introduces the project, provides some international background to innovation in the construction industry and outlines the research objectives, methods and layout of the report.

Section 2 includes the literature on innovation, SCIRT and the classification system used for analysis.

Section 3 sets out the results of the study including the categorisation of the 500+ technology based innovations developed by SCIRT under different impact dimensions.

Section 4 shows the key innovations and analysis of these innovations, including those from two of the partner SCIRT organisations.

Section 5 provides the conclusions and recommendations
Section 2  Innovation Classification System

2. Introduction

This section provides a summary of the current literature on innovation in the construction industry, a description of SCIRT and their innovation KPI, and an outline of the classification system used to analyse the SCIRT database.

2.1  Innovation in the construction industry – a brief review

The construction industry is seen internationally as a traditional or low-technology sector with low levels of expenditure on activities associated with innovation. Reichstein et al.'s (2005) comprehensive survey of UK construction firms indicates that many construction firms do not have the motivation to innovate in order to remain competitive. They are able to sustain themselves by meeting local needs of their undemanding customers. As the scale and complexities of construction projects increase, so does the consequences of failure with regards to public safety and loss of investment. This increases the tendency of the client as well as the companies involved in the project delivery to continue with the previously tried and tested methods and designs, thus resulting in low levels of innovation (Tawiah and Russell, 2008).

In the absence of strong market forces driving innovation in the construction industry, the role of the client or project owner becomes critical for creating the motivation to introduce or develop innovative solutions throughout the various phases of the construction project. In order to entice construction companies to be more innovative, some clients (specially local or national governments) have started to incentivise firms by incorporating innovation related performance indicators as part of the construction contract. Numerous studies have shown that clients can use their purchasing power to demand innovation (Widen et al., 2008; Egbu, 2008, Ozorhon, 2013).

However, in a recent study of the Australian construction industry Loosemore and Richard (2015) observed that most construction clients are not interested in innovation. Instead they seem to be driven
mainly by price. The researchers conclude that for clients to be engaged more with innovation, they need to have a better understanding of what innovation is and how it can benefit them.

Review of literature indicates that there is a lack of systematic definition of what innovation means in the construction industry. Innovation is basically understood in abstract terms and very little attention is paid to the various types and categories of innovation. Consequently, innovation in construction is not managed well.

2.2 Description of SCIRT

The repair and reconstruction of infrastructure in the Canterbury region was one of the largest and most complex civil engineering projects in New Zealand’s history (Christchurch City Council, 2011). It was estimated that a large number of resources over a period of more than five years were needed to cope with infrastructure repair and rebuild demands (CERA, 2012). The policy response to the task of horizontal infrastructure reconstruction was the creation of the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), with a mandate until the end of 2016. SCIRT adopted an alliance-like project management model to deliver the recovery of horizontal infrastructure projects.

Alliancing is a project delivery model, which is often used by governments to procure significant infrastructure. A key value proposition of alliance contracting is that government entities reduce their traditional contractual rights (under a ‘risk transfer’ contract) in exchange for Non-Owner Participants (NOPs) bringing to the project their good faith, acting with the highest level of integrity and making decisions which are best-for-project (Australian Government Department of Infrastructure and Transport, 2011). Following the February 2011 earthquake, the New Zealand government recognized the need for a different approach to deliver the horizontal infrastructure reconstruction. The Government sought guidance from the New Zealand Transport Agency (NZTA) on an appropriate response to restoring the earthquake damaged infrastructure. Experienced in alliancing-based project delivery, NZTA supported the alliance approach, believing that it would enable optimal delivery with the speed required post-earthquake, in comparison with other possible models (Auditor, 2013).
The SCIRT alliance was therefore set up in September 2011, and made up of eight partner organizations, consisting of three owner participants and five non-owner participants. The three owner participants are the Christchurch City Council (CCC), CERA, and NZTA, each of which plays a different role: CCC and NZTA are the asset owners and funders while CERA is the Crown funder and is mandated to coordinate the overall rebuild activity on behalf of the central government. Five private construction companies were chosen as non-owner participants within the alliance. They are City Care, Downer Construction, Fletcher Construction, Fulton Hogan and McConnell Dowell. As illustrated in Figure 6, there was an Alliance Leadership Team (ALT) for governance, under which an Alliance Management Team (AMT) was set up to manage the operations undertaken by an Integrated Alliance Team (IAT). The IAT acted in a project facilitator’s role to deliver the planning, design and management functions to enable the delivery teams to do the work. The delivery teams consisted of five main contractors described above. Together with their subcontractors and suppliers, the delivery teams are responsible for undertaking the repair and reconstruction works on the ground. The alliance model was built via a ‘gain-share, pain-share’ mechanism among five main contracting teams. Under this mechanism, the client and contractor can work together to assess in advance the most likely cost of the works and agree on a method for sharing any cost overruns or cost savings. The ‘gain-share, pain share’ mechanism gives an incentive to the contractor to identify efficiencies and make savings (Le Masurier, 2014). Construction work for each team was allocated based on their performance. Integrating professional and construction services into the alliance model meant that SCIRT could serve as a ‘one-stop shop’, offering flexibility in the way the infrastructure rebuild stakeholders were coordinated.
2.3 SCIRT Innovation KPI

SCIRT adopted an ‘Innovation’ KPI to capture new and unique opportunities to improve performance without increasing the cost, or to achieve the same performance level but with less cost. By focussing the project team to think of new ways to deliver a better service, and incentivising that process, SCIRT was able to realise a significant number of innovations being recorded each month. SCIRT defines innovation as a feature of system, operation or built work that gives better performance at the same cost or same performance at less cost, but this can be subjective. The Innovation KPI required significant effort to validate the performance output, as many innovations can be subjective. Innovations were only recognised as being ‘innovations’ once they had been captured on what is called a Value Register and approved by a committee of impartial senior Alliance members. Overall, over 500 innovations were reported through the SCIRT innovations KPI process. The KPI was considered amongst the wider performance measures being used at SCIRT and was used as a mechanism to improve performance.

