SCIRT Rebuilding Infrastructure

LEARNING LEGACY

Lessons learned from one of New Zealand's most challenging civil engineering projects: rebuilding the earthquake damaged pipes, roads, bridges and retaining walls in the city of Christchurch 2011 - 2016.

The SCIRT Innovation Project

Story: Academic Studies – Driving Innovation in the Construction Industry

Theme: Programme Management

A report created by the University of Canterbury Quake Centre and the University of Auckland, funded by the Building Research Levy. It shows how an innovation process was initiated and managed throughout the rebuilding of the horizontal infrastructure after the Canterbury earthquakes.

This document has been provided as an example of a tool that might be useful for other organisations undertaking complex disaster recovery or infrastructure rebuild programmes.

For more information about this document, visit www.scirtlearninglegacy.org.nz

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The SCIRT Innovation Project

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The SCIRT Innovation Project

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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.

Contents

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 (Office of the Auditor-General, 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.

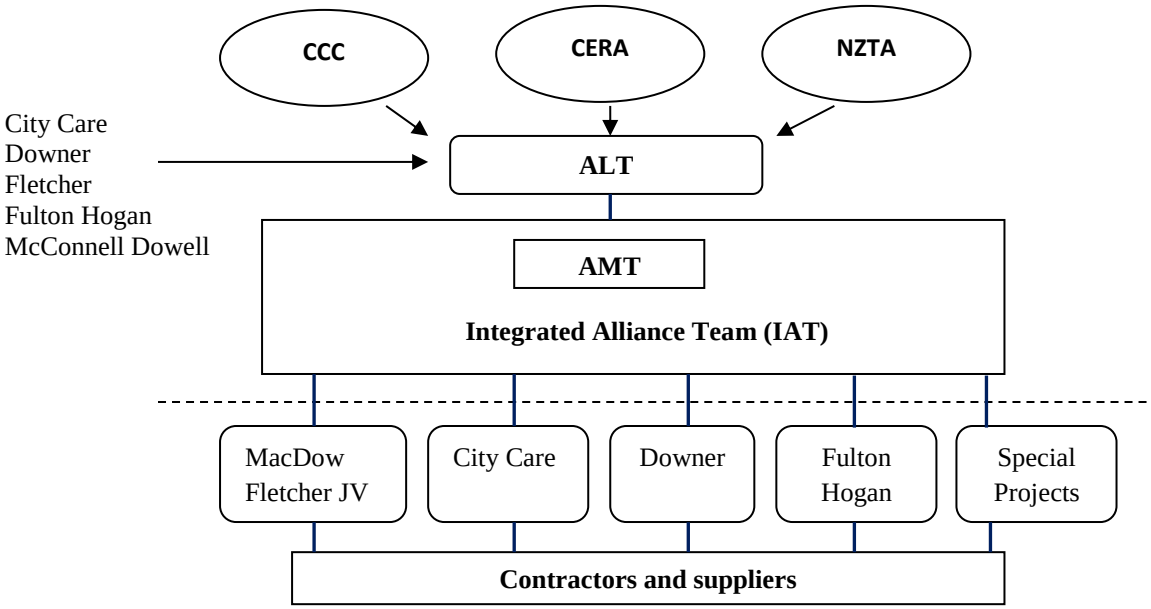

Figure: Alliance structure of the Stronger Christchurch Infrastructure Rebuild Team

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 1. Construction Innovation Types

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

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 2. Construction Innovation Novelty Categories

Novelty Category	Description
Incremental	small change, based upon current knowledge and experience. It is often the result of continuous improvement initiatives and on-the-job problem solving.
Modular	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	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	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

Benefit Category	Description
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.

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.

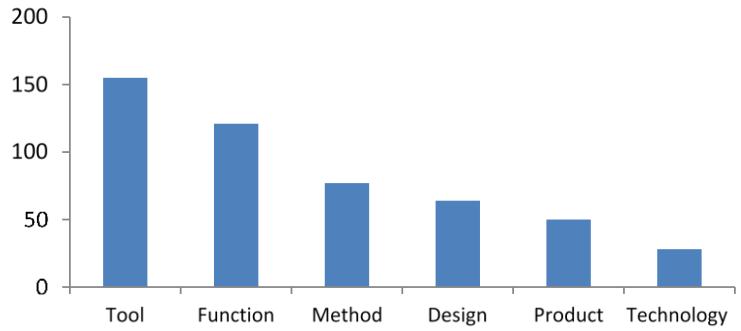

Figure 1. Innovation classification based on Type.

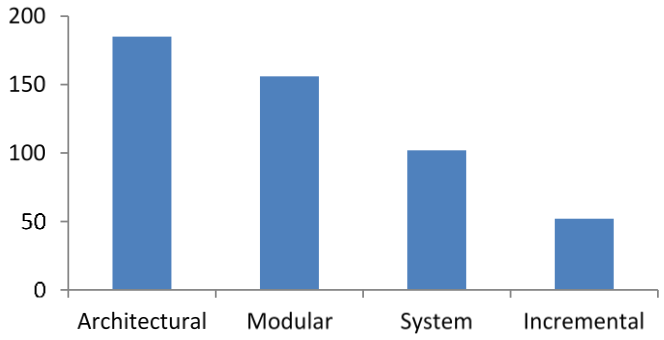

Figure 2. Innovation classification based on Novelty.

