Roadmap for supporting innovation in the New Zealand Construction Sector

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PREFACE

The AECFutures project documented herein, aims to provide context and strategies for supporting innovation in the New Zealand Construction Sector. It is specifically located within the ‘Automation, Innovation and New Technologies’ theme of the BRANZ Industry Research Strategy. The project focus is on making advanced and emerging technology and construction techniques more accessible to the Architecture, Engineering and Construction (AEC) Industry.

This report’s intended audience is people and groups in government, research funding bodies and councils. It contains context and strategies for guiding policy, legislation and research that will support more innovation within the building sector.

Computer Numerically Controlled (CNC) machines have existed for well over half a century. Initially CNC equipment was limited to milling machines and routers but has expanded to cover nearly any machine with a motor and even now includes large manufacturing robots. Not only has the operation of CNC machines become easier due to improved software interfaces, complex tools such as robots have become incredibly affordable as the market for second hand CNC machines increases. A pre-owned industrial robot can now be purchased for less than a new car.

The ease of use and affordability of contemporary CNC machines (such as routers and industrial robots) has made them ideal candidates for use in the building industry. Advances in computers and software have made CNC machines accessible to a wider range of industries and to users with less technical knowledge than previously necessary. The AECFutures project assembled a panel of industry experts in design and manufacturing; this includes marine and construction sector specialists, architects and government representatives. The panel identified three areas of focus to link the use of these new technologies between already existing fields. This report outlines the context of these issues and proposes both long-term and near-term strategies to facilitate the adoption of these technologies into a productive workflow that will contribute to, and increase, a culture of innovation in the AEC sector.

ACKNOWLEDGEMENTS

The authors would like to thanks BRANZ for funding this project – without their generous support the work would not have been possible. We would also like to thank our Advisory Panel who gave their time freely and provided initial direction and insights without which it would have been impossible to begin this work. In Amsterdam we are indebted to Gijs Van Der Velden who gave us an insight into how that city is supporting innovation and in Zurich to the Swiss Federal Institute of Technology (ETH) and Fabian Scheurer of designtoproduction.
EXECUTIVE SUMMARY

New Zealand’s priorities of smart growth for the construction sector (Architecture, Engineering and Construction - AEC) includes more high quality housing to meet the rising demand, improving productivity, increased Building Information Modelling (BIM) uptake and online systems for an improved building approval process. The number and intensity of international research and technological development (RTD) cooperation has grown significantly over the past decade. The factors driving this increase include industrial interest in strengthening domestic, export and international business. In an increasingly globally interdependent and knowledge-based economy, governments around the world are aware that they are in an international race between countries, cities or regions for knowledge, job creation and technological innovation. Countries like Singapore, Israel, Finland and Ireland are current leaders in this race because they are intelligently pursuing strategies for attracting high value-added enterprise.

In order to strategize ways to accomplish some of these goals, this project assembled a panel of experts from a broad spectrum of specialists from the manufacturing, marine, architectural, construction and composite material industries. The panel identified three central issues for innovation in the construction sector:

1. The need for a market and operating environment in which innovation can be nurtured, take root and grow.
2. The need for leadership and guidance addressing emerging technology for the industry, where the future of the industry will be, and how to prepare for it.
3. The need to upskill workers and industry partners in emerging technologies and a forum where organisations can exchange knowledge and expertise in all areas from IP to software and machine use.

Through the study, and documentation herein, of international best practice this report recommends these issues can be addressed by the following:

1. **Issue**: Operating environment  
   **Timeframe**: Long term (10 year)  
   **Recommendation**: Establish a cross-disciplinary working group aligned with the government looking at both the general and the specific legislative, economic and political obstacles.

2. **Issue**: Leadership  
   **Timeframe**: Mid term (3 year)  
   **Recommendation**: Establish a “Centre for Innovation” to provide the leadership, space and resources to encourage innovation in the building industry. The Centre should be a collaborative effort of government, industry and education.

3. **Issue**: Knowledge exchange  
   **Timeframe**: Near term (1 year)  
   **Recommendation**: Create an innovation network that provides workshops and access to technology and experts through existing resources already established in the country.

In summary, there is a lot of potential, knowledge and existing skill in New Zealand to have a dynamic and vibrant innovation culture in the building sector. New Zealand is well placed with organisations like BRANZ, to provide long term support for innovation in the sector.
ABSTRACT

New Zealand’s priorities of smart growth for the construction sector (Architecture, Engineering and Construction - AEC) includes more high quality housing to meet the rising demand, improving productivity, increased Building Information Modelling (BIM) uptake and online systems for an improved building approval process. In order to strategize ways to accomplish some of these goals, this project assembled a panel of experts who identified three key obstacles to innovation in the construction sector, broadly speaking these are: the operating environment; leadership and guidance for innovation; and upskilling for new and emerging technology. During this project the authors have studied international best practices in addressing these issues. The report documents and recommends three approaches based on the research, at three different scales (governmental support, public sector support, and support for the small to medium sized enterprises) addressing three different timescales (long, medium, and near-term).

