National SCIENCE Challenges

BUILDING BETTER HOMES, TOWNS AND CITIES

Ko ngā wā kāinga hei whakamāhorahora

Transforming the Building Industry

State of Nation knowledge report

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Working paper

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

VICTORIA UNIVERSITY WELLINGTON
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About this report

This report is a working paper that outlines work undertaken and funded as part of Strategic Research Area 6: Transforming the Building Industry, which is a part of National Science Challenge 11: Building Better Homes, Towns and Cities.

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Transforming the Building Industry: State of Nation Knowledge report

National Science Challenge 11: Building Better Homes, Towns and Cities

Strategic Area 6: Transforming the Building Industry

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Executive summary

The building construction industry plays a major role in New Zealand's economy. It remodels, grows and enhances our environment, as well as affecting lives of all current and future generations of kiwis. Nevertheless, compared to other industries in New Zealand, the building construction industry has long been criticised for its conservatism and lack of innovation. This in turn radically impedes its productivity in the construction process[1], as well as the performance of the infrastructure during its anticipated service life.

Currently, in-spite of nearly a decade of substantial economic growth in the country, we are building around half the homes that we need in Auckland[2] and the wider quality issues with housing and communities throughout New Zealand are increasingly seen as a critical social problem[3]. In short, we need as a society to produce more housing and societal infrastructure to support our communities more rapidly and sustainably.

The current condition indicates an urgent need for transforming the New Zealand building construction industry to be more innovative and productive. Such transformation not only produces direct benefits to the industry but could also boost the national economy and improve the liveability of our built environment. To create this transformation, we need to consistently increase productivity at a local level, improve innovation, upskill the workforce to both generate and embrace new technologies and techniques, streamline construction and related processes and improve the quality of construction products. All these require developing a healthy, coherent, well-functioning building construction industry in terms of its level of innovation, people, processes and technologies.

[1] Including inter alia BRANZ Study Report SR3410 (2014) https://www.branz.co.nz/cms_show_download.php?id=db0ab6091f9fb125f8fe853534bba2c888af5cd7

[2] http://www.interest.co.nz/property/83282/rate-which-new-homes-are-being-built-relative-our-population-size-less-half-what-it

[3] http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11627203

National Science Challenge 11, "Building Better Homes, Towns and Cities" (Ko ngā wā kāinga hei papakainga) has as one of its Strategic Research Areas an industry focused theme. Our research team has been working consistently in this domain over recent years and has bought together a range of observations as a baseline for further research. The research team has as a result prepared a comprehensive report addressing the four major streams of work embodied at its establishment, i.e.:

Section 1. Innovation;

Section 2. People;

Section 3. Technology;

Section 4. Process.

This combined report addressing the key themes above represents the first deliverable of a multi-year project for guiding and supporting the transformation of the New Zealand building construction industry. The report presents the findings from a comprehensive literature review and a series of focus groups and elite interviews conducted in Auckland, Christchurch, and Wellington. Finally, based on the findings, the future research questions and recommendation are presented.

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1. Introduction

This research project is part of the National Science Challenge (NSC 11) programme that has been undertaken by a group of leading universities and research organisations. The project addresses and is intended to deliver upon the following outcomes:

- Better quality, more cost-effective, housing
- New and affordable housing is to be developed and located to match current and future demand of different demographic groups
- Better current and future urban environments that encourage economic activity and improve residents' well-being
- Helping the building sector to more rapidly adopt innovation, as well as to develop other techniques to improve construction productivity.

Building practice and expectations in NZ are characterised by low productivity and poor housing outcomes, as well as delivering inadequate infrastructure to manage growth sustainably. The reasons behind this gap between needs and expectations are multifaceted and complex, including but not limited to incorporating poor training; lack of skills; cyclic nature of the building industry; lack of technology uptake; changing demographics; inappropriate materials; poor planning etc. Overall this creates an industry with high levels of unpredictability in project delivery, within budget and on time. This variability, unpredictability and poor return on investment generates an atmosphere of uncertainty, impeding politicians and planners in their infrastructure and housing decision-making. Creating a productive sector using new ideas could transform the industry.

Over recent years, housing has been in short supply in several parts of the country and the costs of new dwellings as well as established stock have been rising rapidly. This is a critical problem for Auckland leading to an 'asset bubble' being created in New Zealand's largest city[4]. On 31 October 2016 Statistics New Zealand[5] released a report

[4] Tookey, J.E. (2017) The Mess we Are In: Auckland's Housing Bubble from a Construction Sector Perspective, AUT Policy Observatory accessible at

on building consents and noted that 29,935 new dwellings were consented during the year to date. The value of the housing consented rose 24 percent over the same period. The demand for housing as well as the post-earthquake rebuild in Christchurch has driven up both prices and costs across the building construction industry. In particular skilled trades across the building and construction sector have been in short supply for some time, leading to a substantial escalation in rates charged for the various trades.

In view of these emergent and escalating problems, Ministry of Business, Innovation and Enterprise (MBIE) requested for proposals for the Building Better Homes, Towns and Cities under the umbrella of National Science Challenge in 2015. The intention was to seek collaboration between appropriate academics, Crown Research Institutions (CRIs), industry and wider societal stakeholders to generate transformational change within the built environment domain. The outcomes were to emphasise the ideas, methods, tools, techniques and transformational thinking that would overcome the inertia of a conservative building industry, and thus develop a productive and innovative industry fit to address the challenges and opportunities of the 21st century.

The "Building Better Homes, Towns and Cities" (BBHTC) initiative operates under the overarching umbrella of the National Science Challenge. BBHTC seeks innovative, affordable and flexible solutions for homes, towns and cities; focusing on improving the quality and supply of housing, and creating attractive urban environments. The BBHTC mandate has by its very nature an extremely complex set of issues to address. At one end of the spectrum it has to address the social, cultural, political, economic and environmental issues of a complex industry/society system within Aotearoa/New Zealand. At the other end of the spectrum there are the highly technical and procedurally focussed aspects of a complex industry requiring highly specific craft and engineering skills working together in a complex economic/social system. Thus we see all the features of a classic 'Wicked Problem'[6] – a complex interrelated set of

https://thepolicyobservatory.aut.ac.nz/__data/assets/pdf_file/0005/75083/168465_The-Mess-We-Are-In_Proof4_Digital_PRINT-VERSION-w-May.pdf

[5] Accessible at: http://www.stats.govt.nz/browse_for_stats/industry_sectors/Construction/BuildingConsentsIssued_HOTPSep16.aspx

[6] Camillus, J.C. (2008), Strategy as a Wicked Problem, HBR May 2008 Issue

individually complex problems. Arguably this BBHTC problem transcends the merely wicked into the realms of a fiendish problem.

Following the establishment of NSC11 as BBHTC, the overarching problem was subdivided into Strategic Research Areas, namely:

1. Kāinga Tahi Kāinga Rua
2. Future neighbourhoods in cities
3. Supporting success in regional settlements
4. Next-generation information
5. Improving the architecture of decision-making
6. Transforming the building industry

This report addresses Strategic Research Area 6: Transforming the Building Industry, and the research has been conducted to establish how new ideas can be better adopted by and embedded in the NZ building construction industry. There are strong interdependencies between the overarching theme of innovation and the three key core components of technology, people and processes that can be conceptualised according the diagram below:

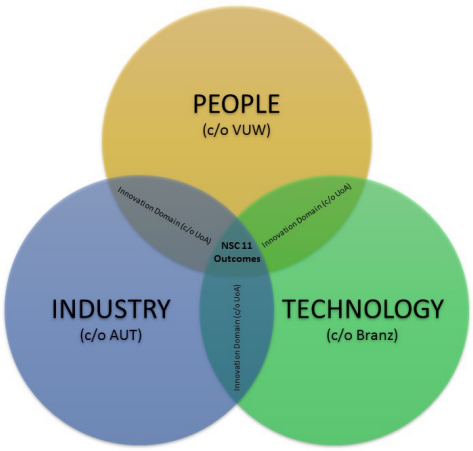

Figure 1-1: Philosophical construct of SRA6

Consequently, the research team developed the research to address these key themes of People, Technology and Processes under the overarching idea of universal innovation for the future of the industry.

Innovation – Improving innovation can lead to significant productivity improvements. Many organisations are aware that they should be innovating, but they lack the awareness and opportunity, as well as the appropriate tools and methods to develop and implement processes and structures to foster a culture of innovation. Productivity has flat-lined at $34/hr added value compared to a pan-industry average of $48/hr. NZ construction company innovation is around 10% below the national average[7]. Indeed more often than not many construction companies exert their main efforts in the direction of corporate (if that word can be applied to such small companies) survival. To be globally competitive, as well as providing the infrastructure that society needs, the New Zealand industry requires a shift in the ways in which it innovates. The industry needs robust, user-focussed innovation tools which can be used at different levels of the industry, in different sectors and which address different needs. Starting from the rationale that there is a need to improve innovation in the building industry, we want to identify the barriers to innovation and think about how innovation uptake in the building industry can be enhanced.

Technology – Innovative technologies are being developed and introduced at a rapid pace within the building industry. Technological innovation means there are opportunities and challenges that are redefining building practice and expectations about the benefit buildings bring to our communities and cities. Technologies are vital to New Zealand's continued sustainability and economic development. However, despite the aspirations of New Zealand to have one of the best construction industries in the world, the industry lacks full appreciation of the role technology plays in industry improvement. Creating a productive sector through using new technologies could

[7] MBIE (2014) New Zealand Sectors Report, http://www.mbie.govt.nz/info-services/business/business-growth-agenda/sectors-reports-series/pdf-image-library/the-new-zealand-sectors-report-2014-main-report/Part%201%20-%20Overview%20of%20the%20Economy%20by%20Sector.pdf

transform the industry. However, the lack of use of transformative technologies within this sector provides genuine concern for the industry. It is hard not to remember that whilst New Zealand is seeking to establish if or whether investment or change is required in certain areas of construction technology, the rest of the world is moving on at breakneck speed. Recently Saudi Arabia signed deals for 1.5m new homes using 3D concrete printing technology from China[8], whilst at the same time the Auckland housing industry struggles to build 7200pa[9] against a modest 30 year 'stretch target' of 14000pa[10].

People – People are at the core of the building industry through all levels and stages of the construction process. People are the source of demand for innovation, the originators of the innovations that are developed as well as the ultimate users and beneficiaries of those innovations. As a result people are at the very heart of this SRA with a research theme dedicated to the issue. Hence, any transformation within the building industry inevitably should perhaps start there? However, the New Zealand building construction industry has trouble attracting, recruiting and retaining competent staff. Another significant challenge relates to the increasing sophistication of technology, which demands rethinking the skills, capabilities, and competencies of people in the building industry and how we train these professionals. This work programme will set a course for how to foster producing people skilled in the tools, technologies, processes and knowledge to shift the building industry towards productivity improvement.

Processes – To provide systematic support for innovation, and new technology integration, there is a need to transform the processes underpinning the NZ building construction industry. There are multiple motivators for change at work at present throughout New Zealand. The now acknowledged (at least locally) housing crisis in Auckland has spawned planning deregulation in the form of the new Auckland Unitary

[8] http://3dinsider.com/saudi-arabia-10-billion-deal/
[9] http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11857015
[10] Auckland Unitary Plan (2015), Auckland City Council http://theplan.theaucklandplan.govt.nz/aucklands-housing/

Plan[11]. Similarly the continued re-build after the Christchurch and Kaikoura Earthquakes has created a re-examination of how we rapidly address emergent problems and get infrastructure back in to operation. It could be argued that current processes are struggling to cope. As these issues have emerged there is a broader effort to address wider systemic issues in the building industry. Significant impacts on current and planned future infrastructure are expected as the result of such changes as the Earthquake Prone Building legislation[12] in concert with the expansion (especially around Auckland) and redevelopment of towns and cities. These issues place great stress on the building industry how it effectively engages with the legislative, procurement and technical processes established. Thus it is apparent that a key element to improving the building construction industry is transforming processes we adopt in the development of future infrastructure. As a result, we need to establish what new processes are needed to create better and more efficient buildings for people, while at the same time address the margins for builders and contractors.

As can be seen the 4 domains of research in this research programme are complex and interconnected. The research that has been undertaken to date and in the future has anticipated this. The result has been a highly integrated team of academics and researchers, collaborating closely in the development of understanding in the building construction industry. The team share resources and findings closely, maximising the access that the team as a whole can gain into various key players in the building construction industry that individuals have nurtured over a number of years. Consequently the team has been able to maximise the effectiveness of the research to date in the establishment of this first interim report.

[11] Auckland Unitary Plan (2015), Auckland City Council http://theplan.theaucklandplan.govt.nz/aucklands-housing/

[12] Building (Earthquake-prone Buildings) Amendment Act 2016 http://www.mbie.govt.nz/info-services/building-construction/safety-quality/earthquake-prone-buildings

1.1. Scope of work

The primary objective of this research is to guide and support the transformation of New Zealand building construction industry. This report largely relies on findings from focus groups conducted in Auckland, Christchurch, and Wellington by the combined research team. Groups of experts including architects, engineers, local authorities, builders, quantity surveyors, construction strategist, planners, project managers, safety managers, and clients were invited to participate in a number of focus groups. During these focus groups, the four major streams including innovation, people, technology, and process were the principle themes of discussion. The focus groups provided up to the minute data and information on the current state of knowledge around these four themes in the industry. More importantly these experts provided detailed and insightful understanding and ideas as to how to best address the critical problems extant in the industry. During the initial research conducted by the team, the complexity of the interrelationships among four streams and their impacts on the performance of the building construction industry became increasingly evident. The intention of this report is to serve as a foundation for the next stage of this multi-year research project by establishing the critical questions to address and outcomes upon which to focus.

1.2. Methodology

A two-stage approach was adopted to achieve the objectives of this study. The methodology of this initial basic research involved a combination of both literature review and focus groups. At the first stage, a comprehensive literature review of national and international reports as well as academic journals has been conducted to achieve a better understanding of the current condition of the building construction industry globally and in the specific status of knowledge in the New Zealand industry. The review is very useful for helping to think around the contexts and reflecting on the relational nature of this study, Gibson and Brown (2009) suggested.

In order to engage with different stakeholders in the industry, and obtain a deeper understanding of the major issues facing the industry, this study also adopted the focus

group methodology[13] as the second stage This is an opinion-seeking panel discussion where participants are requested to share their thoughts on new ideas, products and services (Gill et al., 2008). Focus groups in this study are the means of collecting qualitative data, conforming to suggestions by Morgan (2000), and this has been employed to gain an understanding of innovation, technology, processes and people. This method has been receiving considerable attention among researchers in different research disciplines. In addition to the formal focus groups cited, some additional informal Elite Interviews were undertaken to elicit some further in-depth analysis of current problems in the industry that could not be explored during the focus groups themselves[14]. Meanwhile, interview was chosen as a confirmatory data collection tool for this study because it is an effective method for gaining an insight into people's experiences in particular scenarios as opined in Taylor and Bogdan (1984). Thus, the interviews helped to gain insights into people's experiences in particular project scenarios (Taylor and Bogdan, 1984). Zuo (2010) also suggested that interviews provide detailed understanding emanating from direct observation of people and listening to what they have to say at a particular scene. Hence, general knowledge about transforming the building industry with a focus on the key components: innovation, technology, processes and people was obtained. With the focus group method, the interaction between participants can reveal information that would be impossible to capture in an individual interview. This methodology has the potential to provide deeper insights into the topic through a direct and intense encounter with key individuals. The success of this method strongly depends on the quality rather than quantity of the participants.

A series of focus groups was conducted in June 2017. The focus groups took place in Auckland, Wellington and Christchurch in order to reduce where possible potential geographical impacts and biases associated with specific regional issues. In addition it was intended to ensure a maximized participation rate from the various facets of the industry, as well as focus the participants on the national need rather than the local symptoms.

[13] Cresswell, J.W. (2013), Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Sage Publishing, 4th Edition

[14] Easterby-Smith, M., Thorpe, R. and Lowe, A. (1991), Management Research: An Introduction, Sage Publishing

Furthermore, to enhance the degree of stakeholder engagement with this research project and obtain robust findings, a wide range of expertise (including construction project managers, engineers, architects, quantity surveyors, facility managers, developers, local authorities, construction suppliers and manufacturers and health and safety managers) was invited to participate. Over 50 construction professionals participated in three focus groups. The research team took all the possible measures to capture opinions of all stakeholders especially women and the tangata whenua of the regions in which the focus groups were being staged. This methodology allows us to obtain broad based and reliable findings by engaging and capturing the opinion of all participants in the research. Thematic analysis was used to analyse the qualitative data by pinpointing, examining and recording patterns within them (Gibson and Brown, 2009).

2. Innovation

The building construction industry is critical to the functioning of the economy in any country in terms of both providing society with places to work, places to live and the infrastructure needed to enable the functioning of both[15]. In New Zealand, the building construction industry is one of the largest sectors of the economy accounting for 8% of total employment in the country[16]. However, in spite of its importance to the national economy in terms of size, the building construction industry seems to be lagging behind other sectors in terms of productivity[1718]. In 2010, the building construction industry in New Zealand established the Building and Construction Sector Productivity Partnership to actively address the issue of low productivity in the sector. Although the early focus was on identifying and quantifying the problems that led to low productivity, over recent years the focus shifted to problem solving and addressing the cultural and mechanistic change that is needed to resolve the well documented problems[19].

One of the areas that the productivity partnership has identified as critical for achieving significant improvements in the sector's productivity is innovation. The ultimate goal of 20% productivity improvement by 2020, it was contended, could not be achieved by repeating the old ways of doing things. New innovative approaches are required in order to significantly improve performance at the same cost or maintain the same level of performance at much lower cost. Unfortunately, the building construction industry is one of the least innovative sectors compared to other industries such as manufacturing and

[15] Murray, M.D. and Langford, D.A. (2003). *Rethinking construction: the Egan Report (1998).* Construction Reports 1944-98, 178-195.
[16]Pricewaterhousecoopers (2011). *Valuing The Role of Construction in the New Zealand Economy*, The Construction Strategy Group, New Zealand, 81.
[17]Wilkinson, S., Kempton, T., and Gleeson, A. (2012). *Identifying Canterbury Rebuild Project KPI's (Baseline Report).*
[18] MBIE (2014) New Zealand Sectors Report, http://www.mbie.govt.nz/info-services/business/business-growth-agenda/sectors-reports-series/pdf-image-library/the-new-zealand-sectors-report-2014-main-report/Part%201%20-%20Overview%20of%20the%20Economy%20by%20Sector.pdf
[19]See footnote 7

traditional services[20]. Indeed relatively recent statistics published by Statistics New Zealand (2014) indicate the huge disparity between the levels of productivity achieved by the building construction industry compared with companies in other sectors of the New Zealand economy[21]. As previously noted, productivity is static at $34/hr added value, compared to a pan-industry average of $48/hr – and up to $200/hr for high performance sectors. The research and development report produced by Statistics New Zealand indicates that R&D expenditure in the building construction industry accounts for a low 5% of the total expenditure in the sector[22]. Indeed, this problem is not limited to New Zealand, as internationally the building construction industry is seen as a traditional or low-technology sector with low levels of expenditure on activities associated with innovation[23].

An initial motivation for the research team to focus on innovation as a key concept grew from the foundational work conducted by Wilkinson et al.[24] on the Christchurch Rebuild project. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) Project allowed access for researchers to a major series of infrastructure projects in New Zealand. SCIRT is a purposeful infrastructure project developed in order to address the 2012 Christchurch earthquake's damage to roads, bridges and underground pipes. SCIRT is an alliance between Christchurch City Council, Canterbury Earthquake Recovery Authority (CERA), New Zealand Transport Agency (NZTA), City Care, Downer, Fletcher Construction, Fulton Hogan, and McConnell Dowell. An integrated project delivery system (IPDS) used by SCIRT is considered an opportunity to develop an understanding of innovation practices through the IPDS. SCIRT is considered as a perfect case study due to the huge success on innovation development, having more than 500 construction innovations developed through a strategic plan.