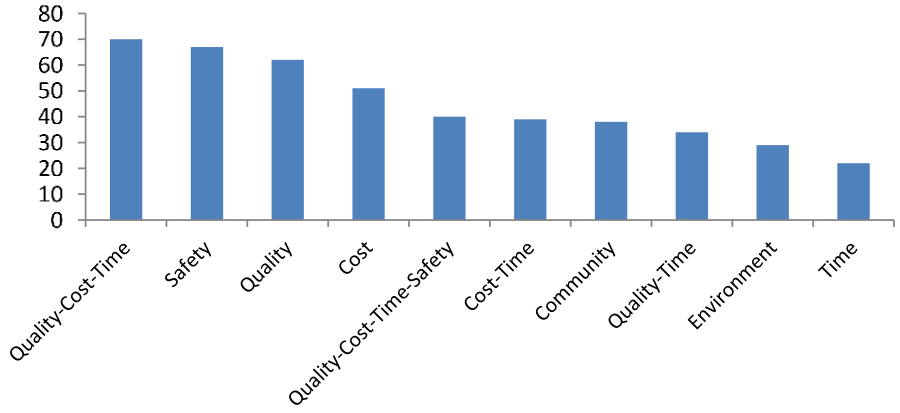

Figure 3. Innovation classification based on Benefit.

The data was also analysed to identify emerging trends that would provide more insight in to 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).

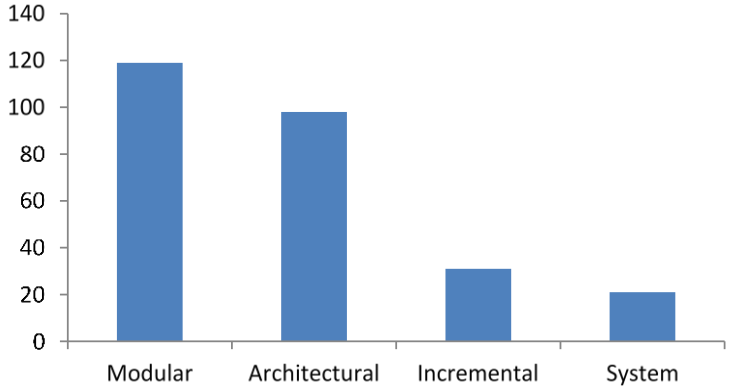

Figure 4. Innovation novelty categories that focused on delivering a single benefit.

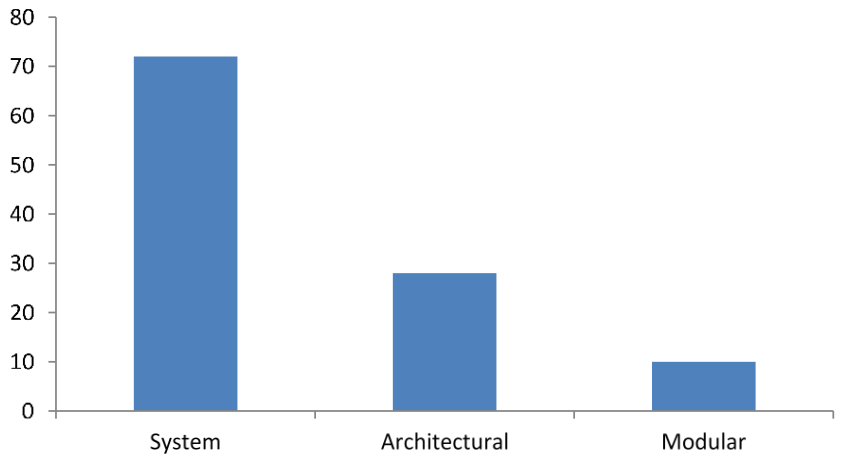

Figure 5. Innovation novelty categories that delivered a combination of quality-time-cost benefit.

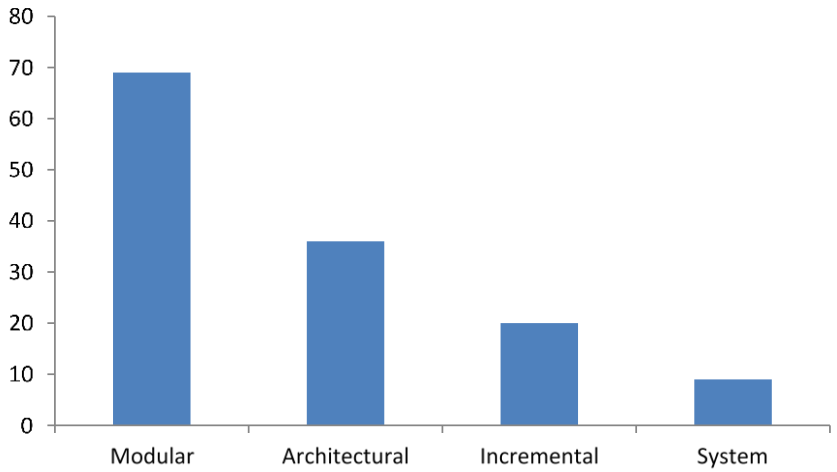

Figure 6. Innovation novelty categories that focused on either sustainability, safety or community.

