CREATING AN OPPORTUNITY TO INNOVATE DURING DISASTER RECOVERY

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Innovating in construction can be a complex task. Innovating in construction whilst recovering from a disaster adds an extra level of complexity. This paper examines a unique innovation process adopted by an alliancing organisation (SCIRT) during the Canterbury earthquake recovery. SCIRT was an organisation formed to reconstruct the damaged horizontal infrastructure (water, waste water, roads and highways). The innovation process developed by SCIRT for capturing and measuring innovations was novel as it came from a desire to recover well from the earthquakes and to seek opportunities to construct better and more efficiently. A process was set up to specifically encourage, capture and measure innovations. This process is described in the paper, but was centred on an innovation KPI. Over 600 innovations captured were reported and analysed for this research, giving a rich picture of where innovations originate, what types of innovations occur more frequently, and where in a construction life cycle different innovation types can best be developed. The paper shows that, despite innovations being created in a time of change and uncertainty, the innovations created can have lasting long term benefits for the wider construction industry.

Keywords: innovation, reconstruction, disaster, SCIRT, New Zealand

INTRODUCTION

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 (Statistics NZ, 2016). 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 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 *et al.,* 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).

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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, and 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 (Seaden *et al*, 2003). Although there is much research on innovation in the construction industry, most of this research tends to consider innovation in relatively stable environments. There are few studies which show how innovation can be encouraged in crisis situations. This paper examines innovation development in a highly stressed environment. A large-scale alliancing organisation (SCIRT) developed innovation practices during the Canterbury earthquake recovery. The innovation process developed for capturing and measuring innovations was novel as it came from a desire to recover well from the earthquake and to seek opportunities to construct better and more efficiently.

INNOVATION IN CONSTRUCTION

There is a large body of knowledge about the innovation in manufacturing and service industries and innovation research in construction industry is becoming a more mature field, although still lags other industries (Barrett and Sexton 2006, Loosemore, 2015a, 2015b, 2015c). Various different 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) or 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" (West and Altink, 1996).

Ozorhon, B (2013) showed that innovations occur at different phases of construction and have multiple benefits, drivers and enablers. Taylor (2005) stated that, "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". This invisibility was also identified by Loosemore (2015c) as in that the majority of construction innovations appear in the form of problem-solving that is developed daily in order to address project difficulties. Loosemore (2015c) observed that although many researchers indicate that construction industry is not very innovative, construction companies do engage in day-to-day problem solving activities. Loosemore refers to these as "Hidden Innovation" (Loosemore 2015c) which 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. Due to the hidden innovation, large scale innovation capture, management and dissemination is unusual in the construction industry, and in order to do this, a systematic process for classifying and managing innovations is required. Seaden *et al*., 2003 agreed, believing that strategic decisions around innovation creation could enhance innovation uptake and that creating innovative thinking business environments and an innovation business strategy increase innovation development. The most commonly accepted innovation classifications have been developed by analysing innovation within the manufacturing and services context (Noktehdan *et al.,* 2015). Three key defining elements of innovation can be identified from manufacturing: types of innovation, novelty of innovation and the benefits the innovation creates.

Innovations in Times of Crisis - The New Zealand Experience

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. A large number of resources 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. Following the February 2011 earthquake, the New Zealand government recognized the need for a different approach to deliver the horizontal infrastructure reconstruction. The Government chose an alliancing-based project delivery model based on country expertise and experience and the need to 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 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 (Canterbury Earthquake Recovery Authority, established as a government department to lead and coordinate the Government's response and recovery efforts following the earthquakes), and NZTA (New Zealand Transport Agency), each of which played a different role: CCC and NZTA as asset owners and funders while CERA as Crown funder and 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 and as the delivery team - City Care, Downer Construction, Fletcher Construction, Fulton Hogan and McConnell Dowell.