KEYWORDS

Innovation, strategy, construction, new technology, robotics, government, network

REPORT PEER REVIEWED BY

Project Advisory Panel (see appendix)
INTRODUCTION

The growing need for innovation and cooperation

New Zealand’s priorities of smart growth for the construction sector (Architecture, Engineering and Construction - AEC) includes more high quality housing to meet the rising demand, improving productivity, increased Building Information Modeling (BIM) uptake and online systems for an improved building approval process. These goals are not unique to New Zealand, nor are the variety of possible solutions. Meeting these goals requires innovation and complex responses, combining expertise across many traditional and non-traditional areas for the building industry. Today’s technology and multi-layered processes make it difficult, if not impossible for a single institute or entity to possess the skills or competence to formulate innovative solutions to these complex issues, so national and international collaboration is crucial.

High Value Manufacturing (HVM) in New Zealand is a sector that performs very well, it is also the sector that developed many of the CNC machines that can now be found driving innovation in the construction sector. Although typically not associated with the AEC industry, a lot can be learned from the HMV sector. While the definition for HVM is potentially broad, it assumes that “value is more than profit,” that companies create strategic and social value through continued research and development and that “companies can be measured for environmental performance, sourcing their policies or their community involvement.”1 Small to medium companies, with an investment in technologically advanced manufacturing machines and a highly skilled workforce, are commonplace and are more than capable of fitting this definition if they are not already. These companies are well equipped to handle small, one-off production runs of many of the products required in the construction industry.2 This ability to be flexible and adapt to varied conditions makes New Zealand a prime location for innovation in the AEC industry.

International exemplars

The number and intensity of international research and technological development (RTD) cooperation has grown significantly over the past decade. The factors driving this increase include industrial interest in strengthening domestic, export and international business. In an increasingly globally interdependent and knowledge-based economy, governments around the world are aware that they are in an international race between countries, cities or regions for knowledge, job creation and technological innovation.3 Countries like Singapore, Israel, Finland and Ireland are current leaders in this race because they are intelligently pursuing strategies for attracting high value-added enterprise. These national strategies tend to leverage pre-existing strengths in areas of their existing tacit and collective knowledge.

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1 Livesey, Finbarr. 2006. Defining High Value Manufacturing. CBI.
Scope and approach

The primary objective of this report is to highlight a number of strategies for stimulating and supporting innovation in the construction sector of New Zealand. The report will provide examples at various scales including the national or governmental, the public sector, and the private, small medium enterprise (SME). This report takes a multi-directional approach and presents strategies that have been implemented at these scales internationally, and have the greatest potential to be implemented in New Zealand.

The report is categorised based on these different scales of operation and includes key facts and a broad description of the available levels of support and lists some of the applicable operational examples studied. The general description is followed by one operational example of a support framework and then identifies the applicable funding model used. Finally, the report provides a strengths, weaknesses, opportunities and threats (SWOT) analysis of each innovation framework.

PROBLEM IDENTIFICATION

The inaugural meeting of the AECFutures Advisory Panel took place in Auckland in the second week of June, 2015. The Panel (see appendix) is comprised of a group of experts from a broad spectrum of specialists from the manufacturing, marine, architectural, construction and composite material industries. The panel deliberated on four central issues to innovation in the construction sector. These issue were identified by the researchers during a scoping exercise that preceded the meeting. The scoping exercise canvassed opinion from stakeholders across the industry including architects, engineers, construction companies and independent consultants. Four general issues were recurrent in this investigation:

1. Intellectual Property: Sharing of data is met with suspicion when manufacturers have spent time and money on developing methods of machining and software for that purpose. In what way can relevant information be shared to improve the quality and speed of communication across design, manufacturing and construction?

2. Code Changes: New engineered and composite materials as well as construction techniques that are suitable for digital fabrication are not always comparable or approved under current building codes. What are the pathways for approving new engineered materials or composite materials that have proven success in other sectors, such as the marine or the manufacturing sector? Can a similar, streamlined process be adapted for the AEC sector?

3. Software and Communication Gaps: Specialised machining and modelling software can prevent the sharing of data from creator (designer, architect) and manufacturer; resulting in simple CAD drawings continuing to be used for communication. This does not need to be the case as new software gives us powerful and easy-to-use tools that can be used to communicate with people and computer controlled machinery through shared data. How can this knowledge be shared and expertise be made available to the industry at large to provide an efficient digital work flow?