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.

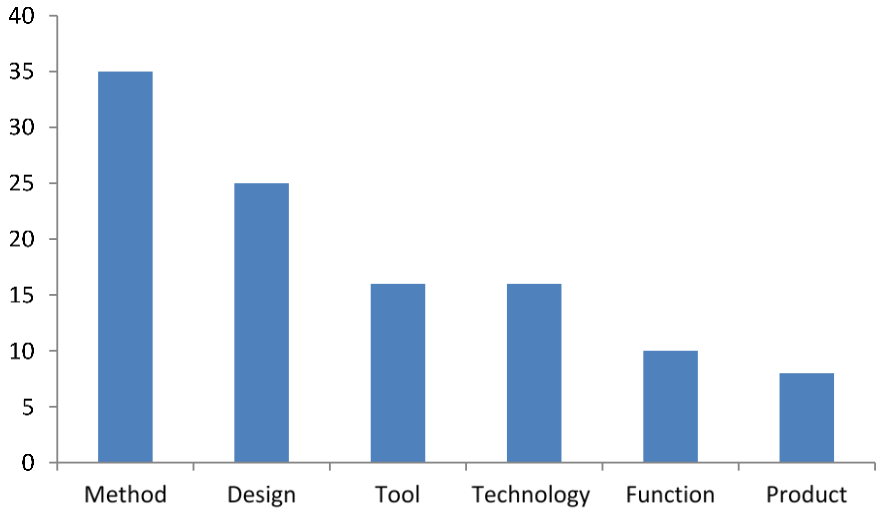

Figure 7. Innovation types that delivered a combination of quality-time-cost benefit.

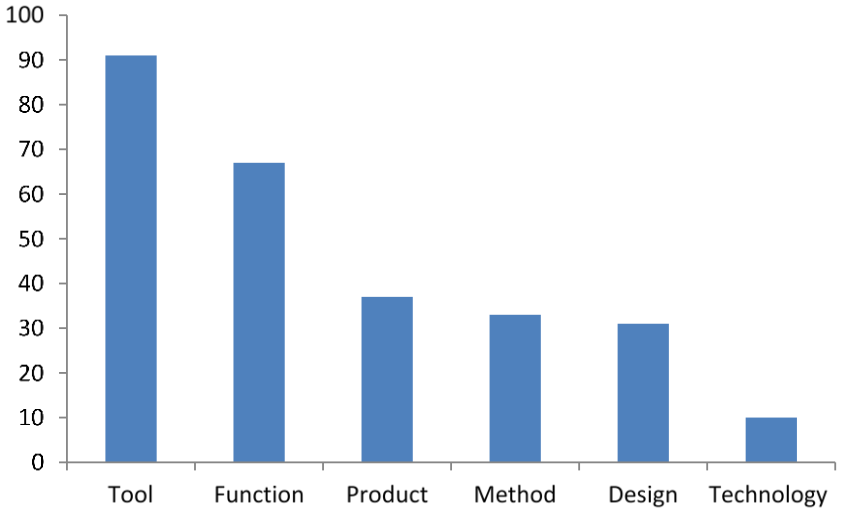

Figure 8. Innovation types that focused on delivering a single benefit.

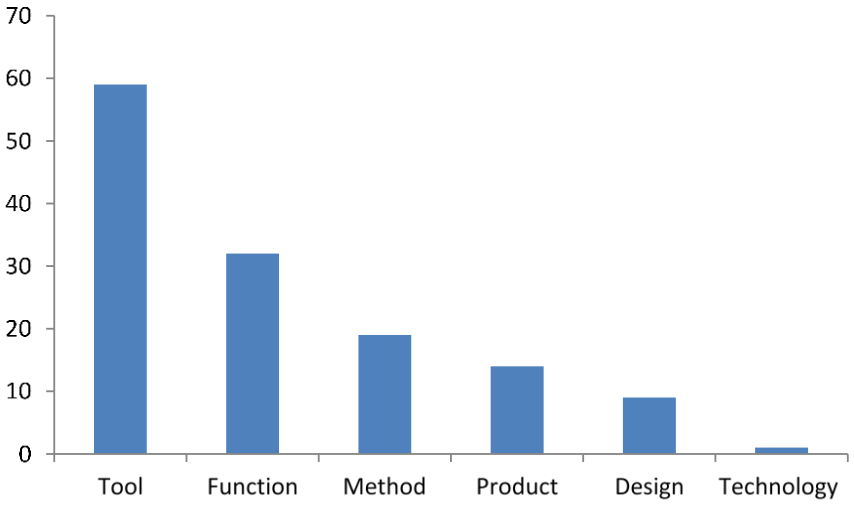

Figure 9. Innovation types that focused on either sustainability, safety or community.