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[20]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.

[21] MBIE Sectors Report 2014 http://www.mbie.govt.nz/info-services/business/business-growth-agenda/sectors-reports-series/pdf-image-library/the-new-zealand-sectors-report-2014-main-report/Part%201%20-%20Overview%20of%20the%20Economy%20by%20Sector.pdf

[22]Statistics NZ. (2012). Research and development survey, Available at http://www.stats.govt.nz/browse_for_stats/businesses/research_and_development/ResearchandDevelopmentSurvey_HOTP2012.aspx

[23]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.

[24]Wilkinson, S., Shahbazpour, M., Finch, R., and Noktehdan, M. (2016). *The SCIRT innovation project (Research Report).* Retrieved from https://www.branz.co.nz/cms_show_download.php?id=ee82da2422cf6149b669f95632b330debac53057

It became clear through the initial research undertaken around the SCIRT series of projects that innovation was a critical aspect of the success achieved by SCIRT. Innovation led to productivity improvements that in turn led to a significant increase in the rate at which new infrastructure could be brought on stream while costs were kept under control. This in turn provided a fundamental basis on which to grow research in the research domain.

2.2 Innovation overview

What makes innovation challenging is the fact that it is very difficult to agree on a common definition[25]. International literature shows various definitions of innovation. This diversity of innovation definitions has made it difficult for researchers to reach agreement. Based on a literature review, the following definitions and purposes of innovation were found useful:

- Creation and adoption of new knowledge to improve the value of products, processes and services[26].
- Ingenuity, entrepreneurship, process improvement, development and growth[27].
- The creation and implementation of changes that are new to the adopting unit or organisation[28].

For the purposes of this study, innovation is best defined as the creation, adoption and implementation of new changes to improve construction values of productivity and project performance. The principle measured improvements are in the form of the key metrics of construction. Cost, time, quality, safety, and organisational performance. In addition to this definition, what are the critical motivators for organisations and companies to engage in innovation? In short, why should we innovate?

- Innovations create solutions to prevent problems, and investing in innovation is beneficial to consumers through higher quality services[29].

[25] Zairi, M. (1994). Innovation or innovativeness? Results of a benchmarking study, *Total Quality Management,* 5(3), 27-44.
[26] Aouad, G., Ozorhon, B., and Abbott, C. (2010). Facilitating innovation in construction: directions and implications for research and policy, Construction Innovation, 10(4), 374-394.
[27] Gledson, J., and Phoenix, C. (2017). Exploring organisational attributes affecting the innovativeness of UK SMEs, *Construction Innovation,* 17(2), 224-243.
[28] Lai, K.S., Yusof, N., and Kamal, E.M. (2016). Innovation orientation in architectural firms, Construction Innovation, 16(4), 425-445.
[29] Gledson, J., and Phoenix, C. (2017). Exploring organisational attributes affecting the innovativeness of UK SMEs, *Construction Innovation,* 17(2), 224-243.

- Having regard to construction, innovation can create awareness of new processes to improve productivity, project and organisational performance.

A global view of innovation suggests the phenomenon as a driving force for continual improvement. In this view, improvement breeds increased productivity and performance, leading to company growth and profit[30] before the resultant shift of indirect benefits to society occurs. However, many construction organisations are characterised by a lack of skilled resources, producing poor output that results in low levels of profitability. Thus, innovation can offer at least a partial solution by improving existing skill, processes and technologies. By doing so, it can lead to significant practical and commercial benefits. To develop a better understanding of innovation in context, it is worthwhile to explore some of the ways that innovation plays out in construction. In doing so, it is informative to encompass innovation orientations.

2.1. Innovation diffusion

International literature views diffusion (literally the spread of new innovations through the social system, such as the economy) of innovations as a means of developing and communicating a new idea through certain channels, and is a key activity in the innovation process[31]. This relates to the adoption and diffusion of new ideas, methods and products within a social system[32]. It is noteworthy that classic diffusion research places great attention on how innovation adopters gain knowledge about innovations. Therefore a focus has been placed on certain sources through which new ideas can be disseminated[33]:

- Media channels,
- Interpersonal communication,
- Information management and awareness,

[30] Same as 13

[31] Lindgren, J., and Emmitt, S. (2017). Diffusion of a systemic innovation: a longitudinal case study of a Swedish multi-storey timber house building system, Construction Innovation, 17(1), 25-44.

[32] Howaldt, J., Schwarz, M., Henning, K., and Hees, F. (2010). *Social innovation: concepts, research fields and international trends,* IMA/ZLW.

[33] Shibeika, A., and Harty, C. (2015). Diffusion of digital innovation in construction: a case study of a UK engineering firm, *Construction Management and Economics,* 33, 453-466.

- Communication network activity and channel building, and
- Interactions among different actors or construction professionals within construction firms.

Understanding the meaning of innovation is insufficient. Ability to innovate and implement innovations are also important. In addition, there is a need to prioritise the implementation of innovation in construction projects. Much literature has focussed on how innovation could be implemented in construction projects[34,35,36&37]. As such, this study finds its significance.

2.2. International Perspectives: What makes successful innovation?

From a UK perspective, the "Sainsbury Report"[38] illustrated the desire to shape the innovation network in such a way as to promote innovation. This is reflected internationally within the construction sector where there is a growing awareness from within the industry of the need to innovate and anticipate possible future as a means of aligning and improving current strategies[39]. For example, Aouad et al.[40] reported that the outlooks section of the International Council for Research and Innovation in Building and Construction (CIB) contained some wide-ranging construction sector outlook reports produced about the last two decades. All of these reports reflected the desire to increase the pace of innovation and to proactively shape the future innovation agenda.

In order to gain an insight into successful innovations internationally and their relationship to the NZ experience, it is worthwhile considering what we can learn from the UK on innovative practices in particular. The UK has a useful perspective since the craft industry basis of the sector there, as well sharing significant historical and cultural references.

[34] Slaughter, E. S. (1998). Models of construction innovation, *Journal of Construction Engineering and management,* 124(3), 226-231.
[35] Slaughter, E. S. (2000). Implementation of construction innovations, Building Research & Information, 28(1), 2-17.
[36] Winch, G. (2003). How innovative is construction? Comparing aggregated data on construction innovation and other sectors- a case of apples and pears, *Construction Management and Economics,* 21(6), 651-654.
[37] Aouad, G., Ozorhon, B., and Abbott, C. (2010). Facilitating innovation in construction: directions and implications for research and policy, Construction Innovation, 10(4), 374-394.
[38] Turville, L.S. (2007). *The race to the top,* HM Treasury, London.
[39] Same as 21.
[40] Same as 21.

What can we learn from UK on innovative practices?

In a survey of UK contractors, Aouad et al.[41] reported an interesting insight into the contractors' perspectives on innovation. The findings of the survey indicated that contractors largely innovate to improve their processes and services. Specifically, their innovative practice is driven by their clients and partners. Having regard to innovative practices, a useful insight was provided by a question that asked which innovations do contractors believe they excel at. An understanding of this helped inform the types of innovation that they might be expected to introduce. Based on their responses (Table 1), it can be seen that contractors believe that they are good at organisational innovations such as collaborative practices and contract management/client relations. In terms of technological innovations, their practices follow the increasingly significant driver for innovation of environmental sustainability with contractors believing that they excel at waste management and energy efficiency/carbon reduction.

It is also worth mentioning that ICT, advanced materials (composite, high performance), on-site IT applications [geographic information systems (GIS), global positioning systems (GPS) and radio-frequency identification (RFID)], and automation of processes are among the least adopted practices. These findings also support previous evidence that much of construction innovation is process and organisation based, and often characterised by the widespread adoption of new practices as a result of advances in technological and business processes[42].

[41] Aouad, G., Ozorhon, B., and Abbott, C. (2010). Facilitating innovation in construction: directions and implications for research and policy, Construction Innovation, 10(4), 374-394.
[42] Aouad, G., Ozorhon, B., and Abbott, C. (2010). Facilitating innovation in construction: directions and implications for research and policy, Construction Innovation, 10(4), 374-394.

Table 2-1: Innovation practices

Practices[43]	Mean
To what extent does your organisation excel at the following innovative practices?	
Collaborative practices	4.3
Contract management/client relations	4.3
Waste management	4.1
Energy efficiency/carbon reduction	4.0
Knowledge management	3.9
Design solutions (virtual/collaborative design, modelling and simulation tools and BIM)	3.8
Web-based project management/extranets	3.8
Off-site manufacturing, modern methods of construction (MMC)	3.7
Business process reengineering	3.7
Marketing strategies	3.7
Information and communication strategies	3.6
Advanced materials (composite and high performance)	3.3
On-site IT applications (GIS, GPS and RFID)	3.3
Automation of processes	3.2

2.3. Innovation drivers and barriers

Gledson and Phoenix[44] reported an investigation by the Chartered Institute of Building (CIOB) in the UK. The investigation centred on aspects of innovation as they revealed cost efficiency as the biggest driver for innovation, followed by sustainable processes and client demands. In addition, the development of new ideas around sustainability to improve the environment are considered to be of lesser importance than company survival. In contrast, Rosenbusch et al.[45] argued that the negatives associated with innovations such as risk, uncertainty and high installation costs are outweighed by the benefits, although this should be taken contextually and will not be suitable in all scenarios.

Mostly, the barriers to effective innovation have occurred as unintended consequences of regulation, and attempts to reduce risk to the industry. By its very nature, the introduction of an ordered set of rules associated with practice and technology will tend to militate away from significant changes in process and technology rather promoting such change. It is

[43] Same as above.
[44] Gledson, J., and Phoenix, C. (2017). Exploring organisational attributes affecting the innovativeness of UK SMEs, *Construction Innovation,* 17(2), 224-243.
[45] Rosenbusch, N., Brinckmann, J., and Bausch, A. (2011). Is innovation always beneficial? A meta-analysis of the relationship between innovation and performance in SMEs, *Journal of Business Venturing,* 26(4), 441-457.

therefore unsurprising that the desire to remove risk (in terms of cost in particular) has led to a slowing in improvement of quality, speed and safety, by reducing the desire to actively promote innovation and change[46]. Further from New Zealand experience, Clark-Reynolds and Pelosi[47] have grouped the barriers into the following categories:

- Banking
- Lack of information and data
- Uninformed customers
- Traditional industry
- Threat of the new
- Regulatory issues

Interventions are needed to be across all of these issues if we are to transform the ibuilding industry and build better, as they are interconnected and interdependent[48]. To gain an insight into the drivers and barriers to innovation within the building construction sector learning from UK and Sweden contexts is worthwhile.

What can we learn from the UK about innovation drivers & barriers?

In Ozorhon et al.'s[49] report, results were intended to shed light on the main drivers for innovation at the firm's level to understand what drives an organisation to innovate. The results (see Table 2) showed that the main driver is performance improvement, whereas the least driver is aesthetics/design trends. This indicates that although there is a recognition that successful innovation ought to bring improvement, there is also a requirement to meet external factors such as environmental factors or client/user requirements.

[46] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, New Zealand, 1-44.
[47] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, New Zealand, 1-44.
[48] Same as previous source.
[49] Ozorhon, B., Abbott, C., Aouad, G., and Powell, J. (2010). *Innovation in construction: a project life cycle approach,* SCRI Research Report, Salford, 1-49.

Table 2-2: Drivers of innovation

Drivers[50]	Mean
To what extent do the following factors create the need for organisations to innovate?	
Performance (cost reduction, productivity, effectiveness)	4.8
Environment/sustainability	4.7
End-user requirements	4.6
Technological developments	4.3
Competition	4.1
Regulation and legislation	4.0
Aesthetics/design trends	4.0

Meanwhile, the top two barriers to innovation are clearly to be seen as economic conditions and availability of financial resources[51]. It is noteworthy that financial concerns can both act as a driver and a barrier. The companies surveyed claimed to innovate in order to increase their profitability but believe that they cannot innovate unless economics allows. Similarly, architects' perception of the Swedish construction industry indicated the following barriers to the innovativeness of the industry, and the top two barriers are financial concerns[52] i.e. a focus on initial/project costs rather than life cycle, and the economic risk associated with innovations.

2.4. How can the industry/government drive more innovations?

In New Zealand, innovation in the building construction industry has tended to be primarily at the product level, rather than by changing methods of funding, costing and for that matter training of people and attenuation of societal expectations. New Zealand is not alone in this – the building construction industry internationally is similarly limited in terms of its acceptance of the drive to actively seek change,[53] nonetheless the sector is constantly changing, and so are all of the fields within it. Innovation and new technologies that are

[50] Ozorhon, B., Abbott, C., Aouad, G., and Powell, J. (2010). *Innovation in construction: a project life cycle approach,* SCRI Research Report, Salford, 1-49.
[51] Same as 34.
[52] Hemstrom, K., Mahapatra, K., and Gustavsson, L. (2017). Architects' perception of the innovativeness of the Swedish construction industry, *Construction innovation,* 17(2), 244-260.
[53] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, NZ, 1-44.

rapidly changing the sector are many and varied, however the bulk of current industry innovation efforts are largely occurring in the domains[54] of:

- New materials, building techniques and smarter tools[55]
    - 3D printing[56]
    - Robots[57]
- Prefab and modular housing (although this technology has been widely cited since the 1960s)[58]
- Structural insulated panels (SIPs)[59]
- Cross Laminated Timber (CLT)[6061], and various other new forms of laminated timbers that allow for fast builds with high strength, insulation and integrity[62].

To sustain our standards of living into the future and to continue our long-term national agenda for continuous economic growth, the government is looking to break complacency and drive up productivity by encouraging more innovation, competition and entrepreneurship.

In a recent Construction Leaders Forum hosted by the Faculty of the Built Environment at the University of New South Wales and supported by the Australian Constructors Association and the Australian Institute of Building; 25 leaders from Australia's largest

[54] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, NZ, 1-44.
[55] David M. Gann (1996) Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan, Construction Management and Economics, 14:5, 437-450, DOI: 10.1080/014461996373304
[56] Gosselin, C., Duballet, R., Roux, Ph., Gaudillière, N., Dirrenberger, J. and Morel, Ph. (2016), Large-scale 3D printing of ultra-high performance concrete – a new processing route for architects and builders, Materials and Design 100 (2016) 102–109
[57] Anna Kochan, (2000) "Robots for automating construction – an abundance of research", Industrial Robot: An International Journal, Vol. 27 Issue: 2, pp.111-113, https://doi.org/10.1108/01439910010315418
[58] Blismas, N., Pasquire, C. & Gibb, A. (2006) Benefit evaluation for off-site production in construction, Construction Management and Economics, 24:2, 121-130, DOI: 10.1080/01446190500184444
[59] Medina, M.A., King, J.B. and Zhang, M. (2008), On the heat transfer rate reduction of structural insulated panels (SIPs), outfitted with phase change materials (PCMs) Energy 33, 667–678
[60] Van de Lindt JW, Pryor SE, Pei S. (2010) Shake table testing of a full-scale seven-story steel-wood apartment building. Eng Struct 2011; 33(3):757–766. DOI: 10.1016/j.engstruct.2010.11.031.
[61] Folz B, Filiatrault A. (1999) Blind predictions of the seismic response of a woodframe house: an international benchmark study. Earthquake Spectra 1999; 20(3):825–851. DOI: 10.1193/1.1774989.
[62] Pang W, Rosowsky DV, Pei S, van de Lindt JW. (2010) Simplified direct displacement design of six-story woodframe building and pretest seismic performance assessment. J Struct Eng; 136(7):813–825. DOI: 10.1061/(ASCE)ST.1943-541X.0000181.

contractors came together to share ideas around increasing innovation and productivity in the building construction industry[63]. Our industry/government can learn more from Australia in respect of driving more innovations to improve productivity performance.

What can we learn from Australia on what Industry/Government can do to drive more innovations to improve productivity?

The recommendations that emerged from the discussions outlined below, point to the need for collective responsibility between industry, clients and government regulators in improving building construction industry innovation and productivity[64].

- Increase predictability of delivery
- Drive greater integration and collaboration
- Move to a service-based rather than a product-based delivery model
- Increase industry engagement with new technologies
- Improve project management and supervisory skills
- Deeper supply chain collaboration
- Workplace culture is critical
- Increase transparency and reduce uncertainty around project pipelines
- Provide enough time to plan and innovate
- Ensure realistic project planning and feasibility
- Review contract and procurement models
- Incentivise innovation
- Early contractor involvement
- More efficient regulation and reduced bureaucracy
- Attach greater value to good design
- Better use of data and analytics, and
- Increase R&D sponsorship

[63] Loosemore, M. (2015). How to ensure innovation and productivity in construction, Construction News, Available at https://sourceable.net/what-industry-leaders-say-about-construction-innovation-and-productivity/#
[64] As above.

2.5. Focus group findings

The major aim of this report was to provide insights on current innovation practices and performance of the industry that would inform the next stage of the research. The questions for the focus groups explored what innovation means; diffusing innovation; internationally successful innovation; internationally successful innovations; drivers and barriers; and possible ways by which the industry/government can drive more innovations.

What does innovation mean in the building construction industry? As explained by a facility manager, a workshop participant:

> *The subject is around improving upon what we currently do. How we improve our processes, the design and quality of products. The whole concept is sharing information in a shared learning environment that is problem-solving, risks involving, solutions are robust and value added to business.*

Understanding the meaning of innovation is insufficient as has been cited in the literature on various occasions[65]. Knowing why we should innovate, ability to innovate and implement innovations are also important. Innovation involves people doing something new. This newness involves three stages of development: ideas, actions, and outcomes. Each of these stages is a position along a continuum, and each is a necessary condition for the subsequent stage. When all stages occur, there is a fully-fledged innovation and a new technology is used to such an extent that there are material changes and social and/or economic impacts. In addition, it takes a team/collaborative effort to innovate and this principally involves the client, designer and contractor depending on the project delivery system. These actors/innovators must be prepared to bear the risks involved in the problem-solving process; this is challenging, and hence client value must be clearly defined.

What are the current methods used for diffusing innovation?

The workshop participants stressed that time is involved in diffusing innovation, in addition to the natural inhibiting factors related to 'giving away' innovations to your industrial

[65] A.M. Blayse, K. Manley, (2004) "Key influences on construction innovation", Construction Innovation, Vol. 4 Issue: 3, pp.143-154, https://doi.org/10.1108/14714170410815060

competitors if the 'secret' of how to do things better is shared around the building construction industry. The innovation decision process through which an individual within an organisation or other decision-making unit passes from first knowledge of an innovation to forming an attitude towards the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision.

Five steps were identified in this process: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. An individual seeks information at various stages in the innovation-decision process in order to decrease uncertainty about an innovation's expected consequences. The decision stage can lead (1) to adoption – a decision to make full use of an innovation as the best course of action available, or (2) to rejection – a decision not to adopt an innovation. In this context, a number of current methods used for innovating were mentioned by focus group participants as stated below:

i. There is need to embed a culture of removing the fear of giving ideas away. There is therefore a need to create a culture in which all employees are actively encouraged to put ideas forward in order to help firms innovate. But how do you get the best from people and encourage them to be at their most creative is a good question?
ii. Innovation forums – This gathering could be government/industry-sponsored or a national, non-profit organization formed to recognize and encourage innovation that improves quality, efficiency and cost effectiveness in construction. Such a forum's interest in expanding innovation awareness may extend to the show casing of innovators, showing innovation in action, supporting innovation networking, promoting innovation, and finding innovative contractors. Arguably this is in place through the existence of such industry events as 'Buildex' here in New Zealand. However inevitably this type of event tends to recruit a limited subset of the industry and is regionally specific in such events tend to only be held in Auckland.
iii. Formation of innovation groups by the government or industry to drive innovation.
iv. Raising awareness of the measurable effects of innovation both within the building construction industry and more widely in society. There is an apparent need to create a culture of innovation throughout society if our industrials capabilities are to improve according.

v. Showcasing innovations and innovators to the extent that the status of such individuals and organisations become cultural icons that affect change. This can be demonstrated in various ways e.g. advertising in social and professional media and has occurred in other industries such as with the creation of the image around, and impact of, 'Nano-girl' (Dr Michelle Dickinson) in the Biomedical Materials space. The very real question is 'Who is/are the ambassadors of construction innovation here in NZ?'

vi. Funding innovation by the government and multinational companies most particularly through research and development goes a long way to help the building construction industry.

vii. Development of a team ethos, rather than an individual focus, in organisations presents a significant opportunity to enhance the ability of companies to innovate. Internal collaboration among employees and team work or effort will help enhance the innovation process.

viii. Inclusion of innovation as a critical aspect of the non-price attributes of construction companies in government procurement policy will go a long way to add value to projects and products that our created by leading innovators. The reality is that government has a huge amount of power to influence and shape behaviour in the construction sector.