4. Hardware, Education and Skills: The design and construction sector has seen a dramatic uptake in computer controlled machinery, which is set to increase further in the next 10 years as general purpose robotics become more and more affordable and
easier to use and programme. Are the skill and educational needs of the sector being met? Are there changes needed so that the industry will have the sufficient graduates/apprentices with key skills to meet its needs?

The panel deliberated on the obstacles within these four categories.

1. Intellectual Property

Key points made with regards to intellectual property (IP):

1. There is resistance and uncertainty in some parts of the AEC sector regarding IP - this seems to be accompanying the interest in creating more and more complex and detailed building information models (BIM) which are markedly different and (may) hold more sensitive information than a simple geometric computer aided design (CAD) model.
2. Other parts of the industry rely on moving and innovating quickly and perceive IP and patents as things that can stifle innovation.
3. The marine and robotics sector approach IP and trade secrets very differently, often issues of IP, copyright etc. are in very early negotiations that occur early on. They establish clarity at an early stage of what each stakeholder will or will not be expected to share as well as which parts of the IP lie with each party.
4. We have national groups - like Callaghan Innovation - that are highly knowledgeable about IP, Patents, Copyright etc.

Obstacles

1. This is a new issue for the industry, which is not as developed as the marine, manufacturing or robotics sector in digital fabrication.
2. Companies might use IP to claim a particular expertise, where they have a proprietary right over a particular new design or engineering solution for example and stifle possible innovation.
3. The AEC sector does not have particularly good access to clear and understandable information on IP, patents etc.

Key questions

1. How can we separate the realities from the myths concerning intellectual property, copyright, patents etc?
2. How do we address concerns over IP as digital systems and information exchange becomes more commonplace?

2. Code Changes

Key points made with regards to the building code:

1. 66 local councils all interpreting the performance-based code differently.
2. Burden of proof in meeting the performance specification (structural, weather tightness, durability) rests with producers.
3. BRANZ role is not regulatory, they undertake testing and an appraisal service.
4. Codemark is a product certification scheme.
5. There is considerable interest in innovation within the industry - but there are many obstacles to approving new methods and materials.
Obstacles
1. Council expertise is decentralised, making it difficult to use an innovation approved by one local council region in another council region.
2. NZ 3604 (Timber Framed Buildings) construction guidelines have become the default easy path for approval.
3. The leaky building problem has created a very risk averse industry - it is very difficult to deviate from NZ3604.
4. The extensive cost and testing required to get approval in New Zealand means many tried and tested North America and European construction systems cannot be used in New Zealand.
5. The absence of a national board for innovation in construction means no strategic overview of what changes the industry might benefit from and subsequent oversight of how these changes can be worked through.

Key questions
1. How do we bring down the cost and streamline the approving of new methods and materials for construction?
2. How can we create an atmosphere for innovation by encouraging or rewarding successful new methods and materials for construction while ensuring that these methods remain safe?

3. Software and Communication

Key points made with regards to software and communication:
1. With the increased use of computer numerical controlled (CNC) machines there is larger potential for miscommunication around expectations of tolerance and precision. CNC machines create components to 0.1mm accuracy, this presents problems if, on site, precision is considered to be 10mm accuracy.
2. The supply chain is increasingly critical when involved in digital fabrication. More precision in digital manufacturing requires more precision in the products used.
3. Something as simple as a vendor leaving the plywood outside can change its moisture content and render it unusable for digital fabrication. Material handling instructions would have to be clear in using digital fabrication techniques.
4. Quality of New Zealand materials (plywood for example) is highly variable - it is important to identify key ‘preferred’ suppliers as there is no general market incentive to increase quality.
5. Marine and manufacturing sector are more mature in assessing what needs to be communicated, to whom and how. Currently in the AEC sector different organisations just ask for the ‘BIM model’.

Obstacles
1. Organisations have difficulty obtaining continued professional development (CPD) education to upskill in these new digital areas.
2. Stakeholders within the supply chain have no incentive to improve quality without consumer demand.
3. Needs to be a more clarification of what needs to be communicated, to whom and how in the AEC sector.
Key questions
1. How do we have a 21st Century business model that can capitalize on new and emerging technology?
2. How do we educate current users to emerging trends while maintaining profitability?
3. What are strategies for increasing the level and clarity of communication between all parties involved?

4. Hardware, Education and Skill

Key points made with regards to hardware, education and skill:
1. New digital fabrication hardware creates a need to rethink the entire construction process.
2. In the marine sector - changing from traditional materials to composite materials literally changed construction time from two weeks to two days.
3. A ‘digital workflow’ can help to create a ‘smart’ industry but it will require rethinking construction.

Obstacles
1. Industry have the skills to utilise new digital fabrication equipment using traditional techniques but do not have the expertise to innovate with the tools and use them to their fullest potential.
2. Reliance on new graduates to have skills but levels of skill differ from one graduate to the next.
3. Lack of information on where to obtain professional development for existing staff.
4. No examples on how to develop or use existing technology in ways outside of scope of knowledge.