SCIRT points out in the KPI measure that only innovations created and used will be measured as successful innovations. SCIRT suggest 1-3 innovations a month is considered to be on target, 4-6 innovations a month meets the stretch target, and 7 or more innovations a month is considered outstanding. SCIRT observed significant performance improvements in the innovation KPI overall and in the innovations produced throughout the rebuild. One shortcoming of the SCIRT innovation KPI is that the performance indicators used to incentivise innovation are mainly one dimensional and simply count the number of innovative ideas that SCIRT companies introduced. As a result of this and to better
understand the innovation impact, a classifications system was developed within this project to analyse the SCIRT database.

2.4 The innovation classification system developed for the SCIRT project

An innovation classification system was developed to assess the innovations being produced. The innovation classification system was further developed around three key dimensions of innovation type, novelty and benefits.

**Innovation Type**

Table 1 below shows the classification model used for innovation types.

<table>
<thead>
<tr>
<th>Innovation Types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td>New design that is coupled with a new material or product.</td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td>New construction materials and products developed in the project.</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td>Innovative plans, designs, sketches or concepts for the final building.</td>
</tr>
<tr>
<td><strong>Method</strong></td>
<td>Combination of the Tool and Function innovation that involve both a new tool and new tasks.</td>
</tr>
<tr>
<td><strong>Tool</strong></td>
<td>Novel construction machinery equipment or tools in the construction project.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>New tasks developed or introduced in the construction project.</td>
</tr>
</tbody>
</table>

The researchers found it necessary to distinguish between development or utilisation of innovative construction materials or componentry and the development of innovative designs and features for
buildings or infrastructure. Therefore, the product innovation category was limited to cover new materials or products used in the construction phase, and a new category was added, called Design, to account for the innovative design features introduced at the design phase of the project. Furthermore, guided by the construction technology classification system developed by Tatum (1988), the “process innovation” category was divided into two sub-categories of Tools and Function.

After further consultation with industry experts two other categories were added where a combination of the previous sub-categories could exist (see Table 1):

**Innovation Novelty**

Typically the innovation literature distinguishes between incremental and radical innovations. However, Slaughter (1998) provides a more detailed categorisation of novelty within the construction innovation context. These categories are Incremental, Modular, Architectural, System and Critical. Definitions, as defined in Table 2.

<table>
<thead>
<tr>
<th>Novelty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incremental</td>
<td>small change, based upon current knowledge and experience. It is often the result of continuous improvement initiatives and on-the-job problem solving.</td>
</tr>
<tr>
<td>Modular</td>
<td>significant level of novelty in one area of a system, but without impacting the other components of the system. Modular innovations may be developed within an organization and implemented without much negotiation with parties involved in the development or selection of other components.</td>
</tr>
<tr>
<td>Architectural</td>
<td>small change within a component of a system, which results in major changes in the links to other components and systems. The distinction between modular and</td>
</tr>
</tbody>
</table>
architectural innovations is made on the region of the change and, specifically, the degree of interaction with other components of the system.

System integration of multiple independent innovations that must work together to perform new functions or improve the facility performance as a whole.

Critical breakthrough in science or technology that often changes the character and nature of an industry. While incremental innovations occur constantly, critical innovations are rare and unpredictable in their appearance and in their impacts.

Innovation Benefit

This dimension of the classification system deals with the type of performance improvement that is achieved through implementation of the innovative ideas. As mentioned previously SCIRT assessed their innovations based on the value they provided. Combining the KPIs tracked by SCIRT and the innovation benefits identified in the construction literature the following performance indicators were used to distinguish between the types of benefits that are delivered by the given innovations (Table 3).

Table 3. Construction Innovation Benefit Categories

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Direct cost savings or better utilisation of resources</td>
</tr>
<tr>
<td>Time</td>
<td>Reduction in lead-times or increasing speed for the project or sub-tasks</td>
</tr>
<tr>
<td>Quality</td>
<td>Improvements in degree of conformance with specifications and/or satisfaction of stakeholders with the outputs of the construction project.</td>
</tr>
<tr>
<td>Safety</td>
<td>Improving safety, health and wellbeing of the employees and public during and after the construction project.</td>
</tr>
<tr>
<td>Environment</td>
<td>Reducing adverse impact of the construction processes as well as the final building or infrastructure on the natural environment.</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Community</td>
<td>Reducing adverse impact on communities affected by the construction project and improving communication with the stakeholders.</td>
</tr>
</tbody>
</table>

### Section 3  Results of the Study

#### 3.1 Categorisation of the innovations developed by SCIRT

Figures 1–3 represent the spread of innovation categories in each dimension of the classification system: type, novelty and benefit. Most innovations in the SCIRT database seem to be made up of tools or functions in terms of innovation type, and modular or architectural in terms of novelty. They also appear to deliver a wide spread of performance benefits, mainly dominated by quality, time and cost.