Can you think of successful innovations internationally which could be adopted or modified to work in New Zealand?

To gain an insight into the successful innovations internationally, the workshop participants gave an idea about the innovations and new technologies that are rapidly changing the construction sector and can be adopted or modified to work in New Zealand; these include the following:

i. The Sky tower panelling (structural insulation panels) system that was adopted in 1997 for the construction of Auckland's landmark building. There is no fundamental reason why this technology could not be adopted more widely into more mainstream of the construction sector;

ii. Zero energy buildings[66] were seen as presenting a significant opportunity to expand the capability and capacity of the NZ building construction industry. This is a building with zero net energy consumption. The total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site. These buildings consequently contribute less overall greenhouse gas to the atmosphere than similar non-ZNE buildings. They do at times consume non-renewable energy and produce greenhouse gases, but at other times reduce energy consumption and greenhouse gas production elsewhere by the same amount. A similar concept approved and implemented by the European Union and other agreeing countries is nearly Zero Energy Building (nZEB), with the goal of having all buildings in the region under nZEB standards by 2020. Traditional buildings consume 40% of the total fossil fuel energy in the US and European Union and are significant contributors of greenhouse gases. The zero-net energy consumption principle is viewed as a means to reduce carbon emissions and reduce dependence on fossil fuels and although zero-energy buildings remain uncommon even in developed countries, they are gradually gaining importance and popularity.

iii. Smart cities and the principles embodied in them was considered to be of import by the focus groups - The European Union (EU) has devoted constant efforts to devising a strategy for achieving 'smart' urban growth for its metropolitan city-regions. The EU has developed a range of programmes under 'Europe's Digital Agenda". In 2010, it highlighted its focus on strengthening innovation and investment in ICT services for the purpose of improving public services and quality of life. A smart city is an urban development vision to integrate information and communication technology (ICT) and Internet of things (IoT) technology in a secure fashion to manage a city's assets. These assets include local departments' information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. A smart city is promoted to use urban informatics and technology to improve the efficiency of services. ICT allows city officials to interact directly with the community and the city

[66] Sartori, I., Napolitano, A. Voss, K (2012) Net zero energy buildings: A consistent definition framework, Energy and Buildings 48 220–232

infrastructure and to monitor what is happening in the city, how the city is evolving, and how to enable a better quality of life.

iv. Mandatory building performance assessment monitoring in Europe (and elsewhere) has been seen to significantly increase the energy efficiency of buildings and their fitness for purpose[67]. It was believed that there is a significant opportunity to develop this type of capability in the NZ context and should be explored further.

v. 3D printing - Using 3D printing instead of current construction methods could be a more cost-effective process and create a new standard for housing construction in the future. The concept of 3D printing has been hovering around for some time now. The actual use of 3D printing and its adaption into the building construction industry is now starting to become a reality. Contractors around the world have built the first 3D residential structures including houses and apartment buildings. What makes 3D printing different from current construction methods? The 3D printing is done using super-size printers which use a special concrete and composite mixture that is thicker than regular concrete, allowing it to be self-supporting as it sets. Therefore 3D-printed components do not have the same design constraints that may hinder current construction methods. In addition, curved concrete structures created through 3D printing can be hollow, using less material and creating space for building services inside the structural elements. Not only could this revolutionize the building construction industry, but the less expensive process could also affect housing affordability. Lower material usage and lower labour costs create a less expensive construction method which can in turn create lower-cost housing.

vi. Prefab and modular housing - The emergence of building information modelling (BIM) is influencing design and construction processes and how project teams collaborate. The participants stressed that a key benefit of BIM is enabling the increased use of prefabrication and modularization, which in turn improves worksite productivity and overall project performance.

vii. Carbon emission control, both philosophically and through legislation has significant potential to affect (positively and negatively) the productivity of the building construction industry in NZ. There is an emergent need in NZ to 'get ahead' of the

[67] Schlueter,A., Thesseling, F. (2009), Building information model based energy/exergy performance assessment in early design stages Automation in Construction 18 (2009) 153–163

problem of emissions control – especially in the context of the wider international responsibilities of NZ – so that in the event of wider emissions control legislation is introduced it does not collapse construction productivity.

What are the drivers and barriers for innovation creation in New Zealand?

During the workshop sessions, a number of issues were identified as drivers or factors that create the need for organisations to innovate (drivers), and the reasons why the building construction industry is slow to innovate (barriers) respectively.

Innovation involves people doing something new. Consequently, the a*bility to create new ideas and implement them* should be the major attribute of an innovator and our creative ability lies in the development of our mind. *Understanding what we are trying to change* is very important and developing "why not approach" is a force behind the willingness to implement innovations. As potential innovators adopt this approach, barriers are turned to drivers, and threats to opportunities; they take the risks to succeed. Also, an innovator should have a *bold vision* towards building issues and other challenges (e.g. energy, infrastructure, transportation, etc) as well as *building industry technologies* (e.g. ICT, logistics, BIM, tools, new designs and products, techniques, etc). *Environmental issues* (e.g. emission of materials, air pollution) should not be left behind, as the strength to innovate effectively lies in this quality of having a bold and aspirational vision.

Innovation capture denotes having respect or recognition for the value of innovation as a driver for organisations or employees to create new ideas for their own immediate and future benefits. *Getting professionals from various disciplines* (architects, quantity surveyors, builders, planners, project managers, developers, etc) *to work together in innovative fields* will go a long way to ensure effective innovation and robust solutions. Similarly, *collaborative contracts* (e.g. alliance, public-private partnership, joint venture, partnering, etc) is a driver, as one is conscious of the fact that internal or external collaboration/team work among professionals, organisations/firms, government and industry will ensure efficiency during innovation process.

In addition, innovation brings success and higher profit to companies that engage in it. Therefore, such companies need to *define their profit margin* and this is a determinant for

innovation creation. Although, innovation is capital intensive and some people think they cannot innovate because it costs money, whereas the end result is higher profit. They lack understanding of the loop – is a lack of profit inhibiting innovation growth or is a lack of innovation inhibiting profit growth?

Having to show to people that innovation ensures positive results, *case studies and big data from case studies* are needed. Examples of successful innovations from other countries and organisations, and their best practice and performance can be seen as case studies providing some degree of confidence for future innovators by seeing the success that has been achieved by innovators elsewhere.

Meanwhile, barriers to innovation creation are the reasons why the building construction industry is slow to innovate. *Innovations are risk-based.* Innovation can be a company's most powerful tool and a key driver of value.

Many executives, fearful of the risks inherent in pursuing new ideas, may hesitate to unleash its full potential. Inevitably there is a difficult line between 'Leading Edge' innovations and 'Bleeding Edge' innovations. The former is seen as a positive for obvious reasons of market advantage and growth; the latter the inevitable consequence of trying to grow and introduce ideas ahead of their time and the ability of mainstream technology to cope[68].

They prefer, indeed, to renovate rather than to innovate – becoming the fast follower with proven concepts rather than the leading light. For example, 64 percent of the 519 companies in Accenture's 2012 innovation survey—a cross-industry sample of US, UK and French players — found only 20 percent viewed their innovation efforts as potential changers and 16 percent said they were using innovation to drive competitive advantage. An innovator needs to be bold to innovate and not being conservative. Having *uneducated clients/actors* that are conservative and they *lack understanding of their requirements as well value of innovation, training, fresh thinking/creativity, technical confidence/competence and knowledge development* could be responsible for such lukewarm or nonchalant attitude towards innovation.

[68] NARASIMHALU, A.D. (2005), Innovation Cube: Triggers, Drivers and Enablers for Successful Innovations, Singapore Management University Press

Condition of contract (NZS 3910) does not have innovation content and this document should encourage innovation. This needs to be reviewed to reflect a clause that bears innovativeness for practice. Another barrier is *bidding system (tendering).* If bidding is based on pricing and price is the main determinant for bidding success, the contractor with low price wins. Such a contractor may not be keen to include a transformational, innovative aspect to the tender. Moreover the newness of a solution may affect apparent and residual values in constructed property. For example if we consider the apparent versus residual values of an engineered timber building in comparison to standard concrete and steel construction, we can consider the problematic nature of new innovation in construction. How much will the timber building cost in terms of through lifecycle maintenance etc in the absence of empirical evidence and costings from such buildings constructed in the past? Is it reasonable to expect a client to specify a new technology that there is no ability to plan and cost model for? As one client said in a telling discussion with a researcher at a focus group:–

> *"I would love to have an engineered timber building as part of the university's commitment to environment sustainability and resilience. But how can I present this as an option to the University Council when I can't in all honestly tell them how much maintenance will be in 5 let alone 50 years' time? Similarly what will the residual value be in the same time period…. Let alone what building liability insurance is likely to be with unproven concepts. I know it is chicken and egg. At this stage I am chicken!*

Affordability to innovators is another barrier because thinking and implementing innovation cost money but this results in higher profit in the long run. In addition, *lack of data management* is a crucial issue that needs attention. Lessons learnt from projects completed are data that need to be compiled and kept. As projects are completed, they are discarded and their data are not used to improve proposed projects in the face of problem-solving exercise. It would seem apparent that the *government* needs to change its attitude towards innovation – especially in the domain of crown properties owned by ministries, councils, and other entities such as universities, colleges and schools etc as they are seen not having a *long-term plan,* support and goals for innovators. If anything government tend to discourage innovation in this space. Given the context of New Zealand and the recent

history of leaky buildings as the result of construction materials / planning / design innovations like monolithic cladding and internal guttering etc, it is not hard to understand the reticence of governmental bodies given their liabilities and the consequences of innovation failure.

How can industry/government drive more innovations?

The workshop participants pointed to the need for collective responsibility between the government and industry to be able to drive more innovations in the following ways:

i. Collaborative contracts (e.g. alliance, public-private partnership, joint venture, partnering, etc) can be used to drive more innovations (as previously mentioned), as one is conscious of the fact that internal or external collaboration/team work among professionals, organisations/firms, government and industry will ensure efficiency during innovation process.

ii. Shared best practice/Shared future vision – Holding periodical meetings/discussion is essential between industry leaders and government decision makers to share and mutual understanding towards the future of innovation.

iii. Case studies to be made generally available – As mentioned above, case studies are needed to show people that innovation ensures positive results i.e. Examples of successful innovations from other countries and organisations. At present another inhibitor for the industry is a lack of interest in or access to literature and findings from active research.

iv. Comparing projects – Failed practices that innovation could have saved can serve as a lesson to drive more innovations.

v. Better understanding of business improvements – Goals should be set and methods should be defined to achieve the goals. Understanding that business improves through innovation is a way to drive more.

vi. Once area flagged by multiple participants was the need to substantially rethink the standard methods of construction using timber as a means to increase timber use and the affordability of housing in NZ. With this in mind NZS 3604 for timber framed buildings was cited as being in substantial need of a rethink and expansion in order to take timber framed structures beyond their current limit of 10m. The

specification, as well as access and adherence to it, can be used as a tool to drive more innovations and this is useful to practitioners.

vii. Government policy/regulation with innovation clause will go a long way to add value to projects and products. This can be used to drive more innovations.

viii. Challenge and change what is currently understood by innovation in the NZ building construction industry - Investigations have revealed a substantial perceived inability of the industry to innovate effectively. This current state of the industry must be challenged to drive more innovations.

ix. Understanding what we are trying to change is very important and developing "why not approach" by the industry leaders and government is a force behind the willingness to implement more new ideas.

x. A need to look at New Zealand environment/NZ competence and capability – A solution for transforming the industry through innovation should be tailored specifically to New Zealand environment bearing in mind the NZ competence and capability to drive more ideas.

2.6. Future research in innovation

Potential future research questions include:

- Identify the actions/processes that organisations take to generate new ideas i.e. internal inputs of innovation?
- Identify the sources of new ideas/innovation, and to what extent does your organisation utilize the external sources of innovation?
- Identify the factors that are seen as significant in enabling innovation within your organisation (enablers of innovation), and to what extent do the factors help promote innovation within your organisation?
- Drivers of innovation have been identified in the study, but to what extent do the drivers create the need for your organisation to innovate?
- Barriers to innovation have been identified in the study, but to what extent do the barriers impede the uptake of innovation within your organisation?

- Who are the major actors of innovation (innovators) within the construction sector, and to what extent do you think the actors drive innovation within the construction sector?
- How can innovation be implemented in construction projects?
- What are the expected benefits/impacts (outcomes) of innovation, and to what extent does your organisation enjoy or derive the benefits?
- How do we assess the applicability of innovations for wider implementation in the NZ building construction industry?
- How can innovation contribute to a whole building life cycle approach in the building construction industry?

2.7. Recommendations

There is no single way to transform the building construction industry but rather a collection of changes that can support a cultural, technological and process shift. Creating a culture of innovation can influence both stakeholders and the whole industry, and their ability to innovate. Investment is an important input for innovation. Investing in people, technology and process, as well as conventional Research and Development (R&D) initiatives, will create an environment where innovation can support the building industry to prosper. Based on the findings are the following recommendations that can support this transformation to happen, turn barriers into drivers and most importantly, drive more innovations across the New Zealand industry.

Innovation and People: Innovation is driven by people having good ideas. Good ideas occur where there is a focus on outcomes, a culture of challenge of concepts, and there is space in the expected programme of work for people to think and test new ideas. There has been an industry acknowledgement that a skills shortage exists across the entire construction workforce. For this reason the following actions are recommended:

- Investing in enhancing existing and prospective industry-professionals' skills and capability.
- Providing individuals, teams and organizations with incentives (e.g. prizes, awards, recognitions) for ideas is a good motivator to nurture innovation culture.

- Implement effective and internationalized curricula in universities, polytechnics, technical colleges and apprenticeship schemes
- Offer training programmes at job centers and in collaboration with companies or the industry
- Enhance the attractiveness of construction professions through intellectual campaigns or media

Innovation and Process: With upfront investment in innovation, processes can drive efficiencies and generate value for businesses. For this reason, the following actions are recommended:

- **Research and Development (R&D):** Research and development provides an opportunity for ideas to be tested to ensure suitability for universal application. The opportunity provided by R&D to carry out a pilot study or project makes it an integral part of the innovation process. Investment in R&D by the construction industry has been low. Modern infrastructure and construction can benefit enormously by increasing R&D investment to exploit the use of new technologies to provide innovative new solutions, thereby making radical changes to the construction and management of infrastructure.
- **Data Acquisition:** Good data enables projects to start off on the right foot. It is crucial that there is investment in reliable data acquisition from the onset, as well as in an adequate capability to correctly interpret data. This ensures there is an application of sound science in the problem understanding process.
- **Knowledge sharing:** The ability to capture ideas for application in future projects or learning what others are doing through forums should be considered for investment. Platforms should be provided that allow for knowledge sharing and feedback can help ensure good ideas are not lost. Traditionally, the construction industry has not been proactive in sharing and learning from its successes and failures. The lack of knowledge capture from previous projects results in repeated mistakes. Knowledge sharing also promotes creative thinking and knowing what competitors are doing pushes others to think faster and raise better ideas, thus moving the industry forward. Collaboration between companies and different groups including academia, consultants, contractors and institutions results in a greater ideas' source to draw

from, faster development of ideas and shared benefits, with the industry moving forward together. Cultivating strong lines of communication within companies and encouraging knowledge sharing externally can lead to greater collaboration and innovation. In essence, knowledge sharing leads to better quality information enabling the industry to effectively harness ideas and promote innovations at all levels.

- **Marketing:** From identifying gaps in the market to generating new ideas is germane to promoting innovation. Promoting innovation both internally and externally is essential and is a key component in the innovation cycle to ensure it becomes embedded.

Innovation and Technology: Technological advances realize their full potential only when they are widely adopted across the industry. Acquisition of new technologies, materials and software will drive efficiencies and generate value for businesses.

Given the economic significance of the construction industry, the Government can have an important role in supporting the industry, academia and institutions to enhance R&D, technological innovation, education and training. In particular, the government can take the following steps:

- Providing financial support for demonstration projects involving new technologies and processes
- Setting up incentive schemes for innovation deployment
- Supporting centrally funded research institutions and joint industry-academia funds and technology centers
- Promotion and funding of R&D investments by the construction industry offering tax incentives and establishment of schemes for industry contested R&D funding
- Support workforce education, training and capability development through policy measures.

3. People

People are the biggest asset and at the core of the building industry through all levels and stages of the process. As has been mentioned previously, people are the source of the need for both the constructed product and any innovations it encompasses. People are the principle source of the funding for the construction process, the labour to deliver the buildings we need and ultimately the end users of the constructed facilities. In short people are the start and end of the construction process as well as contributing to all elements in between. For this reason, transforming the building industry should be initiated by creating a positive flow of new talent into the industry and retaining competent staff. The industry must focus on attracting the young generation and competent experts from other industries to guarantee a positive flow of new talent and establish a culture conducive to innovation and improved skills. This falls into the classic mantra of 'recruitment and retention' of critical human resources.

Emerging major construction companies who dominate the industry have an enormous impact on the building and construction workforce and the relationship between employers and the workforce. To get a maximum benefit from their technical and construction capabilities, some of the major building companies are management and financial shells, engaged in very limited direct construction activities and so employing minimum workforce who is directly engaged in physical construction activities[69]. These major building and construction companies tend to implement risk transferring strategies based on sub-contracting which creates an extended subcontracting chain. This strategy reduces profit margin for subcontractors and intensifies competitive pressures[70]. The competitive pressures weaken the commitment of employees to reskilling and upskilling their workforce, which will have pervasive impacts on the industry as a whole.

[69] McGrath-Champ, S., Rosewarne, S., & Rittau, Y. (2011). From one skill shortage to the next: The Australian building industry and geographies of a global labour market. *Journal of Industrial Relations*, *53*(4), 467-485.
[70] McGrath-Champ, S., & Rosewarne, S. (2009). Organizational change in Australian building and construction: rethinking a unilinear 'leaning'discourse. *Construction Management and Economics*, *27*(11), 1111-1128.

Currently the major challenge for the building industry is labour availability which is driven by a lack of interest among the younger generations and a demographic shift similar to other developed countries[71,72]. Similarly a shortage of skilled workforce is another serious challenge that needs to be addressed in order to realise lasting transformation[73]. The industry urgently needs to create a strategic workforce plan to meet current and future skills and capability demands.

3.1. Labour shortages

Based on a literature review and results obtained from focus groups, the followings are identified as roots of labour shortages in New Zealand building construction industry:

3.1.1. Construction demand

The industry is experiencing a significant growth driven by the Canterbury rebuild, Auckland housing investment, leaky home remediation and major infrastructure projects. According to The National Construction Pipeline Report 2016, construction activities will increase across the country. The current trend indicates that labour demand will increase by 49,000 between 2015 and 2021[74]. Over 27,500 were employed in the building industry in the year to December 2015. Nevertheless, the industry is facing significant shortages in labour.