Key questions
1. How do we make different computer systems and software, that designers, contractors and consultants need to use, talk to each other in an efficient digital workflow?
2. With digital technologies changing fast how do we provide a platform for consistent education, knowledge transfer and training?
3. How do we provide opportunities to innovate using existing machines and tools?

Key Issues

Focusing on innovation in the building industry, the advisory panel narrowed the focus of the four identified problem areas down to three key issues. These three redefined issues are derived from the panel discussions and were agreed upon by the Advisory Panel as key issues that would provide the most success for innovation in the building industry with urgent an long term support.

These issues are:
4. The need for a market and operating environment in which innovation can be nurtured, take root and grow.
5. The need for leadership and guidance addressing emerging technology for the industry, where the future of the industry will be, and how to prepare for it.
6. The need to upskill workers and industry partners in emerging technologies and a forum where organisations can exchange knowledge and expertise in all areas from IP to software and machine use.

In the following section we look at some international best practice for addressing each of these points (1.) Assisting government to support innovation (2.) Where and how to provide publicly funded support for innovation and (3) How to support small to medium enterprises (SME's) to innovate.
“Governments will always play a huge part in solving big problems. They set public policy and are uniquely able to provide the resources to make sure solutions reach everyone who needs them.”

Bill Gates (Founder of Microsoft)

SUPPORTING GOVERNMENTAL INNOVATION

This section looks at ways in which governments have been successful at supporting innovation. It begins with a short synopsis of international best practice in this area. It then looks at one example in depth and provides details on funding, organisational structure and a strengths, weaknesses, opportunities and threats (SWOT) analysis.

Synopsis

There are many international organisations that have deployed large national programmes to support innovation in the construction sector. Examples of these internationally and locally include the building SMART group \(^4\); the BIM Task Group \(^5\) based in the United Kingdom; the BIM Acceleration Committee \(^6\) and Productivity Partnership in New Zealand. The New Zealand innovation initiatives are similar in many ways to the aforementioned models of innovation support, they are well known and documented and this report will not dwell on them for that reason. This report will instead include national as well as transnational entities intended to support government and large scale industries in a coordinated approach to innovation and technological development (ITD). In this regard the Information Technology & Innovation Foundation \(^7\) (ITIF), the Institute for the Future \(^8\) (IFTF) and eu|te|ma are of interest. The ITIF and IFTF are standard not-for-profit organisational models. We will focus here on eu|te|ma, a research strategy consultancy. Within the context of New Zealand this type of approach offers a number of benefits in that the consultancy is smaller, more agile and operates with fewer people than the not-for-profit organisations.

eu|te|ma

What sets eu|te|ma aside from other national initiatives is they are an independent consultancy. This has offered a number of distinct advantages for the European Commission (EC). Namely it has enabled eu|te|ma to be significantly more agile and responsive to the changing research and innovation landscape that would not have been possible if they were within the governmental structures of the EC. They have also been able to extend their services beyond the EC departments and provide research strategy and management advice to

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4 http://www.buildingsmart.org
5 http://www.bimtaskgroup.org
6 http://www.building.govt.nz/bim-in-nz#bim-acceleration-committee
7 http://www.itif.org
8 http://www.iftf.org/home/
multinational and national organisations, thus benefiting innovation and the economy in additional ways.

“Since 2001 we develop strategies in the area of technology development for our clients. We successfully realize these strategies in co-operation with our European partner network. Our clients appreciate our technical competence as much as our year-long national and international experience. We develop research strategies, manage complex technology initiatives or plan and realize international research projects.”

They support industry in developing and realizing complex funding projects, provide consulting in national and EU-funding schemes and support them in the strategic orientation of technology policy in Austria and the EU. For clients in the public sector, they develop research strategies, manage research programmes, and maintain communication with a diverse range of target groups. In this regard they provide the expertise that a Government typically does not need for day to day governance. However, the expertise is critical in devising government strategies that impact on research and innovation.

In the area of research policy and technology policy, they perform evaluations of technology initiatives and research programmes and deliver strategic technology studies.

Key Facts

Who funds it: Government & National Industry (via contractual work)
Who uses it: Government & National Industry
Who gets support: The primarily beneficiary is governments and national industries. They are supported in the form of being delivered better research and management strategies. Although in principle there are secondary beneficiaries in the form of smaller organisations and the public in general, as - in theory - when governments and national industries are better at what they do, everyone benefits.
Start-up facts: Low expenditure for start-up, low people costs (approximately 4 at start-up)

Operational framework

The business and funding framework could be represented by the diagram below:

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9 http://www.eutema.com/
eu|te|ma is a private consultancy, which enables it to remain agile and reorganise to changing market demands. It primarily delivers management strategies to the European Commission and to other public sector industries on a commercial contract by contract basis. The funding base is primarily through private contract from the EC, government and large industries. The organisation has a very focused scope it performs two main functions 1) develops research strategies and 2) manages research. It is very much focused at delivering outcomes at very high levels such as to governments or the EC.