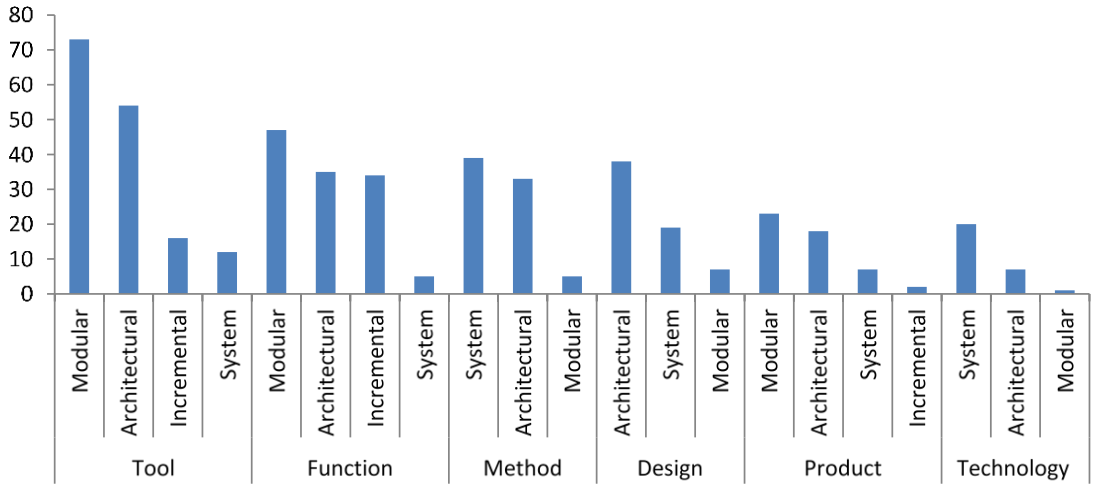

Figure 10. Degree of novelty of various types of innovation.

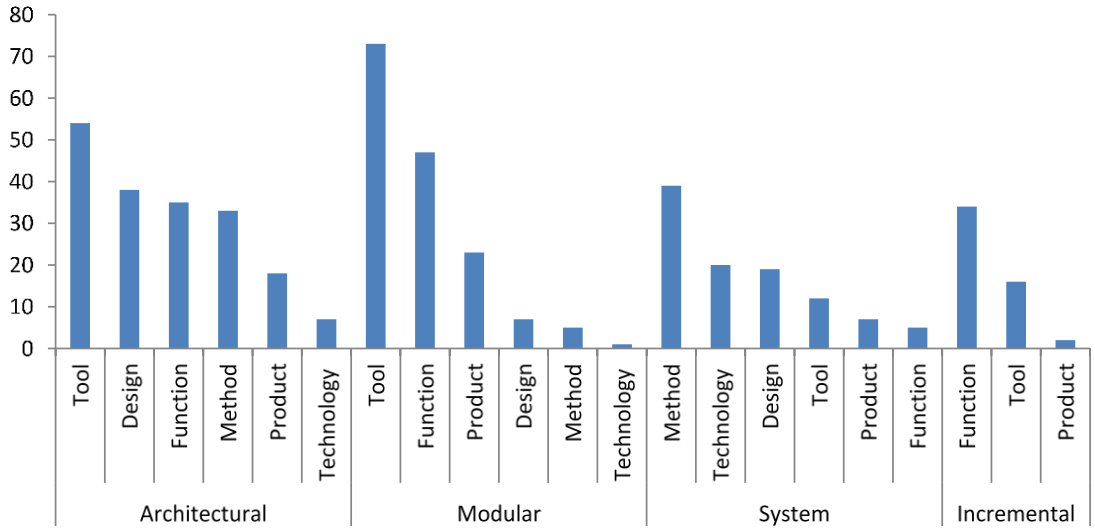

Figure 11. Spread of innovation types for each level of novelty.

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

Innovation types	Preliminary	Design	Construction
Design	7%	82%	11%
Function	4%	4%	92%
Method	8%	80%	12%
Product	10%	80%	10%
Technology	68%	16%	16%
Tool	3%	10%	87%
Overall	9%	42%	49%

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

	Innovation Types	Example SCIRT Innovations
Product Innovation	**Technology**	"Lightweight Localized Storm water Pump Station ": 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.
	Product	"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.
	Design	"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.
Process Innovation	**Method**	"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.
	Tool	"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.
	Function	"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.

Interview with	**date**	**company**	**Intent**
Utilities Manager	20 May 2015	SCIRT	Discussion on process for innovations
Value Manager	3 June 2015	SCIRT	How the innovation process is working and future use
Focus group- 5 SCIRT employees involved in SCIRT innovation process	17 June 2015	SCIRT	Focus discussion on SCIRT innovation process and choice of top innovations
Interview- project manager	9 Feb 2016	SCIRT	Refining innovations choice
Interview- project manager	9 Feb 2016	SCIRT	Refining innovations choice
Interview- project manager	9 Feb 2016	Fulton Hogan	Refining innovations choice
Interview- project manager	9 Feb 2016	SCIRT	Refining innovations choice

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:

1. 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.

2. 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.
3. Pilot the introduction of a selection of the top 50 innovations initially through an innovations workshop and feedback session
4. Highlight the benefits of innovation as a way of encouraging innovation uptake and use.