The participants in this research project highlighted the significance of this issue which negatively affects their businesses and the overall performance of the industry. Since the Canterbury earthquake, the industry has struggled to handle the demand for a skilled workforce and now the industry cannot find sufficient number of unskilled labourers to cope with the construction demand especially in the housing sector. Currently, the industry is capable of building almost 60% of houses needed in 2017. This situation pushes the industry to get away from the traditional workforce (European male, aged 35-59) and diversify its human resources. According to the participants, the

[71] BCITO (2013) Older workers in the building industry
[72] WEF (2016) Shaping the Future of Construction, A breakthrough in Mindset and Technology
[73] PWC (2016) Valuing the role of construction in the New Zealand economy
[74] MBIE (2016) Future demand for construction workers

industry needs to attract more women, provide career pathways for Maori, and support migrants with appropriate technical, experiential and language skills to seamlessly enter the New Zealand building construction industry.

3.1.2. Demographic changes

Demographic shifts in terms of career choices and aspirations, alongside an aging workforce amongst existing tradespeople, put further stress on the building industry across the world and negatively affects the availability of labour. For instance, the number of construction workers ages 55 and over in Queensland (AUS) has increased from 8% of full-time workers in 1992 to 14.2% in 2014[75]. In the U.S, the portion of "soon to be retired" among construction labourers increased from 25% to 40% between 1985 and 2014[76].

Similar to other developed countries, the employment share of older workers in New Zealand building construction industry increased between 2000 and 2007[77]. According to Department of Labour (2009), 18% of workers in the building industry are aged 55 to 64[78]. These older workers tend to have both the experience and skills that puts them in high demand – even more so in the context of recent substantial growth in the construction demand throughout the country. Unfortunately, the physical demands of the building construction industry, even at the high end of the skills spectrum, is such that increasingly these older workers are not able to keep up with the demands being made upon them. This in turn significantly reduces their efficiency and productivity. In addition, using aged workforce on construction sites creates further challenges for construction/site managers to provide a working condition to match physical and health conditions of their aging workers as part of their responsibility due to new Health and Safety Act. All these factors impose enormous costs to construction companies and exacerbating the chronic affordability crisis especially in the housing sector.

[75] ABS (2015) Labour workforce, Australia, Detailed.
[76] WEF (2016) Shaping the Future of Construction, A breakthrough in Mindset and Technology
[77] BCITO (2013) Older workers in the building industry
[78] Department of Labour (2009) The working patterns of older New Zealanders

3.1.3. Unattractive for the young generation

Few younger men and women see construction jobs as desirable – a feature of the industry that has been seen to be problematic for some years[79]. The lack of technology and innovation and poor health and safety records[80] make the industry less attractive for the young generation[81]. Lack of investment in R&D and innovation makes the industry unattractive to talent who prefer to follow their dreams in a other high-tech and innovative working environments. Studies conducted in the U.K found that the majority of young people perceives construction as low status, dirty and badly paid[82,83].

The New Zealand building construction industry lacks diversity and it is actually becoming more male dominated amongst the trades in particular. Men significantly outnumber women in the New Zealand building industry. According to NZ Statistics women make up only two percent of all building trade workers in New Zealand, while the 2013 Census shows that only five percent of those employed in construction were working in the trades and 37% were working in clerical roles[84]. In contrast, only one percent of men in the industry worked in clerical positions. This situation makes the industry less attractive to young females. Therefore, the building industry loses almost half of the young workforce to other industries.

Furthermore, the current recruiting practice in the building industry causes further issues in attracting the younger generation. Demand for specific workers in building and construction is a function of experience. Therefore, young graduates with a lack of experience face major barriers to entry and find it very difficult to obtain a job.

[79] Murray, M., Chan, P. and Tookey, J. (2001) Respect for people : looking at KPI's through 'younger eyes'! In: Proceedings 17th annual ARCOM conference. Association of Researchers in Construction Management (ARCOM), UK, pp. 671-682. ISBN 095341616X

[80] Bentley, T. A., Tappin, D. C. and Legg, S. J. 2004. An exploratory analysis of falls in New Zealand small business residential construction. Occupational Safety and Health: Australia and New Zealand, 20: 539–546.

[81] Gillena,M., Baltzb,D., Gasselc, M., Kirschd,L., Vaccaro, D. (2002) Perceived safety climate, job demands, and coworker support among union and non-union injured construction workers, Safety Research 33, 33– 51

[82] Marriott, J., & Moore, N. (2014). NHBC Foundation: improving recruitment of young people into home building: a literature review. University of Derby.

[83] London Chamber of Commerce and Industry / KMPG 'Skills to Build' report (2014)

[84] Statistics New Zealand (2015). Women at work: 1991–2013. Available from www.stats.govt.nz

3.1.4. Cyclical nature of the industry

The cyclical nature of the industry produces unexpected shocks with significant impacts on employment[85,86]. The development and retention of suitably skilled and experienced personnel in the construction sector are highly vulnerable to cyclical demand. Therefore, labour shortages are exacerbated by this characteristic of the industry. It is a common practice in the industry to lay off a large number of labourers due to insufficient workload. In every bust period, many of those trained labourers leave the industry for more "predictable" opportunities in other industries and rarely return[87]. Attracting labourers who left the industry is costly or even impossible as many of them do not want to take the risk and return to an industry with high levels of uncertainty. The cyclical nature of the industry also negatively affects recruitment of new employees as the industry is known as an unstable career choice[88].

3.2. Skills shortage

The New Zealand building construction industry has exhibited an upskilling trend over recent years[89]. The rationale for this is related to the increase in building code and standards, as well as the efforts to professionalise the industry through the introduction of initiatives such as the Licensed Building Practitioner (LBP) etc. Consequently it has become a significant challenge for the industry to find sufficient skilled labourers to cope with demands being placed upon it. The industry also has difficulties to attract a sufficient number of appropriately qualified project managers, site manager/supervisors and designers (in particular engineers). As far as the focus group and interviews were concerned, the participants have identified skill shortage as the major issue that reduces productivity and building quality (discussed in section 3.4).

[85] Fan, R. Y. C., Ng, S. T., & Wong, J. M. W. (2011). Predicting construction market growth for urban metropolis: An econometric analysis. Habitat International, 35(2), 167-174.
[86] Quezada G, Bratanova A, Boughen N, and Hajkowicz S. 2016. Farsight for construction: Exploratory scenarios for Queensland's building industry to 2036. CSIRO, Australia.
[87] McGrath-Champ, S., & Rosewarne, S. (2009). Organizational change in Australian building and construction: rethinking a unilinear 'leaning'discourse. *Construction Management and Economics*, *27*(11), 1111-1128.
[88] PWC (2016) Valuing the role of construction in the New Zealand economy
[89] Construction and Infrastructure Sponsor Group (2014) Workforce Skills Roadmap for Auckland Construction Sector (2013-2018).

The majority of employees in the building and construction industries have either low level or no qualification[90]. For example, only seven percent of construction employees have bachelor or higher degrees – which is well below the national average of 24%[91].. The key issue for the industry at this transition period is whether construction companies are willing to invest their resources on training and upskilling their workforce.

Education and training plays a significant role in skilling and upskilling the construction workforce. The cyclical nature of the industry also negatively affects any investment in training and upskilling programs across the industry[92]. The cyclical nature of the industry makes investment on training and human capital less attractive for building and construction companies and their employees. Consequently, construction companies consider it as a risky investment due to the high industry turnover. While from the employees' point of view, it is not justifiable to invest time and money on training for a career that is temporary and project-based. The number of employees in the industry changes significantly between boom and bust parts of the cycle[93]. In this situation, only large-scale companies can offer official training for certain roles and for the small percentage of their employees that the companies can retain even during downturns of the sector. However, such practices are not practical for small businesses.

Finally, over the next 10-15 years the nature of the building industry will change significantly due to emerging new technologies that at present are in their infancy. As a result of dramatic technological change, new jobs and competencies will emerge and many current jobs and position will fall away. These new roles will require new skills that have never existed previously in the industry. This creates further challenges for the industry to prepare and train a sufficient number of skilled workforce to implement such emerging technologies.

[90] MBIE (2013) New Zealand Sectors Report 2013, Construction
[91] MBIE (2013) New Zealand Sectors Report 2013, Construction
[92] New Zealand Productivity Commission (2012) Housing Affordability Inquiry
[93] Buckett, N,R., (2013) Advanced Residential Construction Techniques for New Zealand, BRANZ

3.3. Focus group findings

There were a range of interesting observations and findings that were extremely useful in informing this study.

- Construction companies prefer to hire experienced workforce rather than inexperienced fresh graduates. According to industry participants

  > "*The main issue for the young generation is recruitment. Based on our communication with HR, they are more interested in experienced applicants than fresh graduates with no experience in the industry*".

  In this situation, it is very challenging for fresh graduates to get an opportunity in the industry. This has caused a significant barrier for entry into the industry.

- According to a builder who has been working in the industry for more than 25 years:

  > *We have a cyclical industry. We turn the people out when the industry is experiencing a recession. Now, we are dragging people in, but if we dive down we are going to kick them out. If they do not want to leave New Zealand they have to leave the industry. Young guys are not going to work in the construction if we cannot give them a sense of job security. We are wasting so much resources because of cyclical nature of the industry.*

  A lack of appropriate government intervention to control the boom-bust cycle of the industry causes significant issues in attracting young talent and retaining current staff. The younger generation, as has been shown, does not consider construction as a secure career pathway. In addition to attracting the younger generation, current staff may also seek more secure job opportunities in other industries or migrate to overseas for better and more reliable opportunities in the building industry. In every boom cycle, the industry trains many people to meet the emergent demand. However, during downturns many of the trained workforce must leave the industry or even the country and often never to return. This imposes a significant loss to the industry and more broadly to New Zealand society.

- Lack of technology and innovation make the industry less attractive to the younger generation who prefers to work in more automated and high-tech working environments.

> *New Zealand's building industry is a traditional and low-tech. So the young people like my kids who brought up with computers are not interested in such environment. Other industries are utilising really advance technologies and very hi-tech stuffs. But, our industry is still so low-tech and far behind them. The young generation want to see more BIM and high technology in the industry. We are getting too traditional and boring for them*.

A apparently low-tech industry such as construction cannot compete with other industries in attracting the younger generations unless the industry invests in R&D, promotes innovation and demonstrates a broad implementation of technologies to change the low-tech and traditional image of the industry.

- The industry finds it increasingly difficult to retain older workers because of the physically demanding on-site construction activities which are a common feature of the building industry.

> *I have a 52 years old mate with many years of experience in the industry is trying to get out of the business as he cannot cope with the pressure and he wants an easier life. With the current way of working we cannot retain people like him in the industry. Simply because it so hard for their age to handle the work pressure*.

Thus, many of the older workforce may prematurely end their career in the industry if they cannot find a suitable role in the industry.

- Other industries are seemingly more successful in engaging with the young generation and introducing their opportunities than the construction. According to a senior quantity surveyor:

> *The young generation are not familiar with many construction professions or the roles and prospects that they can be expected to perform*.

Thus professional associations perhaps need to engage more strategically with schools in order to expose the profession to students as an option for their future career. The professional groups and associations possibly need to invest in the process of connecting with young people and schools to promote current and future opportunities in the industry.

- Many participants highlighted the significant impact of skills shortages on the industry workforce and its ability to deliver on-time and on-budget.

> *We are always going to be a shortage of people [now and future]. It is a fundamental issue for the industry. There never going to be enough skilled people in the industry. So we need to change the way we are working*.

The industry cannot get a sufficient number of skilled workforce to meet market demand through traditional on-site construction methods. Shifting to off-site construction methods such as prefabrication could assist the industry to meet the demand and on the other hand minimise the negative impact of skill shortage on the performance (or more specifically the output) of the industry.

- Improving the quality of buildings (especially in the housing sector) is a critical topic for the industry and the government.

> *Currently there is an ongoing debate on a new legislation to transfer liabilities back on to builders rather than councils. The consequence of this liability shift on people turnover can be significant*.

New legislation such as Health and Safety Act, licenced building, new insurance legislations and potential changes in regulations to shift the liability to builders will mean many will exit the industry. Transferring liability should be based on acceptable solutions and observation rather than 'blame'.

- Current training systems are still teaching low-tech and traditional building methods. There is little difference in building technology employed today compared to that used 70 or 80 years ago. According to an architect:

I often visit training centres across the country, trainees still are learning traditional and low-tech building methods. There is a lack of futuristic vision in the construction training systems that we employ – the emphasis is more of the same and steady as she goes.

- Currently, the building industry is not the first choice for many women for a variety of reasons. As one female participant observed:

  We have a man culture thing in the industry. We have to change this culture in our working environment. Is this culture open to women? Is it attractive to them? Changing the working process and new technologies can also facilitate presence of woman in the industry.

  To attract women into the industry, cultural and technical aspects of the industry need to be changed and improved. Shifting from traditional working methods can attract more women into the industry. Car manufacturers provide a useful counterpoint to the traditional world view of the building industry[94].

- Currently, there appears to be a gap between the building industry and the education system, especially in universities. As noted by one a senior project manager:

  "*It is a very common practice among construction companies to train graduate from the scratch and prepare them for actual construction works*".

- The proportion of Maori in the building industry is higher than the industrial average in New Zealand. Over 20% of the Maori workforce in the industry is under 25 years but they make up a large proportion of low skilled labourers. As stated in this report and previous studies, there is large demand for a skilled workforce in New Zealand building industry. However, this opportunity is not being realised by or for Maori at present. Generally, low skilled labourers are more vulnerable to cyclic effects of the industry. They are by their very nature more unstable in their tenure of employment. It indicates the importance of skills training in general, as

[94] Hasewaga, Y. (2006), Construction Automation and Robotics in the 21st Century, ISARC2006, 565-568

well as the up-skilling in particular, of Maori. Despite the importance of this issue for the building industry and the Maori community, the three summits found deep seated challenges that negatively affect skilling and up-skilling Maori.

From their perspective:

I. The loss of the Trade Training Scheme and access to apprenticeships was a significant loss.
II. Historically, there is a strong connection between Maori and buildings, indeed one that is perhaps not realised fully by Maori.
III. The impact of policy. Issues of compliance and education disproportionately affect Maori.

From training providers/employers' perspective:

I. "*Being able to turn up on time with the tools*". Some participants from training organisations and construction companies found it difficult to get some young Maori on time and prepared at work. This situation sometimes stops employers from hiring.
II. The need to take apprentices out of their current living situations to be in a more 'hostel' like one that was the *key for the Maori Trade Training Schemes*.

3.4. Future research in people

Transformation of the building industry cannot be achieved in the absence of competent workforce. Feedback from the summits and our literature review suggests that the industry needs to become more proactive and develop a strategic workforce plan as a response to current and future challenges. This transition requires a close collaboration across the industry and full support from professional and trade bodies as well as Government.

Potential future research questions include:

- How can the public image of the industry be improved to be recognised as a reliable career pathway for the young generation and high skilled professionals from other industries?
- What are the critical steps that should be taken to promote diversity across the industry?
- How can the industry and businesses be prepared for the transition to a future of higher skilled jobs and to invest in upskilling today?
- How can continuous training and knowledge management be institutionalised across the industry?

3.5. Recommendations

- Policy

  The industry should diversify the workforce in order to meet challenges of the future. This could include new forms of contract, staircasing and engagement with educational institutions. The goal is to create a dynamic and open industry with a diverse workforce to be the true representative of New Zealand society as a whole.

- Industry Training

  The industry needs to implement new attraction and retention strategies to be able to compete with other industries for qualified, competent, skilled and experienced professionals. Industry training appears to be a key component of such a strategy.

- Doing It Better

  Using hi-tech and off-site construction methods such as prefabrication reduce the need for physically demanding on-site activities and manual labourers. This can provide opportunities to attract more young people and woman to the industry. Using high-tech and off-site construction methods also create a new set of skills and job opportunities.

- New Technologies

Emerging virtual and augmented reality technology can transform and improve the quality of training process in the building industry. Implementation of this technology in the training process can significantly improve health and safety and productivity across the industry.

- Apprentices

  In order to overcome barriers to include more Maori within the industry

  - Establish a more meaningful engagement between the industry and the Maori community. For instance, connecting career paths with the Maori community and Maori's values.
  - Providing a better access to training and new technologies through a more direct connection to training providers.

- Connection to Clients

  Overall the building industry probably needs to gain a deeper client understanding of how and where the industry provides 'value'. This could also include interaction with the educational institutes across the educational spectrum. The goal has to be 'leave no-one behind'.

4. Technology

New Zealand is a developed country located in the South-western Pacific Ocean, with a total land area of 270,500 square kilometres and a population of about 4.5 million people. It has great potential for improvement in the construction sector of its economy[95]. Given the complementary relationship of the construction industry to other sectors[96], it is recognised as an important determinant of national growth[97]. Generally, construction is vital to economic development. According to PricewaterhouseCoopers[98], the sector plays a large role and dominates national investment in the NZ economy. While MBIE[99] claimed that it contributes about 6.3% to the gross domestic product (GDP) and represents over 40% of the national budget revenue; PWC[100] affirmed that construction accounts for more than 8% of employment creation and an average of 50% of the gross fixed capital formation (GCFC). Thus, ensuring the continued sustainability and development of this industry is crucial. However, Miller and Warren[101] argued that despite the important role the industry plays within the country, it is still inefficient. This is especially regarding contract management, as characterised by low productivity (lack of skilled resources), quality, health and safety issues and unpredictability in project delivery within budget and on time. Of these challenges, creating a productive sector through innovative technology tends to be predominant, owing to its economic impact.

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[95] Allan, N., Yin, N. and Scheepbouwer, E. (2008), A study into the cyclical performance of the New Zealand Construction Industry. Christchurch, New Zealand, 1 - 64.

[96] Lai, K.S., Yusof, N., and Kamal, E.M. (2016), Innovation orientation in architectural firms, *Construction Innovation,* 16(4), 425-445.

[97] Same as Footnote 96.

[98] Pricewaterhousecoopers (2011), Valuing The role of construction in the New Zealand economy, The Construction Strategy Group, New Zealand, pp. 81.

[99] Ministry of Business, Innovation and Employment (2014), Annual Report, New Zealand Government, New Zealand.

[100] Same as Footnote 98.

[101] Miller, G., and Warren, A. (2008). New Zealand construction industry vision 2025, Construction Excellence (NZ) Ltd, New Zealand, 1-50.

Meanwhile, the building site of the future will look very different from one of today. Instead of a total reliance on hands on labour, technology will inevitably become more prevalent. In addition to a reduced number of people in high visibility vests and hard hats (hard to picture them gone completely in the foreseeable future!), there will be drones flying overhead giving live progress reports, robotic bulldozers and 3D concrete printers will produce new buildings.

Is this a step too far to consider? Not really. In Shanghai, for example WinSun used a 3D printer to print 10 full size houses from recycled concrete material in one day[102]. In this country, by contrast, innovative practice in the construction industry seems to be at product level, and transformative technologies that are rapidly changing the sector have been documented[103] and discussed in the next section of this report. Innovative technologies are being developed and introduced at a rapid pace within the building industry[103].

In 2010, the construction industry in New Zealand established the Building and Construction Sector Productivity Partnership[104] to actively address the issue of low productivity in the sector. Although the early focus was on identifying and quantifying the problems that lead to low productivity, over the recent years the focus has shifted to problem solving and addressing the cultural and mechanistic change that is need to resolve the well documented problems[105]. One of the areas that the partnership has identified as critical for achieving significant improvements in the sector's productivity is innovation and technologies. The ultimate goal of 20% productivity improvement by 2020, cannot be achieved by repeating the old ways of doing things. New innovative approaches are required in order to significantly improve performance at the same cost or maintain the same level of performance at much lower cost. Unfortunately, the construction industry is one of the least innovative sectors compared to other

[102] https://3dprint.com/38144/3d-printed-apartment-building/

[103] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, New Zealand, 1-44.

[104] http://www.mbie.govt.nz/info-services/building-construction/skills-innovation-productivity/productivity-partnership

[105] Wilkinson, S., Kempton, T., and Gleeson, A. (2012). *Identifying Canterbury Rebuild Project KPI's (Baseline Report).*

industries such as manufacturing and traditional services[106]. The research and development report produced by Statistics New Zealand indicates that R&D expenditure in the construction industry accounts for a low 5% of the total expenditure in the sector[107]. 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[108].