**SWOT analysis**

**Strengths**
- Agile: the company can hire or reorganise as necessary to respond to changing consultancy needs.
- Has multiple income streams so not completely reliant on government funding.
- Flexible: this type of framework can started with quite small numbers (1 or 2 employees); can grow quickly if necessary and also has the freedom to supplement a core team with additional manpower hired on a contract by contract basis.

**Weaknesses**
- Serves only Governmental agencies and multinational or national scale organisations.
- Does not monetise research outputs
- Does not support SME’s
### Opportunities

Does not suffer from constraints - either administrative or managerial - of being within a large governmental organisation which would otherwise limit the ability of the structure to perform its core function.

This approach has been useful during the establishment and management of National Science Challenge 11.

### Threats

Possibly insufficient market size in New Zealand to be sustained without governmental funding.
“I think frugality drives innovation, just like other constraints do. One of the only ways to get out of a tight box is to invent your way out.”

Jeff Bezos (Founder of Amazon.com)

PROVIDING PUBLIC SECTOR SUPPORT FOR INNOVATION

This section looks at the provision of public resources that are intended to support innovation in the construction sector. It begins with a short synopsis of international best practice in this area. It then looks at one example in depth and provides details on funding, organisational structure and a strengths, weaknesses, opportunities and threats (SWOT) analysis.

Synopsis

Public sector support typically involves the setup of “Centres”, populating them with people and equipment to support an industry. There has already been a comprehensive report on centres of innovation to BRANZ in 2010.10 Instead, we will look specifically at the financial support framework for a network of coordinated IDC’s (Industry Development Centre’s) that support different aspects of industry needs that are not being served sufficiently by higher education. The 2010 report revealed existing centres predominantly focused on research and its commercialisation, instead of industry support. It should be noted that the IDC’s reviewed here are intended to specifically support a sub-sector of the construction industry. This is perhaps more applicable in New Zealand where the construction sector has a high percentage of small to medium enterprises (SME’s) that lack the resources to fund specific research and development divisions within their organisation. We will look specifically at the Träcentrum (The Wood Centre) in Nässjö, Sweden.

Träcentrum

Foundation Träcentrum (Wood Centre)11 is in Nässjö Sweden and is the country’s first of its kind. A centre for industry education, development and conferences. Thirty-five companies and two municipalities formed the foundation in 1991 and the entire facility was completed in January 1995. It receives a large portion of its operational funding from the municipalities and private companies to provide its services to the local and national timber industry. Wood is the largest export industry in this region. Within a fifteen-mile radius of Nässjö, you will find 75% of the country’s carpentry business, manufacturers of wooden houses, furniture and numerous sawmills. The Wood Centre’s task is to help and promote industrial development and skills for this important branch of industry. The concept of The Wood Centre is based on interaction between groups who can contribute relevant expertise. They work with companies,

10 http://www.branz.co.nz/cms_show_download.php?id=5493b587abf4c44b031a7c859ddcbf016eefe0e
11 http://www.tracentrum.se/sv/start/
universities, professional organisations, government agencies, independent consultants and others to ensure a goal-oriented and long-term effort.

At any one time, The Wood Centre hosts over 500 people on various educational courses. Everything from high school students to advanced vocational training. All students have the opportunity to apply for scholarships from associated foundations, which annually distributes hundreds of thousands of dollars to students at Träcentrum. The facility is run by a total of approximately 60 people, not including the Advisory Panel from wood-related businesses.

**Key Facts**

**Who funds it:** The foundation receives regular funding from municipal government and participating national industries

**Who uses it:** The general public, educational providers and small to medium sized enterprises (SME’s)

**Who gets support:** Educational providers and small to medium sized enterprises (SME’s)

**Start-up facts:** High expenditure for start-up, high people costs (approximately 60 at start-up)

**Operational framework**

The Wood Centre has an extremely broad network focusing on developing and offering services in three high priority areas; business development, product development and production. The Centre’s aim is to create skilled professionals that will then continue to support the development of the local and national wood industry. Within these areas of focus, they implement development projects and programs. The development projects that are currently operating have a strong marketing and networking focus. They also offer customized training in areas such as surface treatment, organisational development, production work, and other items that fall within the three priority areas. This scope is largely made possible because of the steady municipal government and industry funding that forms the basis of this innovation support framework.
For its operational funding framework, The Wood Centre relies heavily on municipal funding and industry contributions. It has additional income streams including providing courses for tertiary institutes and conference facilities. As well as some public usage of the facilities, primarily SME’s and educational providers use its core function, send people to train in the facility to creates a steady stream of well skilled professionals that support the industry and it’s changing needs.