As illustrated in Figure 1, 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. Together with their subcontractors and suppliers, the delivery teams were 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. Construction work for each team was allocated based on 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 (SCIRT, 2013)

Innovation in SCIRT

Innovation was one of the key performance indicators (KPI) at SCIRT. An innovation strategic plan supported creative ideas through the project lifecycle. An innovation strategic plan in SCIRT initiated a culture through the project teams and individuals for developing innovation as one of the project's first priorities. Innovations were captured in the value register, and reviewed and approved by management to count towards performance assessment (Auditor, 2013). Innovation in SCIRT was 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" (SCIRT, 2011). The innovation score was 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 innovations in one of the above groups. The KPI for innovation caused project teams to develop more innovations through the project lifecycle. More than 600 construction innovations were developed through the SCIRT project lifecycle

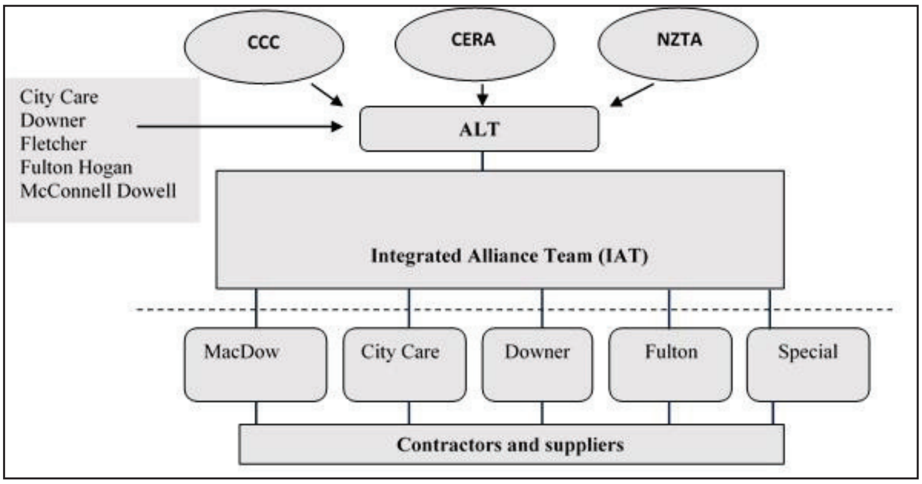

Figure 1: SCIRT temporary organisation

RESEARCH METHOD

The SCIRT learning legacy project was launched in 2014 in order to share the knowledge and experiences of SCIRT. Full access by the researchers to the SCIRT learning project was given through a contract between the University of Auckland and The SCIRT learning legacy project.

A multiple method of data collection was used in this research. The following were the key sources: SCIRT innovation database, SCIRT technical documentation, project reports and SCIRT delivery system guidelines. The researchers were given open access to the SCIRT innovation database. This database had over 600 innovations captured as evidence of the innovation KPIs created by the construction and design companies working in SCIRT. All the reported innovation were registered through SCIRT. The types of information reported for each of the +600 innovations included data codes, innovation name and innovation originator, technical and managerial information for each of the SCIRT innovations was made available to the researchers through discussions with SCIRT employees. Project monthly reports and technical reports were used to supplement the database information, of particular use were those innovations being adopted and trialled on site. The research analysed the SCIRT innovations using innovation models developed for the research. The analysis of the data allowed for the researchers to develop a comprehensive innovation model.

THE INNOVATION RESULTS

The innovation model adopted to understand and categorise the innovations was developed using previous literature. This included the innovation novelty, benefit and type. Analysis of the literature showed that innovation “Type”, “Novelty” and “Benefit” are three main ways of defining innovation. 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 developed different types of construction innovation, with levels of novelty, and varying benefits.Typically the innovation literature distinguishes between incremental and radical innovations.

Innovations by Novelty

Slaughter's (1998 and 2000) research provided the more detailed categorisation of novelty used for this classification model. These categories are Incremental, Modular, Architectural, System and Critical, where:

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

- 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 impact on other components.

- 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 the degree of interaction with other components of the system.

- System innovations are identified through their integration of multiple independent innovations that work together to perform new functions or improve the facility performance as a whole.

- 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.

Analysis of the data shown in Figure 3 represents the spread of innovation categories in the novelty dimension of the classification system. Most innovations in the SCIRT database were made up of architectural or modular innovations. There were no critical innovations. The implications for the construction industry of this finding is to show that it is relatively straightforward to create modular innovations which are contained in one area, and do not impact other areas. For SCIRT, an example would be in redesigning the information technology databases for designers to make it easier for designers to use. Architectural innovations were also high, where an impact crosses usual organisational boundaries, for instance a design change impacting construction. In the case of SCIRT there were redesigns of pipe connections which had consequential impacts on construction. Of interest was the lower numbers of incremental innovations (small changes, every-day changes and problem solving (as referred to by Loosemore (2015c) as hidden innovations)). Despite a process and incentive for capturing innovations, incremental innovations lagged the other innovation novelty classifications. One reason for this might be that the companies were focussing on wider innovation generation and were generally able to record more substantial innovations to meet KPI targets.