References

Apax Partners (2006) "Pathways to Success: A Taxonomy of Innovation", The World Economic Forum, http://www.weforum.org/pdf/techpioneers/apax2006.pdf, Accessed March 2015.

Barlow, J. (2000) "Innovation and learning in complex offshore construction projects" *Research policy* 29, 973-989.

Bassioni, H., Price, A., and Hassan, T. (2004) "Performance Measurement in Construction", *Journal of Management in Engineering*, 20(2), 42-50, Academic Search Premier, EBSCOhost, viewed May 2015

Becheikh, N., Landry, R., and Amara, N. (2006) "Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993–2003." *Technovation* 26, 644-664.

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

Brown, M. (1994), *Introduction to Innovation—Managing Ideas into Action*; Henley Management Center/Price Waterhouse: London, UK.

Egan, J. (1998), "Rethinking construction". Department of Environment, Transport and the Region, http://constructingexcellence.org.uk/wp-content/uploads/2014/10/rethinking_construction_report.pdf, Accessed March 2015

Egbu, C. (2008) "Clients' roles and contributions to innovations in the construction industry: when giants learn to dance", in Brandon, P. and Shu-ling, L. (Eds), *Clients Driving Innovation*, Wiley-Blackwell, Oxford.

Environmental Protection Agency (2007) "The Lean and Environment Toolkit", http://epa.gov/lean/environment/toolkits/environment/resources/LeanEnviroToolkit.pdf, Accessed March 2015.

Garcia, R., and Calantone, R. (2002) "A critical look at technological innovation typology and innovativeness terminology: a literature review", *Journal of Product Innovation Management*, 19(2), 110-132.

Loosemore, M. (2015) "Construction Innovation: Fifth Generation Perspective", *Journal of Management in Engineering*, 04015012, doi: 10.1061/(ASCE)ME.1943-5479.0000368.

Loosemore, M. and Richard, J. (2015) "Valuing innovation in construction and infrastructure: Getting clients past a lowest price mentality" *Engineering, Construction and Architectural Management,* 22(1), 38-53

Love, P., Davis, P., Chevis, R., and Edwards, D. (2011) "Risk/Reward Compensation Model for Civil Engineering Infrastructure Alliance Projects", *Journal of Construction Engineering and Management,* 137(2), 127-136

McAdam, R., Armstrong, G., and Kelly, B. (1998) "Investigation of the relationship between total quality and innovation: a research study involving small organisations." *European Journal of Innovation Management,* 1, 139-149.

Miller, L., and Miller, R. (2012) "Classifying Innovation", *International Journal of Innovation and Technology Management,* 9, 1250004, 1-18. World Scientific, Accessed on March 2015.

Organisation for Economic Development (2005), "Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data", OECD Publishing: Pairs, France.

Ozorhon, B. (2013), "Analysis of Construction Innovation Process at Project Level", *Journal of Management in Engineering*, 29, 455-463.

Reichstein, T., Salter, A.J., Gann, D.M. (2005) "Last among equals: A comparison of innovation in construction, services and manufacturing in the UK." *Construction Management Economics*, 23, 631–644.

Slaughter, E.S. (1998) "Models of construction innovation." *Journal of Construction Engineering Management,* 124, 226–231.

Tatum, C.B. (1988) "Classification system for construction technology." *Journal of Construction Engineering Management,* 114, 344–363.

Tawiah, P.A., and Russell, A.D. (2008) "Assessing infrastructure project innovation potential as a function of procurement mode." *Journal of Management in Engineering* 24(3), 173-186.

Tidd, J., and Bessant, J. (2005) *Managing Innovation: Integrating Technological, Market, and Organizational Change*. 3rd edition. West Errex, Wiley Textbooks.

West, M.A., and Altink, W.M. (1996) "Innovation at work: Individual, group, organizational, and socio-historical perspectives." *European Journal of Work and Organizational Psychology* 5(1), 3-11.

Widen, K., Atkin, B. and Hommen, L. (2008) "Setting the game plan – the role of clients in construction innovation and diffusion", in Brandon, P. and Shu-ling, L. (Eds), *Clients Driving Innovation*, Wiley-Blackwell, Oxford.