Many studies suggested that new ways of organising construction work, e.g. through industrialised building[109], architectural management[110], building information modelling[111], lean management[112] and new contractual forms[113], can help overcome barriers and change the direction of the industry. Still, change has proved difficult to accomplish[114&115]

Furthermore, going digital is another effort that can help industry increase their overall efficiency through productivity increase in data management. Increased digitization of a society will involve industries and this seems to boost innovative practice in the private sector[116]. Some of the technological shifts that are driving ongoing digitization are the Internet of Things (IoT), which enables connectivity of a vast array of objects, and remote monitoring and control through online platforms, as well as big data analytics, advanced robotics, and new forms of visualization through augmented and virtual reality. Europe's digital frontrunner countries are making

[106] 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.
[107] Statistics NZ. (2012). Research and development survey, Available at http://www.stats.govt.nz/browse_for_stats/businesses/research_and_development/ResearchandDevelopmentSurvey_HOTP2012.aspx
[108] 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.
[109] Brege, S., Stehn, L., and Nord, T. (2014), Business models in industrialised building of multi-storey houses, Construction Management and Economics, 32(1/2), 208-226.
[110] Emmitt, S. (2016), The construction design manager – a rapidly evolving innovation, *Architectural Engineering and Design Management,* 12(2), 138-148.
[111] Jensen, P.A., and Johannesson, E.I. (2013), Building information modelling in Denmark and Iceland, *Engineering, Construction, and Architectural Management,* 1, 99-110.
[112] Hook, M., and Stehn, L. (2008), Applicability of lean principles and practices in industrialised housing production, *Construction Management and Economics,* 26(10), 1091-1100.
[113] Kadefors, A. (1995), Institutions in building projects: implications for flexibility and change, *Scandinavian Journal of Management,* 11(4), 395-408.
[114] Sunding, L., and Ekholm, A. (2015), Applying social sciences to inspire behavioural change in the construction sector: an experimental study, Construction Management and Economics, 33(9), 695-710.
[115] Hemstrom, K., Mahapatra, K., and Gustavsson, L. (2017). Architects' perception of the innovativeness of the Swedish construction industry, *Construction Innovation,* 17(2), 244-260.

faster and broader digitization a top priority and providing strong European leadership at the highest political levels to guide cooperation across nations to secure future growth and employment. As explained in the Boston Consulting Group report[116] digitization constitutes a transformative in technology across industry and society in general. The economies of the nations described as frontrunners (Denmark, Belgium, Netherlands, Sweden, Estonia, Ireland, Finland, Norway, and Luxembourg) are to a greater extent driven by economic activities related to the Internet and information and communications technology (ICT).

All of the cited countries are characterized by having a relatively small population and being well-digitized, innovative, and export-dependent, making them more dependent on easy access to a large digital market. In effect clearly relevant exemplars which are largely similar in economic structure and outlook as is New Zealand.

4.1. What do you see as new transformative technologies for the building construction industry?

Advances in technology are widely regarded as major sources of improvement in the competitive position of firms and industries. However, the benefits from technological advances depend on the extent to which these technologies are utilized[117]. It is noteworthy that the construction industry is slow in adopting new technologies with negative consequences on productivity and international competitiveness. Therefore, the need to accelerate the rate of technological innovation in the industry is essential, and this has to be identified and documented.

As evidenced in Gledson and Phoenix's[118] "Exploring organisational attributes affecting the innovativeness of UK small- and medium-sized enterprises (SMEs), responses from large companies and SMEs identified a large number (53) of innovative

[116] Alm, E., Colliander, N., Deforche, F., Lind, F., Stohne, V., and Sundstrom, O. (2016). *Digitizing Europe: Why northern European frontrunners must drive digitization of the EU economy,* The Boston Consulting Group's Report, Retrieved from http://image-src.bcg.com/BCG_COM/BCG-Digitizing-Belgium-Sep-2016_tcm89-43129.pdf

[117] Mitropoulos, P., and Tatum, C.B. (2000). Forces driving adoption of new information technologies, *Journal of Construction Engineering and Management,* 126(5), 340-348.

[118] Gledson, J., and Phoenix, C. (2017). Exploring organisational attributes affecting the innovativeness of UK SMEs, *Construction Innovation,* 17(2), 224-243.

technologies (product/process) that had been adopted or implemented over the previous two business years. These include:

- New product technologies, including quick drying paint
- Increase range of mechanical and electrical (M&E) products that can be installed on site
- Lighting controls, door entry systems, fire alarm systems and various control systems
- Air source heat pumps and wireless sensors
- iPad based progress reporting – start of BIM
- Structural insulated panels (SIP) method of framed construction
- 3D surveying software
- Microsoft SharePoint (collaborative) software systems for Project Managers
- Quick drying adhesive for tiles
- Lumion 5.3 software
- Thermoplan Ziegel blocks
- BIM total workstation
- Rhino deck platforms
- Metsec steel frame
- New CAD (technology)

Another segment of project performance is safety management on which digital technologies are increasingly used to support in the construction industry. We are living in a digital age. Digital technologies (DTs) have changed the way people live, work, communicate, and learn. The past two decades have seen a growing interest among researchers in applying DTs to safety management. A powerful motivator is that construction safety performance has attained a plateau and that DTs have promising potential to eliminate the bottleneck. It is widely believed that DTs can improve limited human conditions and thus revolutionize traditional safety

management process which is largely manual, time-consuming and error-prone[119]. In Guo et al.'s[120] study, 15 DTs were identified, which include the following:

- Real-time location system and proximity warning (RTLS-PW)
- Building information modelling
- Augmented reality (AR)
- Virtual reality (VR)
- Game technology (GT)
- E-safety-management-system (ESMS)
- Case-based reasoning (CBR)
- Rule-based reasoning (RBR)
- Motion sensor (MS)
- Action/Object recognition (AR/OR)
- Laser scanning (LS)
- Physiological status monitoring (PSM)
- Virtual prototyping (VP)
- Geographical information system (GIS)
- Ubiquitous sensor network (USN)

The main purpose of these technologies is to track workers, materials and equipment, and provide real-time warnings when workers approach hazardous areas[121]; this ensures productivity improvement besides safety enhancement. This function is significant because construction seems to be highly dynamic in nature and that hazards emerge due to the dynamics. This tends to pose a huge threat to workers managing the dynamics constantly. For example, traditionally workers are notified about the hazards involved before they perform a task. They have to rely on their own experience and skills to manage both identified and unidentified hazards by utilizing their safety knowledge and adjusting their behaviour. However, such an ability is highly subject to human and contextual factors such as safety awareness, safety

[119] Guo, B.H.W., Scheepbouwer, E., Yiu, T.W., and Gonzalez, V.A. (2017). Overview and analysis of digital technologies for construction safety management, *41st AUBEA,* Melbourne, 1-10.
[120] Same as Footnote 119.
[121] Luo, X., Li, H., Huang, T., and Rose, T. (2016). A field experiment of workers' responses to proximity warnings of static safety hazards on construction sites, *Safety Science,* 84, 216-224.

motivation, work pressure, and peer pressure[122]. Similarly, digital technologies that include digital sensors, mobile devices and software applications integrated with a central platform of Building Information Modeling (BIM) can significantly minimize the total life-cycle cost of a project[123]. In addition, adoption of transformative technologies such as ICTs, off-site fabrication, robotics, materials management systems, automated tracking and GPS, cameras and bar coding technologies, mobile technologies, and augmented reality can lead to significant productivity improvements[124].

In New Zealand, as has been previously mentioned, innovative practice in construction has tended to be focussed at product level rather than in terms of projects or firms[125]. The construction sector is constantly changing, and so are all of the fields within it. Innovations and new technologies that are rapidly changing the sector include[126]:

- 3D printing
- Robots
- New materials and building techniques
- Smarter tools
- Prefab and modular housing
- Structural insulated panels (SIPs)
- Cross Laminated Timber (CLT), and various other new forms of laminated timbers that allow for fast builds with high strength, insulation and integrity.

4.2. How can Transformative Technologies be adopted?

According to Mitropoulos and Tatum[127], adoption in this perspective is the process by which an individual or organisation identifies and implements a new technology[127]. Thus, adoption refers to the same process as diffusion but from the perspective of the

[122] Same as Footnote 119.
[123] Teizer, J., Allread, B.S., Fullerton, C.E., and Hinze, J. (2010), Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system, *Automation in Construction,* 19(5), 630-640.
[124] Yi, W., Chan, A.P., Wang, X., and Wang, J. (2016), Development of an early-warning system for site work in hot and humid environments: a case study, *Automation in Construction,* 62, 101-113.
[125] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, New Zealand, 1-44.
[126] Same as Footnote 125.
[127] Mitropoulos, P., and Tatum, C.B. (2000). Forces driving adoption of new information technologies, *Journal of Construction Engineering and Management,* 126(5), 340-348.

adopting unit or organisation. Diffusion is the process by which a new technology becomes accepted and used by its potential users[128]. In this context, adoption therefore examines how new ideas are encouraged and moved through a particular social system. International literature views adoption of new ideas as a means of developing and communicating a new idea through certain channels, and is a key activity in the transformation process[129]. This relates to the adoption of new ideas, methods and products within a social system[130]. However, it has been observed that in the context of construction, new technology and/or innovation materially increased by the degree to which labour move ('churns') between regions. In the specific situation of NZ, this labour mobility is generally quite low between the regions[131].

Similarly, Rogers[132] viewed innovation diffusion (i.e. communicating a new idea through certain channels) as a key activity in the innovation process. Further, Shibeika and Harty[133] discussed the theory of innovation diffusion and they examined how new ideas move through a particular social system. Following Rogers[132], Shibeika and Harty[133] reported that early studies of diffusion investigated a wide range of innovations within varied homogeneous social systems like tribes and communities. According to Rogers[132], the focus of these early studies was on individual innovation adoption behaviour which consists of five stages[134,135,136&137]:

- Knowledge, where awareness and knowledge about the innovations arises;
- Persuasion, where a favourable or unfavourable attitude is formed about the innovation;
- Decision, where decision about adoption of the innovation takes place;

[128] Same as Footnote 127.
[129] Lindgren, J., and Emmitt, S. (2017). Diffusion of a systemic innovation: a longitudinal case study of a Swedish multi-storey timber house building system, *Construction Innovation,* 17(1), 25-44.
[130] Howaldt, J., Schwarz, M., Henning, K., and Hees, F. (2010). *Social innovation: concepts, research fields and international trends,* IMA/ZLW.
[131] NZIER (2013) Construction Productivity: An evidence base for research and policy issues, https://nzier.org.nz/static/media/filer_public/6e/73/6e73e3ad-7973-42ed-8b30-aa57df2bba78/nzier_report_to_productivity_partnership.pdf
[132] Rogers, E.M. (2003), *Diffusion of innovations,* 5th Edition, Free Press, New York.
[133] Shibeika, A., and Harty, C. (2015). Diffusion of digital innovation in construction: a case study of a UK engineering firm, *Construction Management and Economics,* 33, 453-466.
[134] Rogers, E.M., and Shoemaker, F.F. (1971), *Communication of innovations: a cross-cultural approach,* 2nd edn, The Free Press, New York, NY.
[135] Rogers, E.M. (1962), *Diffusion of innovations,* 1st edn, The Free Press og Glencoe, New York, NY.
[136] Rogers, E.M. (1983) *Diffusion of innovations*, 3rd edn, The Free Press, New York, NY.
[137] Same as Footnote 132.

- Implementation; and
- Confirmation, which is about reinforcing the decision already made.

Further developments extended this research to examine the diffusion of more complex technological innovations like information systems in heterogeneous social systems such as schools, hospitals and organizations[138&139]. These studies argued that the innovation adoption process is more complex in organizations than among individuals[140]. Meanwhile, Rogers[141] identified five stages for the innovation process in organizations, but classified into two main processes:

- Initiation, where agenda setting and matching is included; and
- Implementation, which includes redefining/restructuring, clarifying and routinizing.

However, current research in diffusion explains innovation processes not only within organizations, but also across projects and markets (Shibeika and Harty, 2015)[142]. For example, Garud et al. and Shibeika and Harty[143&144] documented a process approach for innovation that identified the complexities associated with innovation processes in more complex and heterogeneous social systems:

- Co-evolutionary complexity, which relates to multiple levels of analyses for innovation and diffusion;
- Relational complexity, caused by the interaction between social and material elements of the innovation and diffusion processes;
- Temporal complexity, influenced by the fact that innovation and diffusion processes are characterized by multiple temporal experiences; and
- Cultural complexity, relating to innovations being contested within different contexts and they do not diffuse without being transformed by the contexts.

[138] Rogers, E.M. (1995), *Diffusion of innovations,* 4th edn, Free Press, New York, NY.
[139] Ven, A. H. V. D., Polley, D. E., Garud, R. and Venkataraman, S. (1999), *The innovation journey*, Oxford University Press.
[140] Same as Footnote 133.
[141] Same as Footnote 132.
[142] Same as Footnote 133.
[143] Garud, R., Tuertscher, P. and Van de Ven, A.H. (2013), Perspectives on innovation processes, Academy of Management Annals, 7(1), 775–819.
[144] Same as Footnote 133.

These complexities informed new extensions to the theory of innovation diffusion to understand how construction project-based firms organize, and cope with continuous waves of technological innovations to remain competitive in uncertain times during changing environments, Shibeika and Harty[145] suggested.

In addition, the diffusion process can also be discussed in relation to innovation type. In classifying construction innovation types, many researchers[146&147] followed Slaughter's[148] study. Slaughter provided a detailed classification of novelty within construction innovation context. These categories include[149&150]:

- Incremental: Incremental innovation is a small improvement, based upon current knowledge and experience. It is often the result of continuous improvement initiatives and on-the-job problem solving.
- Architectural: Architectural innovation involves a small change within a specific area or component of a system, that requires significant changes in the links to other components or systems in order to function.
- Modular: Modular innovation entails a significant level of novelty within a specific area of a system, but requires no changes in other components or systems.
- System: System innovation is a set of complementary innovations that must work together to perform new functions, and can significantly improve the facility performance or practice.
- Radical: Radical innovation is a completely new concept or approach which often renders previous solutions obsolete, including interdependent components or systems.

[145] Same as Footnote 133.
[146] Gambatese, J.A., Hallowell, M. (2011), Factors that influence the development and diffusion of technical innovations in the construction industry, *Construction Management and Economics,* 29(5), 507-517.
[147] Lindgren, J., and Emmitt, S. (2017). Diffusion of a systemic innovation: a longitudinal case study of a Swedish multi-storey timber house building system, *Construction Innovation,* 17(1), 25-44.
[148] Slaughter, E. S. (1998). Models of construction innovation, *Journal of Construction Engineering and management,* 124(3), 226-231.
[149] Slaughter, E. S. (2000). Implementation of construction innovations, *Building Research & Information,* 28(1), 2-17.
[150] Noktehdan, M., Shahbazpour, M., and Wilkinson, S. (2015), Driving innovative thinking in the New Zealand construction industry, *Buildings,* 5, 297-309.

These categories of innovation can be used to establish the degree to which proposed innovations will require special skills, expertise and activities to be effectively implemented.

It is noteworthy that classic adoption research places great attention on how technology adopters gain knowledge about new ideas and how this communicated through certain channels; therefore a focus has been placed on certain sources of information such as[151]:

- Media channels,
- Interpersonal communication,
- Information management and awareness,
- Communication network activity and channel building, and
- Interactions among different actors or construction professionals within construction firms.
- BIM Acceleration Committee promotes the adoption of new technology. The committee also promotes the application of BIM, its use and removes barriers to its use (https://www.building.govt.nz/assets/Uploads/projects-and-consents/building-information-modelling/bac-terms-of-reference.pdf)

Hansen and Birkinshaw[152] presented innovative ideas as a sequential, three-phase process that involves idea generation, idea development, and the diffusion of developed concepts that includes six critical tasks namely: internal sourcing, cross-unit sourcing, external sourcing, selection, development, and companywide spread of the idea. In their classification, the whole process is referred to as the innovative value-chain (IVC). Table 1 shows the links between idea creation and diffusion at firm-level[153].

Table 4-1: The innovative value-chain at firm-level [154]

	IDEA GENERATION			CONVERSION		DIFFUSION
	In-house	Cross-pollination	External	Selection	Development	Spread

[151] Same as Footnote 133.
[152] Hansen, M.T., and Birkinshaw, J. (2007). The innovation value chain, *Havard Business Review,* 85(6), 121-130.
[153] Ozorhon, B., Abbott, C., Aouad, G., and Powell, J. (2010). *Innovation in construction: a project life cycle approach,* SCRI Research Report, Salford, 1-49.

	Creation within a unit	Collaboration across units	Collaboration with parties outside the firm	Screening and initial funding	Movement from idea to first result	Dissemination across the organisation
Key questions	Do people in our unit create good ideas on their own?	Do we create good ideas by working across the company?	Do we source enough good ideas from outside the firm?	Are we good at screening and funding new ideas?	Are we good at turning ideas into valuable products, businesses, and best practices?	Are we good at diffusing developed ideas across the company?

In addition, there is a need to prioritise the implementation of innovative technologies in construction projects. Much literature has focussed on how new ideas could be identified and implemented in construction projects[154,155,156&157]. These studies argued that the effective use of construction innovations can be planned through a cycle of implementation stages and activities. The six stages often identified in the theoretical literature and empirical studies are:

- Identification: This indicates the first stage of the implementation cycle which presents clear specification of the objectives associated with the project and organization (s), and the identification of potential alternatives to achieve those alternatives.
- Evaluation, alternatives identified are evaluated with respect to the project objectives, and performance of the alternatives on key criteria are measured.
- Commitment: At this stage, the construction company commits its internal allocation of resources to the implementation of the innovations selected after evaluation.
- Preparation: The units that need to be prepared for the implementation include (1) the people within the company who will implement the new ideas, (2) the

[154] Slaughter, E. S. (1998). Models of construction innovation, *Journal of Construction Engineering and management,* 124(3), 226-231.
[155] Slaughter, E. S. (2000). Implementation of construction innovations, Building Research & Information, 28(1), 2-17.
[156] Winch, G. (2003). How innovative is construction? Comparing aggregated data on construction innovation and other sectors- a case of apples and pears, *Construction Management and Economics,* 21(6), 651-654.
[157] Aouad, G., Ozorhon, B., and Abbott, C. (2010). Facilitating innovation in construction: directions and implications for research and policy, *Construction Innovation,* 10(4), 374-394.

project team (e.g. client, designer, contractor, sub-contractors, etc), and (3) the construction company as a whole.

- Use: This is often a time in which changes are made on-site to obtain the expected benefits, or to take advantage of opportunities to increase the level of benefits obtained e.g. changes to the processes or systems to most effectively use and accommodate the innovation.
- Post-use evaluation: The major element in the evaluation is to compare the original expectations of benefits and costs to the actual outcomes. Also, the project and company criteria involved in the early evaluation of the alternatives should be reviewed and updated based on the experience with the innovation.

The effective implementation of new ideas seems to require an appropriate commitment of resources and an understanding of the nature of the activities required[158]. As such, this study finds its significance.

4.3. Barriers to implementing transformative technology

Barriers mostly occur as unintended consequences of regulation, and attempts to reduce risk to the industry. Ironically, the desire to remove risk has led to a slowing in improvement of quality, by reducing innovation[159]. Researchers from USA[160] identified the following barriers to the adoption of innovative technologies which would seem to resonate with the experience of New Zealand innovators and construction companies:

- Technological risk
- Financial risk
- Risk of rejection by workers
- Research filters that may prevent further development of an idea, if it is not expected to be cost effective
- Technical risks preventing contractors from using underdeveloped ideas

[158] Same as Footnote 156.
[159] Clark-Reynolds, M., and Pelosi, A. (2016). When did disruption become a good thing?, BRANZ, New Zealand, 1-44.
[160] Mitropoulos, P., and Tatum, C.B. (2000). Forces driving adoption of new information technologies, *Journal of Construction Engineering and Management,* 126(5), 340-348.