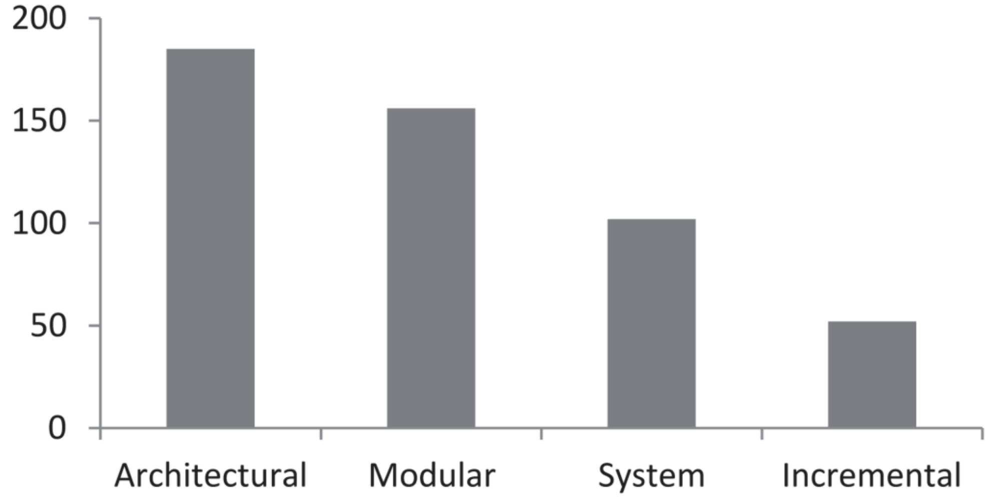

Figure 2: Innovation classification based on Novelty

Innovations by Type

The definitions of the different aspects of type of innovation were developed from the literature (Zhang *et al*. 2003), whereby, the following were chosen as definitions:

Tool: The Tool Innovation involves the development or implementation of novel construction machinery, equipment or tool into the construction project.

Function: The Functional innovation refers to new tasks developed or introduced in the construction project or associated management processes.

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

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.

Figure 3 represents the spread of innovation categories in the "Type" dimension of the classification system. Most innovations in the SCIRT database were made up of tools or functions in terms of innovation type. What is clear is that SCIRT created opportunities to produce new tools, equipment and machinery to deal with the earthquake damaged infrastructure. Many of these innovations stemmed from the need to rebuild in liquefied areas, necessitating new ways of constructing, and using different trenching and tunnelling techniques.

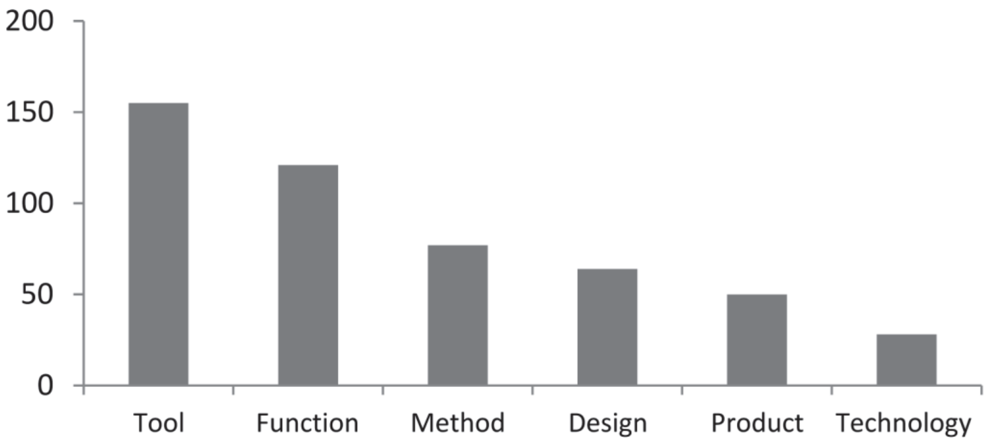

Figure 3: Innovation classification based on Type

Figures 4 and 5 demonstrate the changing trends of innovation through the lifecycle of the projects where Phase 1 "Starting the project": Project definition, Project allocation and Concept design and Phase 2 "Organising and preparing": detail design, TOC, Construction allocation and Phase 3 "Carrying out the work": Construction and Handover.