Appendices

Appendix 1 – 50 innovations

Appendix 2 – Fulton Hogan Innovations

Appendix 3 – CityCare Innovations

Appendix 1

50 Innovations chosen from the SCIRT Innovation database for further investigation

Innovation	Innovation type	Innovation description	Company	Reason of selection	Innovation benefits	Opportunity for wider adoption
Thanks from City Care Sign	Tool	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.	City Care	This innovation has been chosen as a simple one in order to assess the affect of novel Tool on project productivity.	this innovation has improved the quality of community interaction	This innovation has a potential for wider adoption on the project where a high level of community interaction is required
Data logging Pipe	Tool	It is important to record these checks, as 3rd parties (ECan , CCC) may request proof that setups are being monitored closely.	Downer	This innovation has been chosen as a tool in order to assess the effect novel tool on project productivity	Time has been saved by this innovation	This novel tool could be reused in other Piping project
Automated reminder system	Tool	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 email at least 3 days prior to the date that the TMP expires.	Fletcher 0378	This tool has been chosen in order to assess the effect of novel tool on the management process of huge project	this innovation is perfect for saving time and also for improving the quality of project management	This Innovation could easily be adopted to other construction projects
Hose Management system	Tool	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	Fulton Hogan	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	this tool has improved the safety on the project	This innovation is a kind of individual problem solving and could be ideal for the project with similar issue
One meter fence on top of a T2 compliant barrier	Tool	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.	Meadow (0260)	This tool has been chosen as a helpful solution that could improve the project safety	The safety is the main aim of this innovation	This innovation could be use used on any construction project that includes trenching activities
Mobile Skip	Tool	Bars have designed and built a site skip for the ease of transporting and storing of site materials.	Fulton Hogan	This innovation has been chosen as a tool in order to assess the effect novel tool on project productivity	Time and Safety are the main aim of this innovation	This innovation could be used in construction project in any format
Hydraulic Aluminum Shoring	Tool	Aluminum hydraulic shores and shields are an excellent lightweight resource for working around existing utilities, supporting trench walls near structures, curbs, or sidewalks.	Fletcher	This innovation has been chosen because it has a potential for wider adoption	Safety is the main benefit of this innovation	this innovation could be easily used in any construction project that include trenching
Trench Shields with adjustable feet	Tool	True 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 away from above the pipe when the trench shield is removed.	Fletcher	This innovation has been chosen because it has a potential for wider adoption	Safety is the main benefit of this innovation	this innovation could be easily used in any construction project that include trenching
Adding Wheels to the shield lifting bracket	Tool	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.	Fletcher	This innovation has been chosen as a simple one in order to assess the affect of novel Tool on project productivity.	Safety is the main benefit of this innovation	this innovation could be easily used in any construction project that include trenching
Hopper	Tool	Our Subcontractor C & A Cox has developed a hopper for back loading fill to trenches and excavations. This reduces the need for frequent loader movements which reduces the risk to our workers.	Fulton Hogan	assessing the effect of new tool is the main target of this selection	Time and Safety are the main aim of this innovation	this innovation could be easily used in any construction project that include trenching
Scissor lift	Tool	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	Fulton Hogan	A new way of lifting tool has an opportunity for productivity improvement in construction project	Time and cost are the main aim of this innovation	This novel tool is ideal for the construction projects that need easy access to higher places
Tie Wire Caps	Product	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 searching other options a product was found that is available at most hardware stores at 10% of the price of the specified item.	City Care	A simple novel material has been chosen in order to assess the impact on project quality	Safety is the main benefit of this innovation	This novel product is ideal for the project that needs fencing during the construction process.
Corrosion protection solution	Product	The proposed design for the connection between the two lengths of ground anchor on Mafias 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 anchor. Finally an end cap was also connected to the over- sized sleeve and left with a portal for injecting grout.	City Care	The novel idea is worth to assess in order to understand the effect of new material on project technical difficulty	Sustainability of the final outcome is the main aim of this innovation	this innovation is ideal for the project that are faced with corrosion