- Technology transfer barriers that prevent the adoption of mature, cost-effective technologies and include lack of awareness about new ideas, problems in communicating how these ideas could be effective, risk and liability involved in trying something new, difficulty in gaining approval from regulatory authorities, and resistance to change.

In Ozorhon et al.'s[161] report (UK), results were intended to shed light on the main barriers to new ideas in construction technologies. The top two barriers are clearly seen to be economic conditions and availability of financial resources. It is noteworthy that financial concerns can both act as a barrier and a facilitator to transformational technology introduction. The companies surveyed claimed to innovate in order to increase their profitability but believe that they cannot innovate unless economics allows. Similarly, architects' perception of the Swedish construction industry indicated that the top two barriers are also financial concerns[162] i.e. a focus on initial/project costs rather than life cycle, and the economic risk associated with technological innovations.

4.4. Impact of transformative technologies on systems/processes/people?

Every day, we are bombarded with new technological breakthroughs which promise to 'transform' the construction industry and produce a step-change in costs, quality, productivity, safety, sustainability and even the gender balance. The apparent urgency to adopt these new technologies seems great, given stories of overseas competitors investing in this area. Some of the new revolutionary technologies published include[163]:

- Business information modelling, virtual reality and augmented reality which enable project teams to collaboratively build, experience and test a virtual building before work starts on site;

[161] Ozorhon, B., Abbott, C., Aouad, G., and Powell, J. (2010). *Innovation in construction: a project life cycle approach,* SCRI Research Report, Salford, 1-49.
[162] Hemstrom, K., Mahapatra, K., and Gustavsson, L. (2017). Architects' perception of the innovativeness of the Swedish construction industry, *Construction innovation,* 17(2), 244-260.
[163] Loosemore (2015), https://newsroom.unsw.edu.au/news/art-architecture-design/risks-and-rewards-new-construction-technologies

- 3D printing, which allows building components and even whole buildings to be manufactured through new concrete, steel and polymer printing technologies on and off-site;
- Robots and drones which can monitor and undertake tasks in awkward and dangerous places;
- Robotic exoskeletons fitted to workers to boost strength without reducing physical co-ordination;
- Wearable and ultra-mobile computers and apps which utilise touch screen technologies;
- GPS and spatial information systems which enable plant and machinery to be driven remotely and sites to be set out more rapidly and accurately;
- Smart phone technologies which enable customers to interact with buildings more remotely and effectively or to remotely collect safety risk data, track the location of workers on large remote projects and issue warnings around invisible safety risks;
- Extra-high strength lightweight concretes which use basalt fibre or glass composite reinforcement;
- Smart materials which have ultra-high strengths and insulation properties, absorb pollution, clean and repair themselves and monitor their own strength and performance;
- Organic solar cells which can be sprayed using ink-jet technologies onto building materials to make buildings net generators of energy rather than energy users;
- Smart windows which produce electricity and which can change the opacity of glass to filter light;
- Cloud computing, big data and the internet of things, which offers a much cheaper way for businesses to store and analyse information and keep up-to-date;
- Smart metering that can provide real time feedback to users to help them change their energy and water consumption habits; and
- Biomimicry, which enables designers to replicate natural systems in design and products to reduce our consumption of natural resources.

Loosemore[164] further stressed that there is some reliable evidence that some of these technologies can produce productivity improvement in the range of 30 to 40 per cent, a much needed increase in efficiency, quality, safety and sustainability. However, it is also important to be cognisant of the many risks involved in adopting new technologies. Hence, some examples of less obvious impact of technological innovation as it affects systems/processes/people:

- Employees will need to be educated and trained to effectively use and accept new technologies;
- There could be significant inter-operability ripple effects through existing systems and technologies in adopting a new technology;
- Traditional industry cultures and ways of working will need to change. The fragmented and confrontational way in which construction traditionally takes place means that many firms in the construction industry will struggle to understand how to work in integrated teams and to share the large amounts of new data that will be generated in the future about how buildings are built, function and perform;
- New technologies will require firms to reassess and more clearly define their role in the new value streams that emerge. In traditional industries like construction, this will involve developing a new generation of professionals with multi-disciplinary and technological competencies who are able to work across traditional professional boundaries, relationships and knowledge domains;
- Technology will create big challenges for companies in managing cyber-crime and information security and communications. Since large amounts of data can now be downloaded onto smart phones, it can also be lost or stolen far more easily than in the past. The sheer variability of platforms and types of phones used can make the task of managing these risks extremely difficult;
- Successful construction projects are built on relationships and people and new technologies, if used wrongly, can introduce workplace tensions and uncertainties and reduce communication effectiveness rather than improve it; and
- There are also significant ethical issues around tracking and monitoring employees.

[164] Same as Footnote 164.

In their own opinion, Noktehdan et al.[165] presented the following performance indicators that can be used to explain the impact/benefits of technological innovation in relation to systems/processes/people:

- Cost: Direct cost savings or better utilization 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 after the construction project;
- Environment: Reducing adverse impact of the construction processes as well as the final building or infrastructure on the natural environment; and
- Community: Reducing adverse impact on communities affected by the construction project and improving communication with stakeholders.

To obtain a good idea of the expected outcome, benefits or impacts of transformative technologies, we can improve our understanding of why a company would choose to innovate and how it might measure its success. However, modern construction companies largely function and innovate by the quality of their processes, the people operating them and the way in which they change and adapt to suit the changing business environment[166].

4.5. Focus group findings

This section examined workshop participants' perceptions of "transformation of the building industry" by using innovative technologies. The focus group participants (i.e. Architects, Quantity Surveyors, Engineers, Builders, Project Managers, and Property Developers/Managers) are senior professional staff in their individual firms. This information indicates that the participants are reasonably experienced in project developments and therefore have some knowledge of issues relating to technology in

[165] Same as Footnote 150.
[166] Same as Footnote 150.

construction. This enhances the validity of the focus group (Rosenthal, 2016)[167]. Therefore, based on each of the research questions, responses provided below by them could be relied upon for this study.

- What do you see as new transformative technologies for the building industry?

i. Robots, now becoming real in site environment – Construction robots are autonomous devices capable of repairing or building the player's structures. This is a machine designed to execute one or more tasks automatically with speed and precision. The use of robots is now becoming real on construction sites as agreed by the participants. SAM100 is a bricklaying robot for onsite masonry construction, designed to work with the mason, assisting with the repetitive and strenuous task of lifting and placing each brick.

ii. 3D printing – Using 3D printing instead of current construction methods could be a more cost effective process and create a new standard for housing construction in the future. The concept of 3D printing has been hovering around for some time now. The actual use of 3D printing and its adaption into the construction industry has become a reality. Contractors around the world have built the first 3D residential structures including houses and apartment buildings. What makes 3D printing different from current construction methods? The 3D printing is done using super-size printers which use a special concrete and composite mixture that is thicker than regular concrete, allowing it to be self-supporting as it sets. Therefore 3D-printed components do not have the same design constraints that may hinder current construction methods. In addition, curved concrete structures created through 3D printing can be hollow, using less material and creating space for building services inside the structural elements. Not only could this revolutionize the construction industry, but the less expensive process could also affect housing affordability. Lower material usage and lower labour costs create a less expensive construction method which can in turn create lower-cost housing to address current needs in the Auckland market in particular.

[167] Rosenthal, M. (2016), Qualitative research methods: why, when, and how to conduct interviews and focus groups in pharmacy research, *ELSEVIER ScienceDirect,* 8, 509-516.

iii. Cross Laminated Timber (CLT), and various other new forms of laminated timbers that allow for faster construction techniques combined with high strength, high degree of thermal performance and integrity.

iv. Prefabrication and modularisation – The emergence of building information modelling (BIM) is influencing design and construction processes and how project teams collaborate. The participants stressed that a key benefit of BIM is enabling the increased use of prefabrication and modularization, which in turn improves worksite productivity and overall project performance.

- How can new transformation technologies be adopted?

In this context, adoption examines how new ideas are identified, encouraged and moved through a particular social system. In this study, the workshop participants identified the following methods for adopting new ideas:

i. In much the same way as in the section related to innovation behaviours in construction, there is an immediate need to establish a culture within the industry that will allow the establishment of new technologies throughout the processes adopted. There is a need to create a culture in which all employees are actively encouraged to put ideas forward can help firms to adopt new technologies. But how do you get the best from people and encourage them to be at their most creative is of course a challenging proposition.

ii. Technology implementation and/or innovation forums – As previously mentioned in the section on innovation in construction, such a gathering could be government/industry-sponsored or a national, non-profit organization formed to recognize and encourage the adoption of new technologies that improve the quality, efficiency and cost effectiveness of construction. The forum's interest in expanding new technology awareness and adoption extends to showcasing innovators and new products, showing innovation in action,

supporting innovation networking, promoting innovation, and finding innovative contractors.

iii. Formation of innovation groups by the government or industry to drive innovation.

iv. Raising awareness of the value of innovative technologies in the society at large and within organisations.

v. Showcasing new technologies or products and innovators. This can be demonstrated in various ways e.g. advertising in social and professional media.

vi. Funding innovation by the government and multinational companies most particularly through research and development goes a long way to help the construction industry.

vii. Internal collaboration among employees and team work or effort will help enhance innovation process.

viii. Inclusion of innovative technology in government policy and government interference will go a long way to add value to projects and products.

- What are the barriers to transformative technology uptake?

The workshop participants identified the following issues as the factors that impede the uptake of transformative technology in the construction technology:

i. Market size – The size of the New Zealand construction industry is a barrier for technology investment. The small scale of the industry may not allow long-term goals and investment since lack of continuous supply of big projects willing to adopt innovative technologies may affect the long-term success of innovative companies. Clients of the industry tend to be unique and one off. Most people will only ever build one house. Most industrial clients will only ever build one new factory etc. Clients as a result want to be unique in their designs, but will use Prefabrication techniques if they are shown to be affordable. If they want tailored and sophisticated Prefab designs, they need to pay a lot of money upfront. The problem for prefabrication is therefore manifest. Small scale demand precludes investment in prefabrication

technology. Lack of availability of cost effective prefabricated solutions reduces demand still further while bolstering the continued delivery of old technology solutions. Once again we are presented with a chicken and egg paradox.

ii. Risk averse environment - Barriers to transformative technology uptake are the reasons why the construction industry is slow to innovate. Adoption of new technologies occur in a risk averse environment because innovations are risk-based. Innovation can be a company's most powerful tool and a key driver of value. Still many executives, fearful of the risks inherent in pursuing new technologies may hesitate to unleash its full potential. They prefer, indeed, to renovate rather than to innovate. An innovator needs to be bold to innovate and not being conservative.

iii. Funding for R&D by the government and industry – Investment in R&D is low in the building industry, and the funding available is not obviously accessible. This slows the rate of innovation.

iv. Opportunities to find out what is happening overseas are limited. Having to show to people that innovative technology ensures positive results, case studies and big data from case studies are needed but not available. Examples of successful innovations from other countries and organisations, and their best practice and performance could be referred to as case studies as confidence comes from seeing other people's success.

v. Affordability of new technologies and solutions are other barriers to change because thinking and implementing innovative technologies are often expensive with uncertain outcomes..

vi. Having uneducated clients/actors that are conservative and they lack understanding of their requirements as well value of innovation could be responsible for lukewarm or non-committal attitude towards innovative technology uptake.

vii. Contractual models - Conditions of contract (NZS 3910) do not have innovation as an element of content, and potentially this document should encourage innovation and adoption of new technologies. This needs to be reviewed to reflect a clause that bears innovativeness for practice.

- What is the impact of transformative technology on systems/processes/people?

To obtain an idea of the expected outcome or impacts of transformative technologies, it is worthwhile considering the following provided by the workshop participants:

i. Increase in technical competence of workers – Change should be evolutionary and not revolutionary. Transformation can only happen in an incremental way, indicating that transformation should respect workers to be accepted. Therefore, technology should transform the way people work, and in this manner technology will be accepted and workers will be more technically competent.
ii. Opportunities for training – Training should be targeted and planned to get maximum technology adoption since we are at an early stage of technology adoption. People's training should address new technology.

- Which areas of the industry do you think technology could have the greatest impact?

During the workshop sessions, the focus group participants stressed that technology has an impact on every area or stage of the industry. Meanwhile, emphasis was laid on safety, quality, cost and time. Innovation in technology is a feature of system, operation or built work that gives better performance at less cost, but this can be subjective. Technology affects the industry in every aspect as it allows higher safety standard, higher quality within reasonable cost and time.

4.6. Future research in technology

Potential future research questions include:

- What actions/processes that organisations take to generate new ideas in construction technologies i.e. internal inputs of innovative technologies?
- What are the sources of new ideas in technologies, and to what extent does your organisation utilize the external sources of innovative technologies?

- Identify the factors that are seen as significant in enabling implementation of new technologies within your organisation (enablers of innovation), and to what extent do the factors help promote new technologies within your organisation?
- Identify the drivers of new ideas in technologies, but to what extent do the drivers create the need for your organisation to implement the new ideas?
- Barriers to technology uptake have been identified in the study, but to what extent do the barriers impede the uptake of technology within your organisation?
- Who are the major actors for new ideas in technology (innovators) within the construction sector, and to what extent do you think the actors drive implementation of new technology within the construction sector?
- How can transformative technologies be diffused/implemented in construction projects?
- What technological changes need to be adopted/refined/popularised for the industry to deliver housing that provides whole building life cycle performance?
- How can technology contribute to the uptake of whole building life cycle thinking in the construction industry?

4.7. Recommendations

This element of the report has investigated transformative technologies through a literature review and focus group. Based on the findings are the following recommendations that can make this transformation happen, turn barriers into drivers and most importantly, drive more innovative technologies across the New Zealand Construction Industry.

Changes to help government, industry, academia and institutions

- Promotion and funding of R&D, technological innovation, education and training: Given the economic significance of the construction industry, R&D investments by the construction industry is low. The New Zealand government

can create a more fertile environment for developing technological innovations by providing appropriate support to companies and academia. In particular, the government can take the following steps:

i. Establish centrally funded research institutions (e.g. UK catapults, UK Collaboratorium for research on infrastructure and cities programme, Nigerian building and road research institute, etc) and joint industry-academia funds and technology centres (a typical approach to stimulating university-industry collaboration is to design R&D research grants and tax-incentives with a requisite of a consortium of firms and universities for project eligibility)
ii. Offer tax incentives and establish schemes for contested R&D funding (by open competitive tendering for instance)

    EXAMPLE: In 2015, through multiple schemes, *the US Federal Highway Administration* provided funding of almost $500 million for hundreds of research projects related to improving the design, construction and operation of roads, tunnels and bridges[168]

Promoting R&D should be the first step. Technological advances realize their full potential only when they are widely adopted across the industry. In a highly multi-stakeholder industry such as construction, it is therefore equally important to foster the diffusion of innovations by the following steps:

i. Providing financial support for demonstration projects involving new technologies and processes
ii. Setting up incentive schemes for innovation deployment and capability development

The entire construction workforce needs to be upskilled appropriately with regard to new technologies. The New Zealand government can support workforce education and training through the following policy measures:

[168] World Economic Forum (2016), Shaping the future of construction: a breakthrough in mindset and technology, World Economic Forum, UK, 1-64.

i. Implement effective and internationalised curricula in universities, polytechnics, technical colleges and apprenticeship schemes
ii. Offer training programmes at job centres and in collaboration with companies or the industry
iii. Enhance the attractiveness of construction professions through intellectual campaigns or media

EXAMPLE: The EU-wide construction-sector initiative *BUILD UP Skills* provides a joint platform for national programmes and projects aimed at training and educating the current and future construction workforce on energy efficiency and renewable energy[169].

Investing in innovative technologies

Investment is a vital input in innovative technology. Investing in people and other aspects, as well as conventional Research and Development (R&D) initiatives, will create an environment where innovation can survive.

- People: Innovation is driven by people having good ideas. Good ideas occur where there is a focus on outcomes, a culture of challenge of concepts, and there is space in the expected programme of work for people to think and test new ideas. There has been an industry acknowledgement that a skills shortage exists. This needs to be addressed, and can also be aided by building skills and capability into the existing industry professionals, to help enhance their current abilities.
- Incentivisation: Individuals, teams and organisations should be recognised and rewarded for good ideas. Providing worthwhile incentives is a good motivator to ensure ideas are continually generated. These may not be financial incentives. Company awards can be a great motivator.
- Data Acquisition: Good data enables projects to start off on the right foot. It is crucial that there is investment in reliable data acquisition from the onset, as

[169] Same as Footnote 169.

well as in an adequate capability to correctly interpret data. This ensures there is an application of sound science in the problem understanding process.

- Marketing: From identifying gaps in the market to generating new ideas is germane to promoting technological innovation. Promoting innovative technologies both internally and externally is essential and is a key component in the innovation cycle to ensure it becomes embedded.
- Innovative technology and knowledge sharing: The ability to capture ideas for application in future projects or learning what others are doing through forums should be considered for investment. Platforms should be provided that allow for knowledge sharing and feedback can help ensure good ideas are not lost. Traditionally, the construction industry has not been proactive in sharing and learning from its successes and failures. The lack of knowledge capture from previous projects results in repeated mistakes. Knowledge sharing also promotes creative thinking and knowing what competitors are doing pushes others to think faster and raise better ideas, thus moving the industry forward. Collaboration between companies and different groups including academia, consultants, contractors and institutions results in a greater ideas source to draw from, faster development of ideas and shared benefits, with the industry moving forward together. Cultivating strong lines of communication within companies and encouraging knowledge sharing externally can lead to greater collaboration and innovation. In essence, knowledge sharing leads to better quality information enabling the industry to effectively harness ideas and promote technological innovations at all levels.
- Acquisition of new technologies, materials and processes: Upfront investment in new technologies and software will facilitate innovation, drive efficiencies and generate value for businesses.
- Research and Development (R&D): Research and development provides an opportunity for ideas to be tested to ensure suitability for universal application. The opportunity provided by R&D to carry out a pilot study or project makes it an integral part of the innovation process. Investment in R&D by the construction industry has been low. Modern infrastructure and construction can benefit enormously by increasing R&D investment to exploit the use of new

technologies to provide innovative new solutions, thereby making radical changes to the construction and management of infrastructure.

5. Process

Emerging new technologies, material and tools create tremendous opportunities for transforming New Zealand construction industry. To provide a systematic support for the implementation of new technologies and innovation, current construction processes need to be improved across the industry. Generally, the main goal of the process improvement is to produce a product with equal or better worth (quality) at a lower cost. In the construction industry, the aims of process improvement can be simply listed as[170]:

- Reduction in construction time
- Reduction in the cost of building life cycle (construction, operation and maintenance)
- Improving predictability
- Improving sustainability
- Improving health and safety (in construction and operation phases)
- Improving productivity
- Improving quality performance across the industry

The initial stage of process improvement in the industry occurs at the organisational (micro) level. Construction organisations generally apply strategies such as adoption of new technologies and operational processes, development of an innovation friendly business model, redesigning organisational structure and so on to improve their overall performance. Individual actions and strategies are not sufficient to achieve a meaningful process improvement across the industry. Changes in procurement processes, regulations, and collaboration must occur across the industry (macro level) to facilitate the overall process improvement. These challenges should be

[170] Bowden, S., Dorr, A., Thorpe, T., & Anumba, C. (2006). Mobile ICT support for construction process improvement. *Automation in construction*, *15*(5), 664-676.

tackled collectively and the industry as a whole is responsible for the overall transformation.

The implemented strategies for improving construction processes must be evaluated to be aligned with the aims of the construction process improvement (See figure 2). Only strategies which address the main issues pertaining to process improvement should be introduced. This helps the industry and construction companies to maximise the outcome and prioritise allocation of available resources to the most effective strategies.