The data shows (Figure 4) 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 (Figure 5), 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.

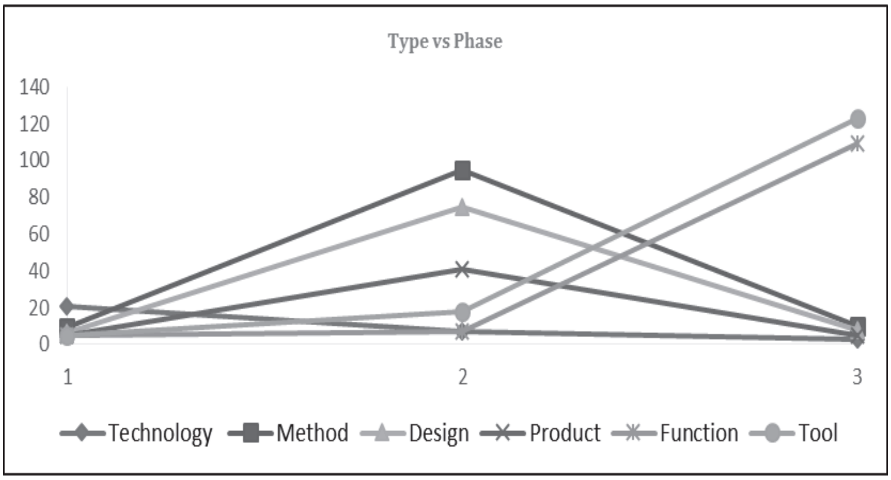

Figure 4: Changing trend of the number of reported innovations categorized by Type

DISCUSSION

The research reported in this paper shows the development of a greater understanding of type and novelty of innovations as created by SCIRT. The research strengthens the view that the industry is by nature innovative. Innovations in this case tended to be modular and architectural in nature. There was evidence of innovations found at SCIRT akin to the "hidden innovations" referred to by Loosemore (2015c), these were the incremental innovation classification.

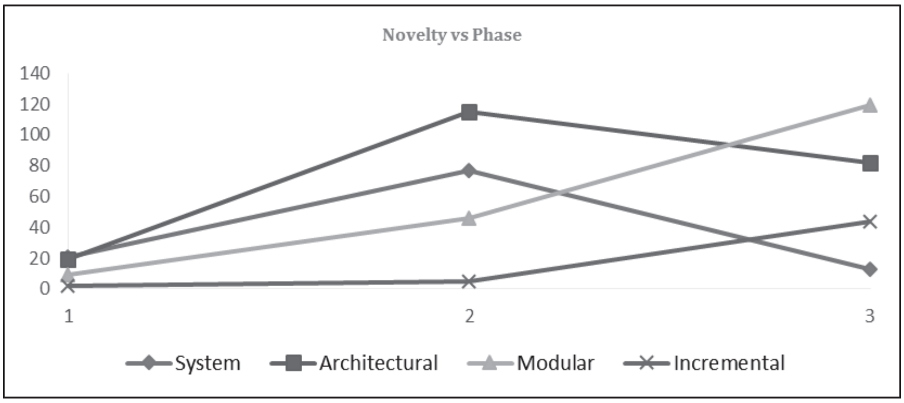

Figure 5: Changing trend of the number of reported innovations categorized by Novelty

The results demonstrably agree with Ozorhon (2013) that developing a culture of innovation at the starting phase of a project increases project innovation creation throughout the project life cycle. The research shows that at the starting phase of the project there is the likelihood of innovations driven by involvement of an influential team of stakeholders, with opportunities to drive innovation creation throughout the whole project life cycle. In the case of SCIRT, attitudes towards risk and uncertainty were favourable, and the encouragement of alternative methods was high. The starting phase provided an enhanced opportunity for development and implementation of systemic technology and method innovations.

Phase two of the project, concerned with organising and preparing details of the construction work. At SCIRT this involved a substantial increase in collaborative activities among the different companies with expertise required for detailed design, planning and tender process preparation, and selection of contractors and allocation of construction work. SCIRT demonstrated that by creating a climate which encourages communication, collaboration and innovation, this can lead to a large increase in innovative behaviour. This supports the view of Seaden *et al*., (2003) who believed that creating innovative business environments increase innovation development. The research in this paper extends this work by showing different phases and innovation types. The development of innovative designs as well as the introduction of novel construction products and methods were found to be the most prevalent types of innovation at phase 2.