![Innovation classification based on Type.](image)

Figure 1. Innovation classification based on Type.
The data was also analysed to identify emerging trends that would provide more insight into the relationship between the three dimensions of the innovation classification system. When looking at the spread of innovation based on a pair of two dimensions of benefit and novelty, an interesting trend emerged. As illustrated in Figure 4, it appears that architectural and modular categories of innovation are more focused on delivering a single benefit. On the other hand, system category of innovation seems to be the one that mostly delivers a combination of quality, time and cost benefits (see Figure 5). Modular innovation also appears to be the most prevalent category which focused on the indirect productivity improvements through safety, environment and community (see Figure 6).
Figure 4. Innovation novelty categories that focused on delivering a single benefit.

Figure 5. Innovation novelty categories that delivered a combination of quality-time-cost benefit.

Figure 6. Innovation novelty categories that focused on either sustainability, safety or community.

When looking at the pair of innovation types and benefits similar trends appear. As illustrated in Figure 7, the majority of innovations are delivering a combination of direct productivity improvement benefits.
such as quality, time and cost, were from the two categories of design and method. On the other hand, function and tool categories seem to be more focused on delivering a single benefit (see Figure 8). Tools also appear to be the most prevalent type of innovation that deliver either safety, environment or community benefits (see Figure 9).

Analysis of the pair of type and novelty also reveals some interesting trends. As illustrated in Figure 10, design innovation was dominated by architectural level of novelty, while product innovation was split between modular and architectural. Technology innovation (design + product) on the other hand was mainly dominated by system level of novelty. Modular and architectural innovations made up the majority of the tools and functions, while those innovations classified as method were mainly system or architectural innovations. Figure 11 also illustrates that the system level of novelty was mainly prevalent in methods, while modular innovations were mostly found under the tool and function categories. Architectural innovations were spread amongst tools, designs, functions and methods. Also, it was found that most incremental innovations were under the tools category.

Figure 7. Innovation types that delivered a combination of quality-time-cost benefit.
Figure 8. Innovation types that focused on delivering a single benefit.

Figure 9. Innovation types that focused on either sustainability, safety or community.
Analysing the innovations over time also provided interesting insights. For this, the SCIRT project was divided into three phases of Preliminary, Design and Construction, and the spread of innovation types over these phases were analysed (see Table 4).

Table 4. Spread of innovation types over project phases

<table>
<thead>
<tr>
<th>Innovation types</th>
<th>Preliminary</th>
<th>Design</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>7%</td>
<td>82%</td>
<td>11%</td>
</tr>
<tr>
<td>Function</td>
<td>4%</td>
<td>4%</td>
<td>92%</td>
</tr>
<tr>
<td>Method</td>
<td>8%</td>
<td>80%</td>
<td>12%</td>
</tr>
<tr>
<td>Product</td>
<td>10%</td>
<td>80%</td>
<td>10%</td>
</tr>
<tr>
<td>Technology</td>
<td>68%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>Tool</td>
<td>3%</td>
<td>10%</td>
<td>87%</td>
</tr>
<tr>
<td>Overall</td>
<td>9%</td>
<td>42%</td>
<td>49%</td>
</tr>
</tbody>
</table>
This analysis reveals a number of notable insights. Firstly, majority of the Technology type of innovation were initiated in the preliminary phase of the project, when special attention is paid by the project clients and stakeholders to the final outcome of project in order to address the need of future users. The design phase also resulted in the maximum proportion of three types of Product, Design and Method innovations. The availability of knowledgeable engineers and designers provided the best opportunity for novel use of materials and designs to be developed in this phase. Also, importantly this phase of project provided an opportunity for the contractors to share their experiences with the engineers in order to develop novel methods before the construction phase of the project. It is likely that such Early Contractor Involvement (ECI) could have resulted in the majority of Method innovations to be initiated in this phase. Finally, the last phase of SCIRT project (construction), gave rise to the majority of Tool and Function innovation with 87% and 92% respectively. The low level of novelty observed in the previous analysis to be associated with the Tool and Function innovations is typical of incremental innovations that take place during the final stages of a project, where there are tighter levels of control and the focus is on completion thus less tendencies to make big changes or take risks.

Section 4  Key innovations

In collaboration with SCIRT 50 innovations were chosen on the basis of the innovations which would most likely have the maximum impact on the construction industry. The 50 chosen innovations are provided in Appendix 1. A set of examples of SCIRT innovations for each of the six different innovation types are presented in Table 5.

Table 5. Construction Innovation Types

<table>
<thead>
<tr>
<th>Innovation Types</th>
<th>Example SCIRT Innovations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product</strong></td>
<td>&quot;Lightweight Localized Storm water Pump Station &quot;: Lightweight Localized Pump Stations</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>utilizes a new innovative design philosophy which focuses on the use of horizontal axial flow pumps which enables shallow and lightweight structures to be used.</td>
</tr>
</tbody>
</table>
“Bridge St Cathodic Protection”: Whilst working on the repairs to the piers of Bridge St Bridge, we have installed cathode protection to the piers. The sacrificial anodes will prolong the period before corrosion of the reinforcement occurs, potentially increasing the lifespan of the piers by up to 25 years.

"Rationalization of waste water pipe in Hawkesbury Ave": When the drawings for Hawkesbury Avenue were reviewed by the Delivery team they identified that a section of pipe could be removed if one additional manhole was installed at the position of the first lateral.