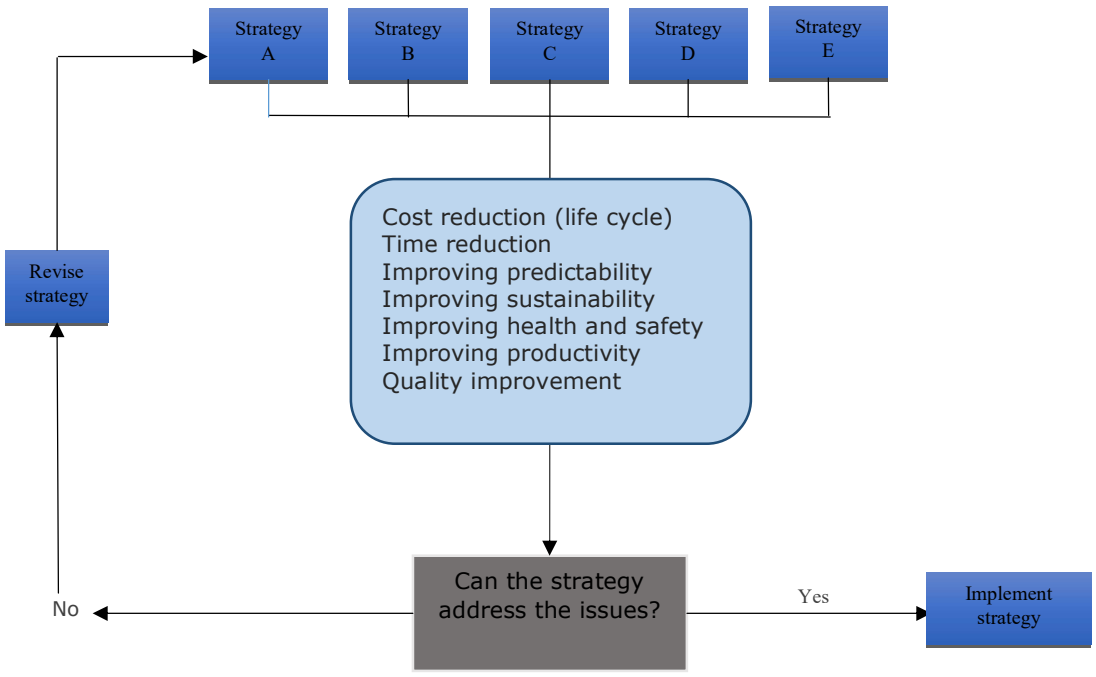

Figure 5-1: Strategy evaluation framework for process improvement in the construction industry.

Despite the importance of process improvement for the industry, improving current processes seems to be challenging for a range of reasons including *inter alia*:

- Complex and fragmented nature of the construction industry.
- Involving different stakeholders with different and/or conflicting interests.

- Construction is a project based industry. Knowledge management and organisational learning is therefore not systematic to enable transfer to organisations on future projects.
- Cultural factors (construction organisations are reluctant to change because they prefer to work in the way that they have been working).
- Lack of a structured framework in the industry for process improvement
- Lack of a measurement of benefits obtained from the process improvement.

In addition to the above factors which are related to the industry, the construction industry is affected by clients, government, financial firms (banks and insurers) and society (figure 3). The involvement of these major players in forming the current condition of the industry creates further challenges in the process improvement and transforming the industry.

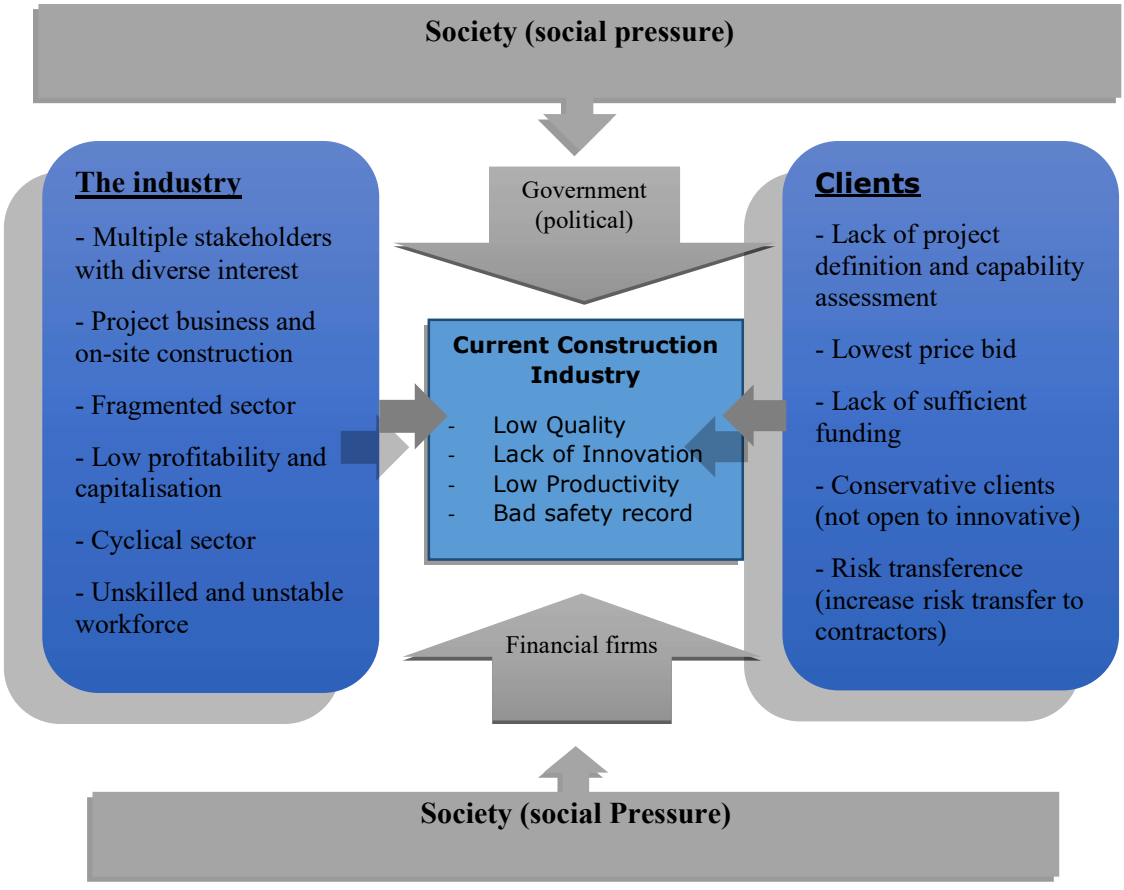

Figure 5-2: Major categories affecting the construction industry

A comprehensive literature review indicates the importance of procurement, supply chain and design in improving the performance of the construction industry.

5.1. Procurement

The procurement methods have significant impacts on the ability of the construction industry to transform and become more innovative. Repeat customers of the construction industry tend to take a more strategic approach to procurement in order to secure a better outcome particularly in the context of whole life value. Government as a major client of the industry can demonstrate the value which a different approach to procurement can deliver for customers. Both government and the construction industry need to improve procurement efficiency and explore innovative procurement options to achieve better outcomes. In the U.K. for example, the government and the industry delivered a combined £447 million of savings measured in the 2012/13 financial year[171]. In this cited example, the redesign of the governmental procurement process was central to delivering these savings.

According to New Zealand government guideline, to achieve a successful and effective procurement strategy, the following issues should be addressed[172]:

- Fully understand the project characteristics, including key drivers, constraints, and risks.
- Assess client and market, capabilities and capacity.
- Evaluate potential delivery models and approach to market for suitability.
- Involve key stakeholders and experts early in the planning and development process.
- Challenge assumptions in order to better achieve desired outcomes.
- Use practical analytical techniques to support the decision-making process.

[171] Construction 2025 (2013) Industrial Strategy: government and industry in partnership, HM Government
[172] New Zealand Government Procurement (2015) Planning Construction Procurement; A guide to developing your procurement strategy

5.2. Construction supply chain integration (CSCI)

The construction supply chain is complex and diverse with many small and medium sized enterprises (SME's). The construction supply chain starts from the design process and works through building component manufacturers. The main issue for the industry is how to bring together all these value adding activities as a whole rather than the sum of the parts[173]. According to a study by Department of Business, Innovation, and Skill (BIS), in a large scale project (£20-25 million) the main contractor may need to manage up to 70 sub-contractors. This demonstrates the fragmentation of the industry and the challenge for creating supply chain integration (SCI) that focuses on building quality and customer value[174]. According to the same study, if the construction industry wants to achieve the targeted improvement, the industry needs to improve the current supply chain process in order to address construction delivery issues that affect the quality of final products and productivity of the industry. Factors such as stringent commercial agreements related to risk transfer and payment, competitive bidding and challenging trading conditions negatively affect integration in the industry.

The current structure of the construction supply chain (CSC) in both in New Zealand and in general around the world is at best sub-optimal. The low price approach in procurement processes puts further pressures on CSC to reduce prices, therefore, the current supply chain structure does not guarantee the best value delivery through the on-site activities. At a New Zealand level, the industry suffers from a tyranny of distance both externally and internally. New Zealand has a population roughly equivalent to metropolitan Sydney in Australia (around 4.6m). In order to supply the building needs of Sydney, there are around 400 building suppliers companies of all types compared to a New Zealand-wide figure of something over 800 suppliers of all types[175]. In short New Zealand has substantially higher overheads and therefore costs than an equivalent population relatively close by in the world. Costs of logistics and

[173] Construction 2025 (2013) Industrial Strategy: government and industry in partnership, HM Government
[174] Department for Business Innovation and Skills (2013) Supply Chain Analysis into the Construction Industry. BIS RESEARCH PAPER NO. 145
[175] Tookey, J.E. (2014), Unpublished report for BRANZ on comparison of construction materials costs between New Zealand and Australia, AUT University

supply are therefore substantially greater as a result of a lack of scale, and yet our expectations are every bit as high as in Australia.

In a fragmented industry such as construction with many business partners, processes and diverse customers supply chain management (SCM) plays a critical role to guarantee a smooth business operation[176]. Applying SCM can rectify issues due to presence of traditional pricing business arrangement, various and fragmented construction processes, high pricing competition because of purchasing from different suppliers, and lack of trust across the supply chain[177]. A research conducted in the U.K. construction industry identified the following aspects of the SCM that have the greatest impact on project performance[178]:

- Financial arrangements: certainty of payment; prompt payment
- Supply chain selection: repeat workload, early contractor engagement
- Design management: early contractor engagement; sub-contractor involvement in design solutions; incentive to contribute
- Management: good communication; well-managed programme; good team relationships
- Price determination: realistic pricing
- Supply chain integration: more effective coordination and use of project resources

All construction companies, regardless of their size and financial resources strongly depend on an elongated supply chain. Only companies who apply supply chain integration (SCI) can take real competitive advantages from this fragmented supply chain. Reliable flows of information and material between suppliers and clients are crucial for the success of SCI. When SCI established, the supply chain operates as a single entity driven directly by the client[179]. SCI comprises both information and logistics. Construction clients can implement SCI through introducing and applying more innovative procurement approaches such as strategic alliance and partnering.

[176] Turban, E., King, D., Lee, J. K., Liang, T. P., & Turban, D. C. (2015). Electronic commerce: A managerial and social networks perspective. Springer.
[177] McDermotti, P., & Khalfan, M. (2012). Achieving supply chain integration within construction industry. Construction Economics and Building, 6(2), 44-54.
[178] Same as 5
[179] Farhoomand, A. F. (2004). *Managing e-business Transformation: A global Perspective*. Palgarve/MacMillan.

Proper implementation of SCI can help the industry to improve waste management process, sustainability, innovation and project quality. In addition to innovative procurements that promote SCI, developing a collaborative culture is the fundamental prerequisite for the implementation of SCI in the industry. Following issues should be addressed in order to foster the collaborative culture[180]:

- External and internal trust
- Mutual pain and gain
- Information exchange in the supply chain
- Transparency and quality of information flow
- Communication and understanding
- Effective cross-functional activities and process alignment
- Notion that collaboration does not need to be based on technology
- Joint decision making
- Use of measures to assess the performance of the whole supply chain
- Commit resources at the early stages of project development process
- Intra- and inter-organisational support
- Corporate focus on SCM
- Demonstration of a business case for collaboration

Example of effective procurement and SCI[181]

"Anglian Water provides water and wastewater services to 4.3million customers over a region of approximately 27,500 square km. The organisation is in the 5th generation of its asset management strategy regulated by OFWAT. Anglian Water has adopted a long term collaborative relationship with its supply chain, known as the @One Alliance, to deliver the challenging efficiency targets demanded by the regulator. This involves developing the supply chain to not only drive procurement savings but to identify new and innovative approaches to product development and efficiency. This strategy contrasts with other approaches in the sector based on risk transferral and a desire to manage contractual risk over a delivery period. These programmes find it harder to tap into the innovation and

[180] *Hedley Smyth (2010) Construction industry performance improvement programmes: the UK case of demonstration projects in the 'Continuous Improvement' programme, Construction Management and Economics, 28:3, 255-270, DOI: 10.1080/01446190903505948*

[181] HM Treasury (2013) Infrastructure procurement routemap: a guide to improving delivery capability

efficiency achieved in alliances as there is less incentive on the part of the supply chain to invest their own resources and capital in new products and processes. The @One Alliance is a successful example of choosing the potential for long term efficiency over shorter to medium term risk transferral. This Alliance and others like it are seen as leading industry thinking in delivering long term efficient infrastructure".

5.3. Integrated design

Buildings are designed with an expected lifespan averaging around 50 years. Therefore, the way a building is designed is going to affect operational and maintenance costs of the building for the next 50 years. This creates pressure on the industry to take into account the life cycle of buildings in the design process. This can be achieved once an integrated design process is utilised as a response to this challenge[182].

The integrated design process often is not achievable under the linear construction process. The traditional procurement strategy (design-bid-build) is a linear and sequential method that lack interaction among professionals such as designers, engineers, contractors and facility managers. This situation often results in rework, cost and time overruns in the construction phase and high operational and maintenance costs during the building life cycle183. The linear and sequential construction process is an effective barrier in applying the knowledge of all professionals in designing and planning a construction project. In this process, engineers are asked to provide their inputs according to the agreed design scheme prepared by architects. As result, they are not able to provide optimum design, but rather add-on features or solutions to rectify design issues. Often the final design is far from optimal and may increase the building operation costs. A better result can be achieved by using integrated design process that provides an opportunity for all professionals to raise issues and contribute to the design at the design stage.

[182] Chiocchio, F., Forgues, D., Paradis, D., & Iordanova, I. (2011). Teamwork in integrated design projects: Understanding the effects of trust, conflict, and collaboration on performance. Project Management Journal, 42(6), 78-91.

[183] McGraw Hill Construction (2014) project Delivery System: How they impact efficiency and profitability in the building sector

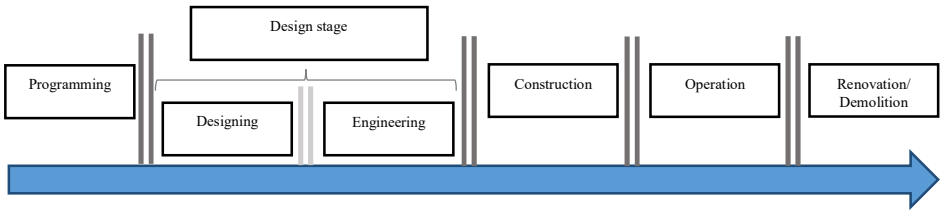

Figure 5-3: linear and sequential design process

Integrated design is "an interdisciplinary participatory process bringing together specialist and key stakeholders during intensive work sessions in order to collectively resolve multifaceted, ill-defined, and intertwined design and construction problems"[184]. A collaborative approach is critical to the success of the integrated design. Collaboration implies effective communication, knowledge sharing and collective actions which is a function of "recursive interaction of knowledge, engagement, results, the perception of trust, and accumulation of activity over time"[185].

Unlike the linear and sequential design process, the integrated design process is formed by a series of action loops throughout each design stage (Figure 3). All relevant team members actively interact through the collaborative approach to achieve the optimal decisions. This requires a significant cultural change across organisations and in a larger scale across the industry. The main players in the industry (government, local councils, major construction companies and professional bodies) need to change their mind-set and their value proposition. Governments play a critical role in the adoption of the integrated design process. For instance, integrated design process is also adopted as a criterion for pre-qualifying consultancy teams for publicly-funded projects in Canada[186], for example.

[184] Chiocchio, F., Forgues, D., Paradis, D., & Iordanova, I. (2011). Teamwork in integrated design projects: Understanding the effects of trust, conflict, and collaboration on performance. Project Management Journal, 42(6), 78-91.
[185] Martinez-Moyano, I. (2006). Exploring the dynamics of collaboration in interorganizational settings. Creating a culture of collaboration: The International Association of Facilitators handbook, 4, 69.
[186] Public Works and Government Services Canada (2011). Integrated Design Process (IDP)

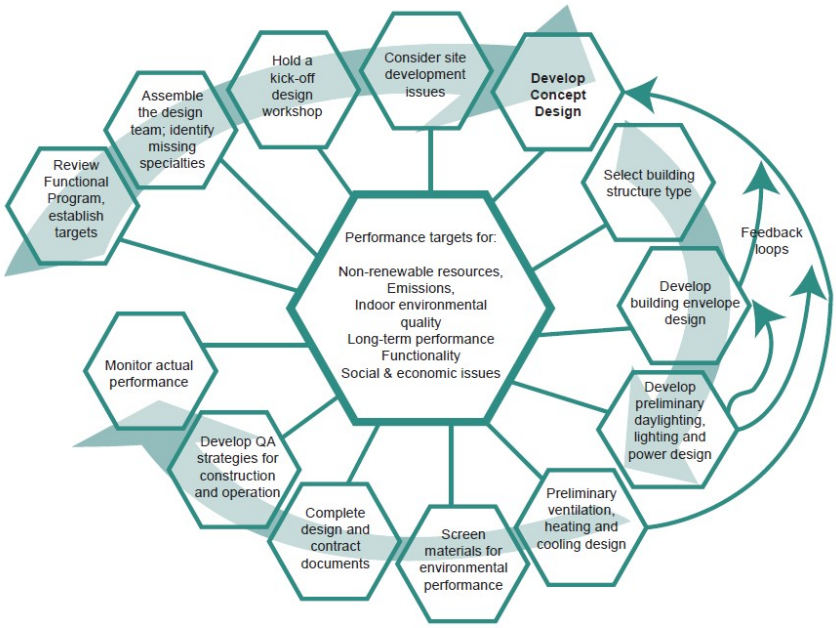

Figure 5-4: Integrated Design process[187]

The construction process is complex and multidimensional. In addition to procurement, supply chain, and design, there are other factors and area that need to be addressed in order to improve construction industry (see table 1). The variety of factors indicates the complexity of the construction process which requires a holistic plan for improving the process and transforming the industry.

Table 5-1: Critical factors for construction improvement

Hong Kong [188]	• Contractual factors (sub-contracting system) • Design and detailing (level of design and detailing, quality of specifications of material and workmanship). • Quality standard (a clear and standard quality assessment system in the industry) • Management competency (supervision and project management competencies) • High skilled workforce • Partnership and collaboration (promoting partnering culture). • Setting up of a statutory body to supervise and co-ordinate the industry (It should have the responsibility of supporting the industry's development through strategic planning, labour skills training, new technology development, management skills developments, as well as licensing construction workers and possibly subcontractors).

[187] Larsson., N, (2004). The Integrated Design Process.
http://www.iisbe.org/down/gbc2005/Other_presentations/IDP_overview.pdf

New Zealand[189]	• Improving the capability of builders and designers • Using prefabrication (off-site construction) and more consistent design • A wider range of mean to manage risk of quality construction and design • Improving consenting process and minimising roles of councils by improving quality assurance and compliance by the industry • Shift to proportional liability and review builder liability durations.
U.K[190]	• Improved image of the industry. • Increased capability in the workforce. • A clear view of future work opportunities. • Improvement in client capability and procurement. • A strong and resilient supply chain. • Effective research and innovation.
WEF (2016)[191]	• Technology and material • Process • Strategy and business model • People, organisation and culture • Industry collaboration • Regulations and policy • Procurement

5.4. Focus group findings

The first stage of process improvement is to determine successful and least successful processes in New Zealand construction industry. It provides further insight into the current condition of the industry and assists the industry to identify processes that require further improvements.