Power connection for shared low pressure wastewater tanks	Product	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	FH (0234	This innovation has been chosen in order to have a view on how a new product solve a technical difficulty	cost is the main benefit of this innovation	this innovation has been developed for an individual issue so it could be adopted to a very similar project.
Bridge St Catholic Protection	Product	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.	Fulton Hogan	A simple material cools solve a big technical problem	Sustainability of the final outcome is the main aim of this innovation	this innovation could be adopted to the project that are faced with corrosion
Mud recycling for PM128	Product	As part of the works to install PM128, 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 removing the sand component.	Fulton Hogan	A perfect material to be reused in a construction project	Cost and Environment are the two main benefit of this innovation	this innovation is ideal for the construction project that use a lot of mud
Self-compacting concrete	Product	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.	Fulton Hogan	This novel material has been helpful for addressing a project need	Coat and time are the main benefit of this innovation	This novel material could be adopted to the project that normal type of concert islimited.
Rock anchor spacers/centralizers	Product	When installing rock anchors into a drilled socket the anchor needs to be centralized to allow an even distribution of grout around the bar. To ensure this happens there is a requirement to place spacers along the length of the anchor.	Fletcher 0379	This innovation has been chosen because it has a potential for wider adoption	quality is the may target of this innovation	This innovation would be very useful in different types of construction project
Caisson methodology for installing lift stations	Method	The caisson method was used for installing two lift stations on Richardson Terrace mainly due to the location of each being under overhead lines. Instead of using temporary works such as sheet piling for the excavation support the caisson method utilizes a manhole ring as shoring and later it becomes permanent formwork for the mass fill surround.	Fletcher 0264	A novel method has been chosen in order to assess the effect of new method on productivity improvement	Time and cost are the main aim of this innovation	this novel method is availabe to be reused for interlining lift station in future projects.
Casings for cofferdam	Method	On Bathurst Bridge, we needed to create dry access for workings when working on piles and pier columns. In order to do this, and instead of sheet piling, we rented large casings, installed them on the outside, filled the area with hard fill, and pumped all the water out. This created a make shift coffer dam, for 1/4 of the price of sheet piling	McConnell Dowell 0382	A Novel method has been chosen as an effective idea in solving a limitation in construction project.	Time and cost are the main aim of this innovation	This innovation could be reused in construction project where a dry access is needed.
Screw pile frame for cession pump station construction	Method	We have had a frame built so we could centre the pile inside the caisson. It was unsafe to have anyone at the bottom of the hole centering the pile, which is what would be normal practice. The guide was made up to centre the pile off the caisson by Pile Tech.	Fletchers	A safer cession method has been chosen to show how a novel method could improve the safety in construction project	Safety is the main benefit of this innovation	this innovation has been specified for an individual issues and therefore could be reused in a similar condition in future project.
Pipe bursting the water main in Buckingham	Method	The Fulton Hogan team proceeded with pipe bursting the main rather than digging trenches as per the TOC for many Community benefits.	Fulton Hogan0345	A brand new method of piping has been chosen to introduce that as a successful innovation in constriction industry	Time and cost are the main aim of this innovation	This novel method of piping has been used globally and therefore has a potential to be used in every piping project specially in crowded area of busy cities.
PVC pipe with push camera	Method	This is an innovative method of inspecting underground pipe work without having to go through the time and cost of setting up for a confined space entry setup.	Downer 0512	A new method of pipe inspection has been chosen in order to introduce the brad new camera and its related method of usage.	Time is the main target of this innovation	This innovation could easily be reused in other piping projects.
Core drilling displaced joints in pipes	Method	The subcontractor Hydro Tech have developed a grinding tool that is able to grind away any displaced joints to create a complete diameter pipe to allow it to be lined, this enables the sub-contractor to eliminate any dig up operation to maintain their lining works.	Fletchers (0219)	A brand new method of piping has been chosen to introduce that as a successful innovation in constriction industry	Time and cost are the main aim of this innovation	This innovation could easily be reused in other piping projects Especially for the rebuilding project.
Lift Station Installation Sequence Review	Method	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 they install the sheet piles and dewatering spears and then excavate to level.	Downer	This innovation has been chosen because it is a novel method that has been developed by project team	cost is the main benefit of this innovation	this innovation could be adopted to the similar dewatering project

Locating services using GPS	Method	Previously, potholing of 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.	Meadow	This novel method has been chosen in order to have an In depth view about a new way of locating services	Time and cost are the main aim of this innovation	this innovation could easily adopted to the infrastructure projects
Barriers for Bridge Pier Assessment	Method	The option chosen involves using Geode sign barriers TM a system imported from Sweden. •create a contained work area •foot and using pontoons control before discharge • This solution was much more economical than	Downer	This innovation has been chosen as a very useful method which has been imported from other country	Time and cost are main aim of this innovation	This innovation could be easily used in any construction project that require dry spaces for its activities
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 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	Fulton Hogan (0174)	This innovation has been chosen in order to assess the way that a novel method which developed by project team could improve the productivity.	Safety and environment are the main benefits of this innovation	This novel method of trenching could be adopted to any construction project that include trenching.
Site Specific Environment al 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	this novel method has been chosen as an innovation for managing environmental issues	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.	Fletchers	This bran new method of piping 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/thrust 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 some reinforcing steel in it and lifting eyes to enable moving it around.	Fletchers 0366	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 .
Lightweight Localized Storm water Pump Station	Technology	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.	Integrated Services Team	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 project
New tank design means one day install - not four!	Technology	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.	McConnell Dowell (0179)	This new technology has been chosen as an effective solution for saving the time and money waste	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