“Pipe bursting the water main in Buckingham”: The Fulton Hogan team proceeded with pipe bursting the main rather than digging trenches as per the TOC for many Community benefits.

“CSS Workshop”: These workshops were a great way to communicate the updates to the team at once, also discussed was the best way to communicate the changes to our subcontractors.

“Hydraulic Aluminum Shoring”: Aluminum hydraulic shores and shields are an excellent lightweight resource for working around existing utilities, supporting trench walls near structures, curbs, or sidewalks.

In addition to the top 50 selected innovations, there was an opportunity to further examine in detail the top innovations produced by two of the SCIRT partners – Fulton Hogan and CityCare. The innovations with potential to have industry wide impact were selected and discussions with SCIRT staff produced two further lists – top Fulton Hogan innovations and top CityCare innovations. Interviews conducted with staff at SCIRT were used to determine what innovations could have the most impact.

The following interviews and focus group took place to select the innovations suitable for future construction industry use. The list of innovations selected from Fulton Hogan and CityCare teams are presented in Appendices 2 and 3.

<table>
<thead>
<tr>
<th>Interview with</th>
<th>date</th>
<th>company</th>
<th>Intent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilities Manager</td>
<td>20 May 2015</td>
<td>SCIRT</td>
<td>Discussion on process for innovations</td>
</tr>
<tr>
<td>Value Manager</td>
<td>3 June 2015</td>
<td>SCIRT</td>
<td>How the innovation process is working and future use</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td>-------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>Focus group- 5 SCIRT employees involved in SCIRT innovation process</td>
<td>17 June 2015</td>
<td>SCIRT</td>
<td>Focus discussion on SCIRT innovation process and choice of top innovations</td>
</tr>
<tr>
<td>Interview-project manager</td>
<td>9 Feb 2016</td>
<td>SCIRT</td>
<td>Refining innovations choice</td>
</tr>
<tr>
<td>Interview-project manager</td>
<td>9 Feb 2016</td>
<td>SCIRT</td>
<td>Refining innovations choice</td>
</tr>
<tr>
<td>Interview-project manager</td>
<td>9 Feb 2016</td>
<td>Fulton Hogan</td>
<td>Refining innovations choice</td>
</tr>
<tr>
<td>Interview-project manager</td>
<td>9 Feb 2016</td>
<td>SCIRT</td>
<td>Refining innovations choice</td>
</tr>
</tbody>
</table>
Section 5  Conclusions and Recommendations

Although a unique situation created the SCIRT innovation KPI, there is a likelihood that similar innovation mechanisms could be used in other projects and organisations. It is clear that what SCIRT aimed to do was to improve performance whilst trying to decreased costs and improved quality. The development of the innovation classification system to illuminate the types and benefits of the innovations provided useful insights to the SCIRT process. The results of the analysis of the reported innovations by SCIRT, clearly demonstrate the diversity of types, degree of novelty and performance improvement benefits among construction innovations. The trends presented in this section have all emerged naturally based on the organisational dynamics and culture present among the member organisations as well as within the virtual alliance organisation. Given that innovation KPI reporting was linked to pay/reward system for the member organisations, there was motivation for all parties to look for opportunities to innovate. However, the data shows that most of the reported innovations were tools or functions that were developed to overcome immediate problems facing the operational teams. As a result, most of these innovations were modular or architectural in terms of novelty. This indicates that most reported innovative solutions were developed to either solve localised problems or issues arising at the interface of operational sub-systems. The data also shows that when architectural and modular innovations were dominant, the reported innovations were mainly focused on a single aspect of performance improvement. In contrast, the results show that when more sophisticated types of innovation such as technology and methods were developed, the impact was more widespread and significant, delivering benefits along multiple dimensions of performance such quality, time and cost. Majority of these types of innovations were initiated in the preliminary and design phases of the project, where there was more stakeholder engagement and more willingness to take risks.

A practical innovation tool for industry is needed, which can be used with different innovation types and with different sectors of the industry. A clear relationship was found between the type of innovation and the different phases of SCIRT projects. Patterns of innovations through different phases of the
project life cycles show that there are opportunities to focus on different types of innovations at different stages. This could lead to development of phase-specific KPI systems.

The top 50 innovations chosen after the analysis have the potential to impact the wider industry producing better products, tools and processes resulting in greater productivity overall. How to fully exploit the potential from the selected innovations needs further consideration.

Recommendations

The main recommendations are:

Consider the introduction of a more sophisticated innovations KPI tailored to various phases of the project which is easy to use, not data intensive but could have wide ranging benefits.

Use the classification mechanism outlined in this research to develop a mechanism to easily capture and report innovation benefits industry wide, especially those innovations which have the potential to improve industry productivity.