Furthermore, in phase 2, 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. 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 (hidden innovations). However, in the case of SCIRT, where all innovation capture were incentivised through the SCIRT innovation KPI, hidden innovations were revealed, and shows that at phase 3, which is predominantly construction, there is a large shift towards tool and function types of innovation. As the emphasis in this phase is on-time and on-budget delivery of the project, the reported innovations had lower levels of novelty.

CONCLUSIONS

This paper has shown how a new and complex organisation (SCIRT), working under difficult circumstances (rebuilding an earthquake affected region), can generate a system of innovation development over the organisations lifespan. The level of innovation potential of infrastructure projects is high, but the mechanisms for encouraging innovations needs to be in place. The innovation development capability of SCIRT was assessed based on novelty and type views of innovation and showed how different innovation types and innovation novelty occur at different project life cycle phases. introduction of a innovation KPI and driving an innovation culture throughout the construction life cycle have been shown, through this research, to reveal the hidden innovations, which are often seen as mere problem solving, but can have transformative impact when viewed as a whole. Although this research was conducted with a dynamic organisation created to provide solutions at a time of crisis, the research shows that it is possible to create the environment where innovation thrives. Specifically, the research recommends incentivising innovation to maximise innovation creation throughout a construction project lifecycle.

REFERENCES

Barrett, P and Sexton, M (2006) Innovation in small, project-based construction firms. *British Journal of Management,* **17**(4), 331-346.

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

CERA, Canterbury Earthquake Recovery Authority. (2012) *Recovery Strategy for Greater Christchurch.* Christchurch. Retrieved from http://cdn.cera.govt.nz/

Loosemore, M (2015a) Grassroots innovation in the construction industry. *In*: F Orstavik, A Dainty, C Abbott (Eds.) *Construction Innovation*. Oxon: John Wiley, 65-78.

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

Loosemore, M (2015c) Construction innovation: Fifth generation perspective. *Journal of Management in Engineering*, **31**(6), p.04015012.

Noktehdan, M, Shahbazpour, M and Wilkinson, S (2015) Driving innovative thinking in the New Zealand construction industry. *Buildings*, **5**(2), 297-309.

Auditor (2013) *Office of the Auditor-General. Effectiveness and efficiency of arrangements to repair pipes and roads in Christchurch*. New Zealand Government

Ozorhon, B (2013) Analysis of construction innovation process at project level. *Journal of Management in Engineering, ASCE*, **29**(4).

Reichstein, T, Salter, A J and Gann, D M (2005) Last among equals: A comparison of innovation in construction, services and manufacturing in the UK. *Construction Management and Economics*, **23**(6), 631-644.

SCIRT (2013) *Rebuilding central city horizontal infrastructure - Update from Stronger Christchurch Infrastructure Rebuild Team (SCIRT)*, Greater Christchurch Recovery Update, August 2013(24), 9.

Seaden, G, Guolla, M, Doutriaux, J and Nash, J (2003) Strategic decisions and innovation in construction firms. *Construction Management and Economics*, **21**(6), 603-612

Slaughter, E S (1998) Models of construction innovation. *Journal of Construction Engineering and Management*, **124**(3), 226-231.

Slaughter, E S (2000) Implementation of construction innovations. *Building Research & Information*, **28**(1), 2-17.

Statistics NZ (2012) *Annual Research and Development Survey*. Wellington: Statistics NZ.

Statistics NZ (2016) *Annual Employment Sector Statistics*. Wellington: Statistics NZ.

Taylor, J (2005) *Unweaving the Rainbow: Research, Innovation and Risk in a Creative Economy*. AHRC Discussion Paper

West, M, Altink, W M M (1996) Innovation at work. *European Journal of Work and Organizational Psychology*, **5**(1), 3-11.

Wilkinson, S, Kempton, T and Gleeson, A (2012) *Identifying Canterbury Rebuild Project KPI's* (Baseline Report) Retrieved from mbie.govt.nz

Zhang, L, Seidel, R, Shahbazpour, M and Haemmerle, E (2013) A three-dimensional innovation process capability assessment tool. *6th International Conference on Information Management, Innovation Management and Industrial Engineering*, Xi'an, 151-155.