5.4.1. Least successful processes

- **Compliance knowledge.** According to a leading architect:

> "*General lack of industry knowledge around compliance and throughout both resource and primarily building consents. From my experience, many architect and designers have a limited experience about the building code*".

[188] Tam, C. M., Deng, Z. M., Zeng, S. X., & Ho, C. S. (2000). Quest for continuous quality improvement for public housing construction in Hong Kong. *Construction Management & Economics*, *18*(4), 437-446.
[189] Buckett, N,R., (2013) Advanced Residential Construction Techniques for New Zealand, BRANZ
[190] Construction 2025 (2013) Industrial Strategy: government and industry in partnership, HM Government
[191] World Economic Forum (2016) Shaping the Future of Construction; A Breakthrough in Mindset and Technology

Lack of compliance knowledge especially among architects and designers can impose significant delays on projects due to the need for reworks and modifications to obtain the consent from local councils. By and large, the first stage of establishing a business or getting into a business sector is to understand how the sector operates. However, in the construction industry people and organisations are getting into the industry without having a clear understanding of how the industry operates, current codes and regulations.

- Performance knowledge. To build a high-quality building, high-quality components must sit together and work in a harmony. This cannot be achieved without having a comprehensive performance knowledge of building components and materials. Lack of performance knowledge is another knowledge base issue that needs to be addressed across the industry. It negatively affects the performance of buildings over their life cycle. According to one of the participants:

  > "*We know building components but, there is a gap of knowledge in the industry about how components get together, work together and the designed system can perform durably*".

  The lack of performance knowledge is due to unavailability of a standard and reliable measurement method. This knowledge gap also affects the process of material selection at the design stage. Lack of performance knowledge can dramatically increase operational costs of buildings, adversely affect indoor environment quality and compromise well-being of occupants.
- Rating systems. It is very challenging or even impossible to improve the quality of buildings when their performance are not measure accurately. This requires a standardised and compulsory rating system to reveal quality issues of buildings

  > "*Currently, using rating systems is voluntarily in New Zealand construction industry and there is no legal requirement to measure the performance of buildings*".

  Lack of a standard and compulsory measurement method is considered as one of the areas that stops the industry to build high-quality buildings as there is no way to compare the performance of buildings. Therefore, construction companies (builders) are not motivated or enforced by the market to build better than building

code requirements. In additions, the current rating systems only cover the design and construction phases and they ignore the performance of buildings over their life cycles. According to an architect with years of experience in sustainability:

> "*There is no mean to measure the performance of buildings once they are built and delivered to the client* (lack regulatory and market enforcement)".

Because the performance of buildings is not measured over their life cycles, their actual performance and quality cannot be understood, the defects cannot be captured. For instance, two buildings get the same score, however, in 20 years, their performance can be totally different. So, the industry misses a great opportunity to improve its performance by learning from previous projects.

- Building code (regulation).

> "*The building code directing building outcome to a certain direction. The building code is not open to alternative solutions which means innovative solutions and methods are harder to pursuit*".

New Zealand building code and standards require a minimum quality for buildings – but it is best to remember that this is the minimum legally acceptable standard for construction rather than some sort of aspirational level of building performance. As a consequence, as expectations of quality (in terms of longevity and performance) in buildings increases the associated cost of construction becomes more and more expensive. The general perception is that the building code is the way we should build, however, in reality, it is the worse we can build. It means code and standards are the bottom line in terms of quality. Not to mention, buildings with better quality need to use different methods or technology, which requires verification and approval from local councils. The building code and approval processes too often hinder innovation and use of alternative solutions. For example, in order to apply a new method or technology, the authority must be convinced that the method is useful and effective in the New Zealand context. Nevertheless, the approval process is complex, expensive and different from council to council. According to one participant:

"*You can get acceptance through one council but it does not guarantee any acceptance from other councils*".

This indicates a lack of homogenisation in the approval process across the country. Building according to the code reduces risk as anything better needs additional approval, which means higher costs and longer delays. In other words, it easier for builders not to innovate or try to build over the minimum requirements.

- Performance incentives. The industry lacks motivations to perform better than the minimum legal requirements. Performance incentives can motivate construction companies to take further voluntarily steps in order to build buildings with higher quality and better performance than what they are currently building. A participant from leading construction company stated:

  "*If a construction company can demonstrate the quality of building or sustainability of the construction process, why the company cannot get benefits such as fast track consenting or higher density* (in residential projects)".

  One criterion that can be used for allocating performance incentives is "energy efficiency" (when properly measured, assessed, and most importantly achieved). Energy efficiency can be achieved through the combination of quality design and construction. It is the criterion that is in place in EU countries and UK for allocation of performance incentives. In the UK, there are several incentives schemes such as UK-GBC Retrofit Incentives, Green Deal Finance, PACENow, and FiTs are available for energy efficient buildings. If a developer can demonstrate a high level of energy efficiency it can be eligible to receive a package of performance incentives (fast track consenting process; higher density; financial incentives). It should be noted that a standardised and compulsory rating system is required prior to introducing the performance incentives.

- Contractual process. Currently, only a fraction of available technologies is deployed in the construction industry. The current contractual method is one of the main reasons that hinders the implementation of available technologies in a

construction project. According to a participant with extensive experience in prefabrication and off-site construction methods:

> "*The contractual mechanism* [especially] *in the commercial sector is set up to be very defensive to allow a party* [client] *to keep control and transfer the risk to others* [contractors] *in the way that the party who carries the risk are unable to control it*".

So, contractors who generally carry the risk have no power to control and manage risks properly. Under the current contractual method, contractors are not willing to apply new technologies as the technologies expose them to further risks that they are not able to control. To motivate the implementation of new technologies and have an effective risk management process in place, the contractual structure and risk transferring process need to be reassessed to match with today working conditions and emerging new technologies.

- Design process. According to a senior facilities management consultant professions need to change their approach at the design stage.

> "*They are doing it and they are doing it worse. I blame consulting professions primarily for the lack willingness to come out early in the design process with details sufficient for contractors to contribute*".

According to another participant:

> "*I think the design process is messed up because of that small influence of specialist sub-contractors who have great ideas*".

Lack of collaboration, especially in design processes is an issue that needs to be addressed. To achieve a better outcome, the design process needs to be redesigned in order to provide sufficient technical details for specialist sub-contractors so they can contribute in an effective and efficient way to final outcomes. How to effectively incorporate construction requirements and knowledge at an early stage of the project (design process) is paramount and undoubtedly leads to an overall improvement in project performance. Early contractor and supplier involvement can facilitate the transfer of construction requirements and knowledge to the design team. The fragmented process under

traditional contracting environment hinders the integration of construction knowledge among contractors and diminishes opportunities for them to influence design decisions. When design professionals fail to consider constructability of their designs, the designed project results in scheduling problems, delays, and disputes during the construction process.

- Off-site construction. The concept of off-site construction received significant attention during the focus groups. Many reasons can be attributed to this. Not least of which is the obvious need for a substantial increase in housing provision in Auckland in particular, as well as the apparent shortage of skilled workers as has been alluded to in previous sections. However, the industry has failed to fully implement off-site construction methods such as prefabrication and modularisation. As one participant noted,

  > "*The idea of prefabrication has been around for many years. The biggest obstacle in applying prefabrication and [off-site construction methods] is, we have a very small and fragmented industry.*"

  Deployment of off-site construction methods that derive better outcomes requires significant investment in financial capital and human capital that cannot be achieved in a small and fragmented industry with current processes and the lack of strategic depth in the industry. As another participant observed:-

  > *"We deal with the largest asset in our entire economy and we apply the most short-term thinking".*

  The justification of such significant investment requires shifting toward a long term thinking and strategic planning. The industry needs to be more strategic rather than focusing only on two percent of building life cycle (construction phase). To develop more strategic thinking, the incentive and delivery models need to be revised and transformed across the industry.

- Waste management. Under the current working processes, as an experienced participant quipped:-

  > "*In an average house is about $100,000 worth of waste in price and $30,000 of that is a waste of materials*".

This is a frightening figure in the context of cost, and yet more disturbing in the context of environmental impact of all of this waste. The waste of time also should be added to these figures. These figures clearly indicate inefficiency of current processes and waste management system in the construction industry. Waste reduction is a multi-dimensional issue. To reduce the waste, ordering process (over/under ordering), material management, site management, design processes and communication need to be reviewed and redesigned. Unfortunately, it is all too frequently accepted by the industry that waste on site is 'a part of the job' and sometimes it is not seen as a problem that needs to be solved since it is ultimately paid for by the client rather than the industry.

Changing this culture is the first step for minimising waste across the industry. In addition to on-site wastes, there is a different type of waste that generally occurs during the design process. A lot of time is wasted between architectures, engineers and other parties due to lack of proper communication. It is the place that BIM can play a significant role to enhance the communication and reduce the amount rework due to design changes by different parties involved in the design process.

- Uninformed Clients. Because of lack of information clients do not have any idea about the alternative solutions. If clients want to have a dry and warm house, they generally expect heat pump and mobile heating units must be part of the answer to their need. However, they are not educated (or indeed told by industry experts) about the different design or construction methods that can rectify damp and cold houses. Alternatively cost savings are made with respect to the sustainability of new housing (for example insulation) in order to lock in more notional value by building a house with greater floor area. The client perspectives affect the way a house is built by builders. As one experienced builder noted:-

> "*Uninformed clients tend to make decisions about their homes based on the initial cost* [construction costs] *and fashion trends rather than life cycle performance. It means they might sacrifice long term gains just for the sake of a short-term saving* [lower construction cost]".

Furthermore an architect interjected:-

"Clients just don't get that they can have a wonderful house, easy to heat, cheap to run with every possible feature in it to make life easier. Instead they build ever bigger properties that they have to cut corners in order to complete. It is crazy to see, but they just don't listen if they are told at all"

This issue should be addressed by a combination of education and regulation approach. High quality of the build can be assured by using a rating system which is enforced by regulations. A national compulsory rating system associated with an open database allows clients to understand operating costs of different solutions. So, the data can assist the clients to make an informed decision.

- Standardised estimation. There is a lack of standardised costing/estimation methods in the construction industry. Lack of data and knowledge increase the level of uncertainty and industry relies on experience and contingencies to compensate this shortage. For that reason,

  "*Estimating through experience is the dominant factor in the industry. Cost and time estimation generally relies on an experienced project manager.*"

  Due to uncertainty in construction projects, project managers are using many contingencies and buffers in their estimations to reduce associated risks. But, in the bidding process, some of the buffers and contingencies are eliminated to achieve a lower price. This common practice exposes companies to a significant amount of risks. This also jeopardises the project delivery and causes quality and programming issues.

5.4.2. Successful process

- ICT in small construction companies. Small construction companies could successfully use mobile phone in order to run their business in more efficient ways especially in term of communication with their customers and suppliers. According to a builder:

  "*In the last 40 years, the processes of how you run a small business in the construction industry have gone from having a person to take your calls*

to mobile and apps that connect you to clients, suppliers, banks and even legal advice".

However, the unsuccessful aspect of that, the implementation of ICT in small businesses did not go further than using mobile phone.

- Fast track consenting. Using dispensation instead of applying for a new consent through credible organisations such as NZTA could significantly speed up consenting process and reduces the bureaucracy around the projects.

5.5. Future Research Directions

Our findings at this stage indicate an urgent need for redesigning many of current processes and develop new process to help the industry to transform from a poor collaboration and business model for innovation, risk aversion and poor management capability to an innovative, well-managed and dynamic sector which is well equipped to deal with future challenges and opportunities.

The followings are questions that need to be in order addressed to achieve a smooth transformation:

1. What are the future development scenarios that the New Zealand construction industry needs to be prepared for?

2. What are the likely critical technical changes that will require process enhancement to maximise the benefits of technological change?

3. What are the critical new processes that need to be developed across the industry to achieve an overall improvement in building time, cost and quality?

4.What are the critical prerequisites and enablers for process improvement in construction companies?

5. How can more effective collaboration be fostered throughout the entire supply chain, throughout all stages of construction?

6. How can new/redesigned processes be implemented across the industry with a minimum interruption for construction companies and related businesses?

7. How can key stakeholders be optimally engaged to maximise positive construction outcomes?

5.6. Recommendations

Redesigning current processes

Redesigning current processes is an appropriate method in process improvement. It improves the effectiveness and efficiency of current processes without disturbing the whole system. Redesigning processes is cheaper and quicker than developing a new process in the system.

- The design process needs to be redesigned to allow the specialist contractors to contribute and be heard in early design stage. However, to achieve this, commercial arrangement need to be modified and the procurement should be selected carefully to reduce constraints and support collaboration among parties. The modified commercial arrangement and procurement facilitates sharing information among parties which maximise the benefits of implementation of BIM in projects. Introducing design management role who is responsible to coordinate the design process and ensure the quality of designs and BIM models can significantly improve the outcome of projects. However, to improve processes across the industry, the government as a major client of the industry needs to redesign government procurements to encourage or enforce the industry to adopt the best practices and coordinate the transformation at the macro level. A good example of government intervention through redesigning procurement is, in the U.K, it is compulsory for construction companies to implement BIM in projects owned by the public sector.

Changes to help the industry

To maximise benefits of implementation of new technologies, changes in construction processes are inevitable. If the industry wants to transform and achieve high quality and reliable outcomes, the value proposition of the industry must be changed. The performance matrix that is driven by minimum requirements (building code) and lowest cost must be replaced with a non-price attribute. The process of transformation should be led by construction organisations. However, in this process, clients, founders (banks and insurers) and the government play an enormous role in leading the industry toward the ultimate aim of this transformation.

- Developing a national database that provides reliable data about the quality and performance of construction materials and building components. Data about the performance and quality of all materials and building components that can be used in New Zealand should be recorded in this database. Developing such database can address issues regarding lack of performance knowledge and material selection across the industry.
- Introducing building performance incentives can motivate construction companies to implement innovative methods to enhance the performance of buildings over their life cycle. The incentive can be obtained through an evidence based approach only if contractors and designers can effectively demonstrate that they took sufficient actions to enhance the quality of buildings over their life cycle and efficiency of implemented construction processes. A national incentive package should be developed and designed by the government with a close consideration to geographical factors and be executed by local governments. The national incentive package should be based on a clear regulation to minimise interpretation by local authorities and homogenise the acceptance process. A series of case studies should be performed in a large-scale comparison study to capture success factors of an effective building performance incentive scheme.
- Developing a compulsory rating system that monitors and evaluates the performance of buildings during their life cycle. The collected data can be used to create a national database to record performance of buildings. Such database provides an opportunity to compare different buildings and set proper

performance benchmarks which drives the industry toward "join up" thinking between cost, consent, performance, and health of occupants. In addition, the data can be used to make business cases for implementing new technologies or alternative solutions to facilitate the financing process of such innovations.

- The government can affect the industry by introducing schemes and regulations. Government schemes to Replace/Subdivide houses should be a combination of incentives to maximise the value of the current housing stock and free market approach. Incentivisation schemes allowing people to replace an old structure stock (house) with rebuilt and subdivided energy efficient houses. Incentives should be allocated based on an evidence based process to guarantee the quality of rebuilding or new houses. Therefore, the success of this strategy relies on the availability of a reliable and compulsory rating system to measure the performance of new materials and buildings. Energy Performance Certificate in the U.K and Germany's new Energy Conservation Ordinance are good examples of government schemes and interventions in the construction industry.

- Current consenting is a long and complex process which becomes more and more subject to environmental and social impacts. If this process conducted inefficiently however, or if there is a backlog in permit decisions, projects are needlessly delayed and their prospects suffer: cash flows start later than anticipated, thereby compromising profitability. An appropriate balance between speed and quality is crucial to protect public and project interests. Homogenising/centralising acceptances between local councils, planning jurisdictions can improve the quality and speed of the consenting process. It also significantly reduces risks of applying alternative solutions and the approval process time. Furthermore, centralising the approval process can be a solution for the lack of expertise in some local councils which has been identified as the factor that delays the approval process.

- The industry needs to shift to a long term thinking to justify the investment in human and financial capitals. Shifting toward strategic planning and long-term thinking is fundamental for implementation of off-site construction methods

which need a large human and financial capital investment. The benefits of off-site construction methods are well understood among construction professionals. However, small scale and fragmented industry hinder full implementation of these methods. To tackle this issue, construction companies need to enhance collaboration and integration across the supply chain in order to reduce the risk of human and capital investments for implementation of off-site construction methods. The collaboration and integration cannot be achieved without shifting toward strategic planning and long-term thinking. A good example of long term thinking is a U.K based company that is going to construct 3000 apartments across the UK under a £600m "built-to-rent" plan. The company has changed overall working processes to create and control the supply chain, in order to build fast and high quality houses with minimum operational costs. Because the company is going to own the houses for a long term, they shift their strategy to build with high quality in order to reduce costs of operation over the life cycle. This strategic planning justifies the initial human and capital investments which are required for building high quality houses in a short period.

6. Summary

The BBHTC National Science Challenge 11 is a hugely complex programme dealing with a wide spectrum of different, complimentary, overlapping research fields in order to deliver the needs of society. The gestation period of the NSC11 was very long, with numerous iterations and rethinking, before finally proceeding to the contracting and research period. As far as Strategic Research Area 6 is concerned, once funding was confirmed and contracts were in place, the research team moved rapidly to appoint the critically important research assistants and undertake the basic research (i.e. literature review) necessary to baseline understanding before moving to the wider industry stakeholders.

Once the basic research had been completed, the lead researchers and research assistants worked extensively and collaboratively to establish mutually supporting focus groups and conduct appropriate interviews. The intent was to engage with as wide and representative group of industry representatives across the various centres of New Zealand. Industry uptake was robust. The team was able to engage a very wide and diverse group of subjects representing all of the key professions and community representatives needed for a truly representative set of views from across the industry. The findings and observations of which are presented in this document.

Over the course of the last year BBHTC Strategic Research Area 6 grouping has rapidly grown together as a cohesive group of researcher working for the common good. The group started out with an extremely effective working relationship. If anything this working relationship has developed and deepened through the various face to face and teleconference meetings conducted during the establishment of the research grouping and subsequent research activities. Indeed the way in which this report was brought to term in itself could be the model for teleworking and collaborative efforts for industry. One lead researcher was out of the country, the remainder were distributed across three centres and five institutions – all of the final edits and amendments were conducted exclusively by means of teleconference.

The result of this work are many and varied. One of the main outcomes is that the research team have increasingly come to realise the extent of the interrelated nature of the research and the fact that the 4 research domains – technology, process, people and innovation – all overlap substantially. The work plan accompanying this report has developed as the result of research undertaken by the team, reflecting the key findings from engagement with the industry during the preliminary research. This plan for the coming year has as an underlying principle the need to ensure that we collectively maximise our co-created outcomes and the collective effect that we can have on the industry.

Moving forward the intention of the research team is to both further and deepen this interrelated thinking, and professionally integrated behaviour. Over the coming year, as this Strategic Research Area moves forward, we will endeavour to maximise the effect of our work. We will be seeking to increase our level of interaction with both the wider NSC11 BBHTC community and industry. Indeed, there are emergent strands of research and thinking from elsewhere in the BBHTC community that has the potential to leverage - and be leveraged by – the work of the SRA6 team. On the other hand, there are other industry initiatives currently being considered or introduced that have the potential to develop a complimentary set of outcomes and effects to the core SRA6 effort. Once again the SRA6 team will seek to establish the means and methods of maximising the value of all work in the area of industry based research and change.

Looking forward the team is confident in the next phases of the work planned. The ground works that have been put in place rapidly since the award of contract are expected to provide a robust foundation upon which to build our further work.