**SWOT analysis**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>Has multiple income streams so not completely reliant on government funding.</td>
<td>Requires steady stream of funding.</td>
</tr>
<tr>
<td>The support it provides is negotiated through current market demand and the board of advisors. It can respond to market change much faster than tertiary curricula providers can.</td>
<td>Does not monetise research outputs</td>
</tr>
<tr>
<td>Provides a broad base of support for the industry’s small to medium enterprises.</td>
<td>Requires significant start-up capital for both the facility and staffing.</td>
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### Opportunities

Does not suffer from constraints, both administrative and managerial of being within a large governmental organisation which would otherwise limits the ability of the structure to perform its core function.

It provides multiple function and can have several streams of funding income.

### Threats

Possibly insufficient market size to be viable.

Cuts to government funding would be very problematic.
“Innovation has nothing to do with how many R & D dollars you have. When Apple came up with the Mac, IBM was spending at least 100 times more on R & D. It’s not about money. It’s about the people.”
Steve Jobs (Founder of Apple Inc.)

SUPPORTING SME’S INNOVATION

This section looks at ways in which SME’s can be supported to innovate. It begins with a short synopsis of international best practice in this area. It then looks at one example in depth and provides details on funding, organisational structure and a strengths, weaknesses, opportunities and threats (SWOT) analysis.

Synopsis

A number of innovation hubs and networks were studied within this category, particularly exemplary were Robots in Architecture\(^\text{12}\), Grymsdyke Farm\(^\text{13}\) and MX3D\(^\text{14}\). All of these groups have modest start-up costs and are supported by interesting combinations of private and public sector funding. Central to their scope is innovation and supporting SME’s to access and share knowledge regarding new and emerging technologies as well as new ways of working.

Robots in Architecture

The international Association for Robots in Architecture (RiA) is a well-established innovation network that was originally a spinoff association from Vienna University of Technology. Its goal is to make industrial robots accessible for the creative industry, artists, designers and architects, by sharing ideas, research results and technological developments. Founded in December 2010 by Sigrid Brell-Cokcan and Johannes Braumann, Robots in Architecture is an open platform for everybody interested in the creative use of and innovative fabrication with industrial robots. Robots in Architecture is engaged in applied research, software and hardware development and “robot pedagogics.”

They pursue their association’s goal by offering workshops and holding lectures at international conferences, schools, and universities, and by maintaining the Robots in Architecture website, which serves as a hub for any topic dealing with the use of robots in architecture, art, and design.

Key Facts

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<tr>
<th>Who funds it:</th>
<th>Host University, memberships and contracted research</th>
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<tbody>
<tr>
<td>Who uses it:</td>
<td>Primarily host university, members, secondarily SME’s</td>
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<tr>
<td>Who gets support:</td>
<td>Primarily its members, although the industry also benefits through innovation as the associations (RiA) remit is to develop the industry market for robots</td>
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\(^{12}\) [http://www.robotsinarchitecture.org/](http://www.robotsinarchitecture.org/)
\(^{13}\) [http://grymsdykefarm.com/](http://grymsdykefarm.com/)
\(^{14}\) [http://mx3d.com/](http://mx3d.com/)
Startup facts: Low expenditure for start-up, low people costs (two at start-up)

Operational framework

RiA is a not-for-profit association which is very closely aligned to the Vienna University of Technology. As such its operational funding and overheads can be much lower than the two previous categories of innovation support. RiA receive funding from conducting research and from membership to the association. Their close alignment to a university means research remains an important part of their scope; as such they do not exist exclusively to support industry. The RiA mandate to provide workshops does mean however they contribute in some way to an informed skilled industry.

SWOT Analysis

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<th>Strengths</th>
<th>Weaknesses</th>
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<tr>
<td>Low operational costs due to proximity to tertiary institutes.</td>
<td>Has additional demands (research) placed upon it by proximity to tertiary organisation.</td>
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<tr>
<td>Close proximity to expertise and researchers.</td>
<td>Suffers from constraints, both administrative and managerial of being within a large tertiary organisation which limits its ability and change to adapt quickly.</td>
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<table>
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<tr>
<th>Opportunities</th>
<th>Threats</th>
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<tr>
<td>Does not suffer from financial constraints of a private company.</td>
<td>Viability of the group subject to host tertiary institute.</td>
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Members of the group subject to other educational commitments (teaching etc.).

CASE STUDIES

This section documents working examples of three approaches to each of the three issues outlined in the 'Key Issues' section.