Pilot the introduction of a selection of the top 50 innovations initially through an innovations workshop and feedback session

Highlight the benefits of innovation as a way of encouraging innovation uptake and use.
References


Appendices
Appendix 1 – 50 innovations

Appendix 2 – Fulton Hogan Innovations

Appendix 3 – CityCare Innovations

**Appendix 1**

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Innovation description</th>
<th>Company</th>
<th>Reason of selection</th>
<th>Innovation benefits</th>
<th>Opportunity for wider adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated</td>
<td>It is important to record these checks, as 3rd parties (ECan, CCC) may request proof that setups are being monitored closely.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One meter fence on top</td>
<td>Engineers are often too busy to remember all the expiry dates of their traffic management plans, dig permits etc. To help overcome this we have created a system through Smart Sheet that automatically sends the engineer and the Traffic Co-coordinator an alert.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic Aluminum</td>
<td>New 40m deep piles are being constructed to support the new abutments for Bridge St. Bridge. The piles are formed of driven permanent steel casings which will be filled with concrete. A hydraulic clamshell (grab) is used to muck out the casings. At full depth this method that we are employing offers no consideration to worker safety as a 1.8 meter high fence is not designed to absorb an impact and is not assigned a deflection rating. Furthermore it is more susceptible to being blown over in stormy weather.</td>
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<tr>
<td>True line Civil</td>
<td>Single line Civil have developed a system that allows the trench shield to sit above the bottom of the trench which allows compaction of bedding against virgin ground and prevents hunching slumping.</td>
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<tr>
<td>Worthington</td>
<td>Worthington has come up with yet another modification to their trench shield. They have fabricated a bracket which allows the trench shield to be lifted off the bottom of the trench.</td>
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<tr>
<td>Civil South</td>
<td>Civil South faced a large scale task in terms of setting up steelwork and preparation for Pump Main 128. Traditionally, the set up for this work has involved scaffolding. Civil South chose to initiate the use of scissor lifts to provide more flexibility at a lower cost.</td>
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<tr>
<td><strong>Power</strong></td>
<td>The new specifications around mesh fencing require much smaller mesh sizes. The result of this is that the lacing wire is impossible to install and requires individual ties for the mesh to the steel bars. This individual tie off leaves a sharp end where the twist is cut off.</td>
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<tr>
<td><strong>Bridge St</strong></td>
<td>The proposed design for the connection between the two lengths of ground anchor on Maflas wall was to use heat shrink covers. It was pointed out that this would not meet the triple protection levels required in the specification. Therefore CCL came up with the idea of using the drilling fluid, while displaced.</td>
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<tr>
<td><strong>Mud</strong></td>
<td>We came across the situation where we had multiple dwellings at an address, like in the case of flats, with simply no room to install separate simplex tanks for each unit/property. A shared tank in the common ground was the only option. The connection to power supply with a shared tank is a dilemma. How can we connect the</td>
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<tr>
<td><strong>Self-compacting</strong></td>
<td>The proposed design for the connection between the two lengths of ground anchor on Maflas wall was to use heat shrink covers. It was pointed out that this would not meet the triple protection levels required in the specification. Therefore CCL came up with the idea of using the drilling fluid, while displaced.</td>
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<tr>
<td><strong>Rock anchor</strong></td>
<td>We came across the situation where we had multiple dwellings at an address, like in the case of flats, with simply no room to install separate simplex tanks for each unit/property. A shared tank in the common ground was the only option. The connection to power supply with a shared tank is a dilemma. How can we connect the</td>
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<tr>
<td><strong>Caisson</strong></td>
<td>The new specifications around mesh fencing require much smaller mesh sizes. The result of this is that the lacing wire is impossible to install and requires individual ties for the mesh to the steel bars. This individual tie off leaves a sharp end where the twist is cut off.</td>
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<tr>
<td><strong>methodology</strong></td>
<td>As part of the works to install PML238, a significant quantity of Mennonite drilling mud was required. CDS were engaged as part of these projects and as part of their work package provided a mud recycling system with the ability to re-use the drilling fluid, while displacing.</td>
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<tr>
<td><strong>screw pile</strong></td>
<td>When working on the repairs to the piers of Bridge St Bridge, we have installed cathode protection to the piers. The sacrificial anodes will prolong the period before corrosion of the</td>
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<tr>
<td><strong>Frame for</strong></td>
<td>sustainability of the</td>
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<tr>
<td><strong>Pipe bursting</strong></td>
<td>The proposed design for the connection between the two lengths of ground anchor on Maflas wall was to use heat shrink covers. It was pointed out that this would not meet the triple protection levels required in the specification. Therefore CCL came up with the idea of using the drilling fluid, while displaced.</td>
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<tr>
<td><strong>the water</strong></td>
<td>When working on the repairs to the piers of Bridge St Bridge, we have installed cathode protection to the piers. The sacrificial anodes will prolong the period before corrosion of the</td>
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<tr>
<td><strong>PVC pipe with</strong></td>
<td>The proposed design for the connection between the two lengths of ground anchor on Maflas wall was to use heat shrink covers. It was pointed out that this would not meet the triple protection levels required in the specification. Therefore CCL came up with the idea of using the drilling fluid, while displaced.</td>
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<tr>
<td><strong>Core drilling</strong></td>
<td>The proposed design for the connection between the two lengths of ground anchor on Maflas wall was to use heat shrink covers. It was pointed out that this would not meet the triple protection levels required in the specification. Therefore CCL came up with the idea of using the drilling fluid, while displaced.</td>
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</table>

The new specifications around mesh fencing require much smaller mesh sizes. The result of this is that the lacing wire is impossible to install and requires individual ties for the mesh to the steel bars. This individual tie off leaves a sharp end where the twist is cut off. We came across the situation where we had multiple dwellings at an address, like in the case of flats, with simply no room to install separate simplex tanks for each unit/property. A shared tank in the common ground was the only option. The connection to power supply with a shared tank is a dilemma. How can we connect the...
### Lift Station Installation

To reduce the costs associated with dewatering deep excavations, March have constructed the entire lift station at ground level adjacent to the permanent location. When the structure is complete, the new lift station and permanent access will be relocated.