Pressure Wastewater	Technology	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 below the ground and once installed, all that is visible at the surface is the tank lid. The power to run the pump can either come from the building's power supply or property owners can choose to have it connected to the street supply.		This innovation has chosen as an expensive technology that has eliminated the risk of waste water fail or as a result of earthquake	Sustainability is the main aim of this innovation	This technology is very helpful for the area where located in the earthquake red zone.
Baxley Road Resurface	Design	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.	City Care 0346	This innovation has been chosen as a change on the prior design.	Time and cost are the main aim puff this innovation	Changing on design is completely depended on the project condition and could be happened on every single project design
Moor house Ave Base Reuse	Design	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.	City Care 0350	A change on the design has been chosen in order to assess the effect it has had on the project productivity	Time and cost are the main aim puff this innovation	Changing on design is completely depended on the project condition and could be happened on every single project design
Recycling AP40 on roads to be cement stabilized	Design	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.	Fulton Hogan0347	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	Time and cost are the main aim puff this innovation	Changing on design is completely depended on the project condition and could be happened on every single project design
Rationalizati on of waste water pipe in Hawkesbury Ave	Design	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. Saving = 30m of pipe ($21000) Add = ($4500).	Fletchers	A design change has been selected which is resulted of a design review process	Time and cost are the main aim puff this innovation	Changing on design is completely depended on the project condition and could be happened on every single project design
Additional lift station on Shirley Road	Design	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 is designed into the area to lift the gravity line out of this poor ground. The cost of the lift station and shallower pipe verses the cost of the deep trench /super soft /undercut heavy dewatering is likely to be lower.	Fletchers	This innovation has been chosen in order to assess the effect of change on the first plan on the productivity.	Time and cost are the main aim puff this innovation	Changing on design is completely depended on the project condition and could be happened on every single project design
Lift Station relocation	Design	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 -3.5 m deep to around 1.5m deep.	Fletchers	A change of a lift station location has been chosen as an innovation .	Sustainability is the main aim of this innovation	Changing on design is completely depended on the project condition and could be happened on every single project design
Using pea metal & plywood in trenches to reduce slumping along the trench line	Function	The sub-contractor chose to use plywood on the inside of the sheet piles before backfilling and to fill these voids with pea gravel.	Fulton Hogan	This innovation has been selected as new function by project team in order to assess the effect on productivity	Community has been focused by this innovation as thee main target	this innovation could be reused in construction project where a noise pollution is considered as the project issue.
Protection of dewatering pipes	Function	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	Fletcher 0380	This new way of pipe protection has been selected as an innovation in order to assess the effect on sustainability of final outcome	Sustainability is the main aim of this innovation	this innovation could be repeated in piping project where the pipe should be protected.
Bridge pleura pile cap overlay utilized in tidal zone of estuary	Function	.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.	Fulton Hogan0293	A new way of barrier construction has been chosen form the innovation list in order to have an In depth understanding about the novel functions and their effect on productivity.	Sustainability is the main aim of this innovation	this innovation could be adopted to the future project which involve tight barrier.
Working around a 50 year old 750 diameter pumping	Function	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	Downer	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.	Sustainability is the main aim of this innovation	this innovation has been developed for a specific technical difficulty. The adoption to a similar projects condition is possible.

Lifting pressure wastewater chambers	Function	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 install the chamber, without putting any pressure on the chamber.	Meadow	A novel way of lifting waste water champers has been selected as a new function that developed the safety on the project	Safety is the main benefit of this innovation	This innovation could be reused for lifting the wastewater champers in future project.
Scale Model of Pump Station	Function	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.	Fulton Hogan	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
Leader Board	Function	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 keen to lift the performance of their project and also their Leader Board ranking	Fulton Hogan	This novel idea has been chosen in order to assess the affect of a simple change on project productivity	quality is the main target of this innovation	this managagerial new idea could be used in any constrcution project
Heathcoat Odawa Bridge Beam Jacking and Excel Program	Function	The first was the use of twin hydraulic jacks installed at each jacking point to save time. The second innovation was the development of an Excel programmed to provide timely updates on the force being applied to the bridge, and the corresponding displacement of the deck span being jacked	Downer	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 .
Utilizing Ship Gangways on Horton Bridge	Function	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.	Fulton Hogan	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

Appendix 2 – Fulton Hogan Top Innovations

Project number	Title	Description
10724	**Hose Management system**	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.
10623	**Scissor lift**	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.
11110	**Power connection for shared low pressure wastewater tanks**	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 dilemmaHow 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.

10623	**Plastic lining to damaged reservoir roof drain**	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.
10724	**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.
10926	**Mud recycling for PM128**	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.
10724	**Self-compacting concrete**	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.

11054	**Clifton Reservoir Repair specialist Fibre**	• 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.
10634	**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.
11110	**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.
10724	**hydro excavated slit trenchesBridge 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 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.

10415	**Revised methodology**	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 & 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 sta-tion 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 re-quire by-pass pumps for each stage at a cost of $30K each time, plus the cost of removing the temporary syphon structure, or grout-ing it. This system existed short term for 2 months only.
10819	**Recycling AP40 on roads to be cement stabilised**	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 stabilised.
10926	**Open ended drill head**	This new methodology could well be replicated across the SCIRT programme where horizontal drilling is required.

10793	**Using pea metal & plywood in trenches**	The sub-contractor chose to use plywood on the inside of the sheet piles before backfilling and to fill these voids with pea gravel.
10724	**Bridge polyeuro pilecap overlay**	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.
11223	**Scale Model of Pump Station**	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.

Appendix 3- CityCare Top Innovations

City Care Innovations		
Project number	**Title**	**Description**
10860	Thanks from City Care Sign	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.
/	Plastic trench protection	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 surface and easy to stack on site.
/	Tie Wire Caps	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 searching other options a product was found that is available at most hardware stores at 10% of the price of the specified item.
10927	Corrosion protection solution	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 anchor. Finally an end cap was also connected to the over-sized sleeve and left with a portal for injecting grout.
/	Sewerage pit proposal	CCL proposed the use of a 'poo pit mini manhole' instead of the concrete manhole structure. The result of this was less excavation on site, removal of the necessity of service relocation and a faster build on site to contain the WW spill.
10927	Temporary Drainage Works	With a quick run through with an excavator we created a trench to intercept the surface water. This was topped up with drainage chip that could intercept the surface water to a temporary asphalt dish and then onto the sumps.
10937-11017	Construction Safety Inputs into Design	During a recent discussion CCL has, through the ECI leads team, proposed the use of the eight critical risks as agenda items for the risk workshops.

11078	Bexley Road Resurface	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 just resurface with minor works to tie into the existing pavement.