1. We look at the municipality of Amsterdam, a regional government that has successfully implemented changes that have caused Amsterdam to be singled out as an excellent example of a place that supports innovation.¹⁵

2. We look at an innovation centre at ETH Zurich

3. Finally, we look at an innovation network creating a self-supporting network of people and resources.

Amsterdam

To better understand how Amsterdam supports innovation we visited two highly innovative projects in Amsterdam. MX3D’s headquarters and the ongoing 3D printing of a canal house. It is no accident these ground breaking projects have emerged in Amsterdam; the forward thinking municipality helps provide space for start-ups in Amsterdam. A highly liveable city, pedestrian friendly and famous for its cycling infrastructure it attracts and supports young entrepreneurs and there is support to help them transition from start-ups into fully fledged companies. Combined with world class companies that can be found on Amsterdam’s doorstep who want to support and be associated with innovation, all the key ingredients are there.

MX3D

MX3D is an innovative technology and design start-up company that has received considerable attention for their robotic 3D printed bridge project. A ‘3D welding’ project began in Joris Laarman Lab (http://www.jorislaarman.com/) that eventually gained enough momentum to spin out into the company that is now MX3D. They are currently focused on using their developed innovative 3D welding technique to print a metal bridge that will span one of Amsterdam’s canals. A common attribute of the many companies that are helping to fund the project have is the long term goal of remaining relevant in an industry that will be changed dramatically by robotics in the coming years. They recognise that although we might not know where automation will be located in the design and construction industry tomorrow or next week it will significantly reshape these industries over the next decade. MX3D’s partners and the city of Amsterdam want to be shaping the future, not trying to catch up with it.

3D Printed House

Within 1 kilometre of MX3D the site for DUS Architect’s 3D printed canal house can be found. Yet another highly innovative project that aims to look at how 3D printing might be used in the construction process. In 2014 Barak Obama visited DUS to discuss this project, which includes...
innovating new types of concrete, new 3D printing materials and techniques as well as rethinking how we might design and construct houses in the future. 

MX3D and DUS are great examples of innovative companies in the design and construction sector. Amsterdam can be looked upon as a city that has deployed a strategy to support innovation and has seen success with these projects. The strategy is a long term strategy that has been allowed to evolve and respond to changing conditions. This has included opening the old shipyards across the river to the north of historic Amsterdam for development. In parallel, ferries have been provided free of charge to connect and stimulate development to the north of the city and the planning situation has been allowed to change and respond as development has accelerated in that part of the city. For example, as housing began to develop in the area and prices began to increase, the Hilton Group opened a hotel. In response, a number of changes to the policy were introduced to encourage more affordable housing and limit price increases.

The municipal government remains alert and active in trying to ensure the conditions that attract young people and innovative companies remain present. This includes:

1. Affordability of housing, recreational and commercial space.
2. Quality of life, which includes easy access to recreational facilities.

**Innovation Centre: Gramazio Kohler Research at ETH Zurich**

Gramazio Kohler Research was initiated from the robotics research being carried out by Fabio Gramazio and Matthias Kohler at the ETH in Zurich. Their pioneering research in the use of robotics in architecture began in 2006 with their work in using a robotic industrial arm to create innovative brick walls. The combination of the robot as a new tool and the research into new uses for an old material helped establish ETH and Gramazio and Kohler as leading researchers in the field of digital fabrication. Since the inception of Gramazio Kohler research at ETH, the research work has grown to include not only robots but mobile robots, flying robots, materials research, on-site construction and anything else related to digital fabrication in architecture. Because of the complex nature of the research, the team collaborates with many fields including material scientists, computer scientists, robotics experts, sensor experts and anyone else that might aid in the advancement in the AEC industry. They recently have begun to collaborate with ABB, a robotics manufacturer, in devising new uses for their robots.
Institute of Technology in Architecture

The work of Gramazio Kohler Research has led to the establishment of the Institute of Technology in Architecture (ITA) at the Faculty of Architecture in ETH Zurich. The ITA is a “world-leading platform for the teaching and development of pioneering technologies in architecture.”¹⁶ Their focus on technology and innovation in the building industry is a prime example of where the building industry is heading and how an educational institution is partnering with industry and government to innovate the industry.

The ITA and Gramazio Kohler Research have partnered to create the new National Centre of Competence in Research (NCCR) for digital fabrication in architecture. Recently the NCCR received funding from the Swiss government and the Swiss National Science Foundation for over $46 million dollars (NZD) over the next four years.¹⁷ The investment has funded the new robotics research laboratory shown in Figure 7 and partners several Swiss universities and the government in innovative research related to digital fabrication using robots.

¹⁷ http://robohub.org/swiss-to-invest-almost-chf30-million-in-digital-fabrication-research-over-next-4-years/
Innovation Networks

Innovation networks have been around for some time. In fact, in New Zealand there are a number of successful ones including the Heavy Engineering Research Association (HERA)\textsuperscript{18} and the Food Innovation Network.\textsuperscript{19} Both these industries have similarities to the building industry in that a large proportion of the people in these sectors belong to SME’s. As this AECFutures project has established a network of people we will document here some of our initiatives to support innovation. One such event was an Industry Workshop hosted by AECFutures on ‘digital workflow’ for professionals from across the design and construction industry.