### Locating Services using GPS

**Method:**
- Previously, locating underground services would be carried out, levels taken and the engineer would either draw a sketch or write the dips on the road for the sub-contractors when digging to relocate.
- By using GPS to take the levels, the information is given to our surveyor who then produces a long section and birds eye drawing of the area showing service clashes and locations (see attached).
- These drawings are then given to the sub-contractors on site.
- This saves time and man hours by not having to dig to locate the services. It allows us to see clashes in advance which we can then forward onto the designers. It provides a more accurate level on services. Since this has been implemented, there hasn't been a service strike in 1300m of the main line.

**Novelty:**
- This novel method has been chosen in order to have an in depth view about a new way of locating services.

### Barriers for Bridge Pier Assessment

**Method:**
- The option chosen involves using GeoSign barriers TM a system imported from Sweden.
  - create a contained work area
  - Most and using pontoons control before discharge
  - This solution was much more economical than... imported from other country.

**Shaker:**
- Fulton Hogan (0174)

**Time and cost are the main aim of this innovation**

**This innovation could be easily adopted to the infrastructure projects**

### Trenching Method

**Method:**
- We made four concrete cuts along the trench before starting then left seal in the middle section there until just before re-sealing.
- Workers take out a narrow bit of seal for the dewatering and then a water trench for the pipe works. This minimizes dust and means there is no sterilized area. It also makes the site look a lot tidier.
- It saves time and money

**Fulton Hogan (0174)**

**Safety and environment are the main benefits of this innovation**

**This novel method of trenching could be adapted to any construction project that include trenching.**

### Site Specific Environment Risk Assessment

**Method:**
- Each construction site has its own specific issues to deal with. Some are business as usual like sediment control around streets and others are more site specific like archaeology, notable trees or sewer over pumping. To help identify and manage these specific issues McConnell Dowell now uses two tools: an environmental section in the Construction Execution Plan (CEP) and the GIS mapping system combined with a descriptive table to clearly define the environmental issues that a site needs to be aware of.

**McConnell Dowell (0207)**

**Environment is the main target of this innovation**

**This innovation could be used as a managerial tool in any project where the environmental issues are considered.**

### Pipe Bursting

**Method:**
- Pipe bursting is a method of replacing buried pipes which reduces the need to dig trenches. While some digging is required, it is substantially less than the traditional trenching method.
- Pipe bursting is our preferred method because it reduces the risk of hitting underground services (power, water, telecommunications lines etc.), as we are not digging through the footpath where most services are laid.

**Method:**
- This novel method has been chosen in order to understand the effects that a global innovation would have on project productivity

**Time and cost are the main aim of this innovation**

**This innovation has been used globally and could easily adopted to any piping projects.**

### Integrated Pipe/Thrus Block detail

**Technology:**
- We are required to construct a thrust block over bends in our PE pipeline. Because concrete developing strength takes time we propose to precast the thrust blocks incorporating an EF coupler with two sections of PE pipe going through it. This will also have

**Method:**
- This innovation has been chosen because of the significant project issue it aimed quality is the may target of this innovation

**This innovation has been developed for a significant issue so it could be adopted to a similar project.**
some reinforcing steel in it and lifting eyes to enable moving it around.

**Lightweight Localized Pump Station**

Technologically, Lightweight Localized Pump Stations utilizes a new innovative design philosophy which focuses on the use of horizontal axial flow pumps which enables shallow and lightweight structures to be used.

This innovation has been chosen in order to assess a new technology which was developed locally. Quality is the main target of this innovation. This innovation could be used in future storm water projects.

**New tank design means one day install - not four!**

Lightweight Localized Pump Stations

The original design (WW4001) had the entire tank encased in concrete. This meant with all the incoming pipes concrete would need to be poured into the pit in three sections. This would take three days per tank as the concrete would need to cure after each pour. The idea for the new oversized concrete lid and chip as backfill around the tank WW4011. This meant we could dig, install and backfill pits to a safe level in one day rather than the three out of four days it was taking.

This innovation has been chosen in order to assess a new technology which was developed locally. This innovation could be used in future storm water projects.

**A pressure wastewater system uses a pump to transfer wastewater under pressure from a building to a pressurized wastewater main (pipe) in the street.**

Part of the pressure wastewater system is a pump and tank. This pump and tank can be installed on private property, or the building can be connected to a tank in Council land. The pump and tank sit during construction City Care suggested that the last 80m of road had only minor shape correction and therefore there was an opportunity to not use the blanket treatment of 100mm AP40 and stabilization and just resurface with minor works to tie into the

**Recycling AP40 on roads to be implemented**

AP40 removed from a 5-year old pavement in Sinclair Street, due to the road being higher level than the new design, and then reused in the full dig out it was also noted that there were areas of high quality base course. Instead of automatically excavating CCL decided to beam test the pavement in these areas to see if full excavation was required. The results showed that certain sections of the pavement were still in good condition and excavation and

A change on the design has been selected in order to have an in-depth understanding of design change and its effect on project productivity. Time and cost are the main aim of this innovation. This innovation has a potential for wider adoption on the project that include tank installation.

**Rationalization of waste water pipe in**

When the drawings for Hawkesbury Avenue were reviewed by the Delivery team they identified that a section of pipe could be removed if additional manholes were installed at the position of a change on design has been selected in order to have an in-depth understanding of design change and its effect on project productivity. Time and cost are the main aim of this innovation. This innovation has a potential for wider adoption on the project that include tank installation.

**Some reinforcing steel in it and lifting eyes to enable moving it around.**
| Lifting | The original lift station located between Innes Road and Weston Road within the public walkway was relocated at our request. This had the effect of swallowing up a considerable length of gravity main from over 3.5m deep to around 1.5m deep. | Sustainability is the main aim of this innovation could be adopted to piping project where the pipe should | Data Points: Lift Station Location, Depth Reduction. |
| Protection of Bridge piling pile cap overlay utilized in tidal zone of estuary | The system consists of a timber/plywood channel that is laid on the road, the pipe is then placed between the timber formed channel and then this is covered with a layer of compacted stone to form a protective barrier. | Sustainability is the main target of this innovation could be reused in another similar project. | Data Points: Protection Barrier System. |
| Working | Using pea metal & plywood in trenches to reduce this innovation has been selected as new function by project team in order to assess the effect on sustainability of this innovation could be reused in another similar project. | This innovation has been selected as new function by project team in order to assess the effect on sustainability of this innovation could be reused in another similar project. | Data Points: Materials Used, Depth Reduction. |

**Case Model of Pump Station**

- David Fry Drainage Ltd and Hinds have developed a system to improve the lifting and placing of Eon Simplex wastewater chambers. This system includes a concrete base and threads a lifting strop underneath, through purpose built voids, to allow the lifting tackle free movement during extraction. A spreader bar is used to A novel function has been chosen as a new function by project team in order to assess the effect on sustainability of this innovation could be reused in another similar project. | Data Points: System Description, Methodology. |

**Fulton Hogan EQ Rebuild since August**

- Fulton Hogan EQ Rebuild since August has been conducting and piloting a Leader Board. The Leader Board has been well received by FH staff that can see the value in driving engagements as a way to increase compliance onsite. This information is directly fed back to onsite crew through site engineers and project managers who are Time is the main target of this innovation could be adopted to the project that need access by | Data Points: Leader Board, Staff Engagement. |

**Utilizing Ship Gangways on Horton Bridge**

- Instead of using a scaffold bridge at each end of Horton Bridge our Engineer came up with the good idea of using aluminum ship gangways from Littleton Engineering. A simple idea has made a big change on project and this is the main reason of cost is the main benefit of this innovation could be adopted to | Data Points: Novel Idea, Cost Benefit. |
# Appendix 2 – Fulton Hogan Top Innovations

<table>
<thead>
<tr>
<th>Project number</th>
<th>Title</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>10724</td>
<td>Hose Management system</td>
<td>New 40m deep piles are being constructed to support the new abutments for Bridge St. Bridge. The piles are formed of driven permanent steel casings which will be filled with concrete. A hydraulic clamshell (grab) is used to muck out the casings. At full depth 60m of hose is needed. We found that when the clamshell is taken up out of the casing to discharge the spoil, the 60m of hose needs to be managed to avoid hose damage.</td>
</tr>
<tr>
<td>10623</td>
<td>Scissor lift</td>
<td>Civil South faced a large scale task in terms of setting up steelwork and preparation for Pump Main 128. Traditionally, the set up for this work has involved scaffolding. Civil South chose to initiate the use of scissor lifts to provide more flexibility at a lower cost.</td>
</tr>
<tr>
<td>11110</td>
<td>Power connection for shared low pressure wastewater tanks</td>
<td>We came across the situation where we had multiple dwellings at an address, like in the case of flats, with simply no room to install separate simplex tanks for each unit/property. A shared tank in common ground was the only option. The connection to power supply with a shared tank is a dilemma. How can we connect the tank to one power supply and how do we then separate the cost per property? The final solution is the first of its kind across SCIRT, a great example of where the delivery team input into IST design process.</td>
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<tr>
<td>Task</td>
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<tr>
<td>Plastic lining to damaged reservoir roof drain</td>
<td>We identified a fast, cost effective repair for the broken outfall pipes on Worsleys Reservoirs #1 and #2 which will save the reservoirs water supply from being contaminated. Jeremy and his team came up with a method of using Sika combiflex bandage and PVC pipe to line the insides of the roof outlet pipes on the reservoirs, which were broken and leaking water into the tanks’ water supplies.</td>
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<tr>
<td>Bridge St Cathodic Protection</td>
<td>Whilst working on the repairs to the piers of Bridge St Bridge, we have installed cathode protection to the piers. The sacrificial anodes will prolong the period before corrosion of the reinforcement occurs, potentially increasing the lifespan of the piers by up to 25 years.</td>
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<tr>
<td>Mud recycling for PM128</td>
<td>As part of the works to install PM128, a significant quantity of Bentonite drilling mud was required. CDS were engaged as part of these projects and as part of their work package provided a mud recycling system with the ability to re-use the drilling fluid, while removing the sand component.</td>
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<tr>
<td>Self-compacting concrete</td>
<td>Bridge St Bridge required concrete pours under the deck. Space was very limited so the initiative was taken to use self-compacting concrete as access was limited.</td>
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<tr>
<td>Project</td>
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</table>
| **Clifton Reservoir Repair** | • We repaired the central column, increasing the ductility, therefore making it more resilient for future seismic activity.  
• When repairing the central column we used a specialist Fibre Reinforced Plastic wrapping and protective coatings that are potable water compliant.  
This innovative approach to repair the column of the existing tank removed the need for it to be completely demolished and re-built, saving both time and money. |
| **Main Road Causeway: Dewatering within western culvert works** | Site crew from FH Drainage crew put together a sediment control system that made the most of the local conditions by utilising a verge area as a temporary detention basin, addition of flocculants to assist with settlement of sediments and the use of the seawall as a dissipaton device. The dewatering was highly successful, and both Environmental Canterbury, CCC, Downers and SCIRT IST having praised the team on their actions. This system has now been replicated on the main culvert (works being undertaken by FH Civil South team) and also on the eastern culvert. Use of flocculants is relatively new to SCIRT, and will only work in certain conditions (where we have reduced flows to aid settlement), however its use here will add value at a programme level. |
| **Owles Terrace - Dealing with the tidal surge through a work site** | There was a requirement to install a 90mm PE pipe at 900mm in Owles Terrace. It was noted that for most high tide events, the site would be inundated with the incoming high tide as it entered the site through the stormwater network. Investigations were organised by the Project team to limit the requirement to remove surface waters after each high tide event using a sucker truck. After discussion with the Environmental Advisor it was agreed that as the catchment... |
was relatively small in size and capacity, the network could be blocked to limit tidal inundation of the work site. The sumps within the catchment were blocked using a 225mm and 300mm blow up bung, the outlet valve was blocked using a drain test plug, and a rudimentary bund was created using sand bags and plastic lining to limit and surface flows from adjacent catchments entering the work site. The initiative was highly successful, and the cost savings associated with the reduced hire rates for the sucker truck was approximately $10,000. Delivery of the 90mm PE pipe was completed within program.

<p>| 10724 | hydro excavated slit trenches | Safety to existing services and personnel - Bridge Street Bridge Safety to existing services and personnel - Bridge Street Bridge 1) To avoid damaging existing services at bridge street during jet grout works, we hydro excavated slit trenches to expose the services, installed and backfilled ducts - to accommodate the drill stem. This removed the requirement for large excavations, therefor removed the requirement for anyone to be in an open excavation, also protecting existing services. |
| 11130 | Pipe bursting the water main in Beckenham | The Fulton Hogan team proceeded with pipe bursting the main rather than digging trenches as per the TOC for many Community benefits. |
| 10793 | pipe thrusting under the | a successful solution when thrusting the pipe to the steel casing under the railway line on Wrights Road, where we were dealing with elevated water levels. A false wall was welded to the inside face of the sheet-piled thrusting pit and filled with |</p>
<table>
<thead>
<tr>
<th>railway line on Wrights Road</th>
<th>foam/resin to act as a water stop. This enabled us to continue with the pipe thrusting and avoided any settlement of the railway tracks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revised methodology</td>
<td>1 Eliminating need for long term by-pass pumps and 2 Eliminating need for a temporary syphon and 3 Reducing 6 stage benching process to a 2 stage process through the manhole at the intersection of Frosts &amp; Beach Roads. The original design required a temporary syphon (at a cost of $60K) to be constructed in the process of commissioning Pump Station 128 to maintain existing wastewater flows until the new pump station became live. Fulton Hogan worked with our sub-contractor Barr’s, and reviewed our proposed methodology and developed an alternative process to save on cost. The 6 stage process for the manhole at the intersection of Frosts and Beach Roads would require by-pass pumps for each stage at a cost of $30K each time, plus the cost of removing the temporary syphon structure, or grouting it. This system existed short term for 2 months only.</td>
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<tr>
<td>Recycling AP40 on roads to be cement stabilised</td>
<td>AP40 removed from a 5 year old pavement in Sinclair Street, due to road being higher level than the new design, and then reused in Baker Street to top up a road that was to be cement stabilised.</td>
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<td>Code</td>
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<tr>
<td>10926</td>
<td>Open ended drill head</td>
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<tr>
<td>10793</td>
<td>Using pea metal &amp; plywood in trenches</td>
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<tr>
<td>10724</td>
<td>Bridge poly euro pilecap overlay</td>
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<td>11223</td>
<td>Scale Model of Pump Station</td>
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## Appendix 3- CityCare Top Innovations

<table>
<thead>
<tr>
<th>Project number</th>
<th>Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>10860</td>
<td>Thanks from City Care Sign</td>
<td>City Care have made a ‘Thanks from City Care’ sign that we get the crew to hold and take a photo of on the site where they have been working.</td>
</tr>
<tr>
<td>10937-10947</td>
<td>Plastic trench protection</td>
<td>To overcome issues on the footpath CCL has sourced specific plastic plates to use in pedestrian areas. The benefits of this system are they are easy to install (two person lift), they have a treaded surface to lessen slipping, bright in colour to make people aware of the change in The new specifications around mesh fencing require much smaller mesh sizes. The result of this that the lacing wire is impossible to install and requires individual ties for the mesh to the steel bars. This individual tie off leaves a sharp end where the twist is cut off. Upon The proposed design for the connection between the two lengths of ground anchor on Maffeys wall was to use heat shrink covers. It was pointed out that this would not meet the triple protection levels required in the specification. Therefore CCL came up with the idea to place an oversized sleeve to cover the coupler and also the end of the CCL proposed the use of a ‘poo pit mini manhole’ instead of the concrete manhole structure. The result of this was less excavation on Temporary Drainage</td>
</tr>
<tr>
<td>Bexley Road Resurface</td>
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<tr>
<td>During construction City Care suggested that the last 80m of road had only minor shape correction and therefore there was an opportunity to not use the blanket treatment of 100mm AP40 and stabilisation and</td>
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