Attendance

There was attendance from across the industry, with major national architects and contractors represented, as well as building envelope specialists, digital fabrication specialists and design management specialist. There were also researchers who specialise in automation and robotics.

The aim

The workshop brings together technology and industry specialists to transfer knowledge and skill to enable the uptake of new technology to benefit the design and construction sector.

The workshop

The workshop introduced parametric or ‘procedural’ design processes. This has been on the forefront of the design industry for several years but has been slow in making it into professional practice. With Revit now including a procedural design workflow tool in the form of ‘Dynamo’ for Revit it is becoming increasingly common in the industry. The workshop introduced these new tools and provided examples for a computational to digital fabrication work flow. For example, they can be utilized to extract or generate the data required to directly control an automated computer numerical controlled (CNC) piece of machinery. The workshop provided hands on experience in extracting data from a design to control a typical CNC router. As a lot of numerical controlled system run on very similar concepts the workshop finally showed how you can reuse a digital workflow to control other types of CNC machines.

\textsuperscript{18} https://www.hera.org.nz/MainMenu
\textsuperscript{19} http://foodinnovationnetwork.co.nz/network
Outcomes

As a consequence of this networking several things have followed:

1. Developed a cross disciplinary group interested in innovation.
2. Established that the group would want more upskilling in new tools.
3. Discovered many have new equipment not being used to full capacity.
4. Confirmed there is a willingness to share/subcontract resources and skills.
5. The organisations continue to be re-contacted by workshop attendees, who want advice on other aspects of new technologies.

In conclusion, with a very modest amount of funding and using mainly existing resources of other organisations during their ‘down’ time, it was possible to establish a group that continues to support each other in both knowledge and technical resources.

SUPPORTING INNOVATION
In summary this report has documented various support entities and funding mechanisms for three levels of support for innovation within the construction sector. Namely 1) governmental 2) public sector and 3) small to medium enterprise. The documented models for innovation all have 6 standard components in common:

1. **Funding**: All the models, to a greater or lesser extent, receive funding from state and/or private/public sector. Innovation has risk associated with it and the funding lessens the risk taken, particularly where SME’s are targeted. In most cases there are multiple funding sources: a combination of state/council and public or private sector sources. This spread the funding load to multiple organisations that eventually benefit.

2. **Access to tools**: Innovation, particularly in the building sector necessarily involves machinery of varying size and complexity. Interestingly in the models that are engaged in undertaking practical research or skill-based training all have only basic machinery. Where additional or more sophisticated machinery is required, business/social networks are used to access this machinery. This principle makes for low start-up costs for a functioning innovation entity.

3. **Business/social network**: All of the above examples have very active business and social networks. They are of critical importance in marketing and publicising their work and in being able to draw on the relevant expertise as and when needed for innovation projects.

4. **Skilled workers**: Some, but not all, of the innovation mentioned involves making use of machinery from other sectors. When this happens it is of critical importance that the relevant skills are available to utilize the equipment to its fullest potential.

5. **Space**: Organisations work in space that works for them. Innovation needs additional space, which is not always practical for an organisation. The above models engaged in undertaking innovation and research all provide space in which to conduct experimentation.

6. **Good ideas**: This appears to be in abundant supply, from international research and meeting with the advisory panel there are lots of people with good ideas for innovation. What prevents the implementation of those ideas is access to tools, skills or too much financial risk on the part of the individual or group.

Typically, in an industry like construction where innovation will involve carrying some aspects of risk, reskilling, multiple disciplines as well as prototyping at relatively large scales - it is likely that any support for innovation in the construction sector should involve all 6 of the above components. As New Zealand has a large number of SME’s in the construction sector, regional support would be most likely to succeed and involve lower setup costs. In the case of RIA and MX3D, space is provided at a University and governmental/municipal level respectively. The latter appears to provide greater freedom of the organisation and deliver more benefit to industry. Both receive some state level funding but this is supplemented by additional funding from either the private sector or competitive research funding.

**CONCLUSIONS**

Returning to the key issues that the advisory panel identified as needing immediate action:
1. The need for a market and operating environment in which innovation can be nurtured, take root and grow.
2. The need for leadership and guidance addressing the needs of where the future of the industry will be, and how to prepare for it.
3. The need to upskill workers in emerging technologies and a places where organisations can exchange knowledge.

Item 1. The need for a market and operating environment in which innovation can be nurtured, take root and grow

On this there are major obstacles. Firstly, we know from Europe and Ireland in the 1990’s where there was an unprecedented economic boom, there was an enormous demand for housing - any housing. The result in many parts of Europe including the United Kingdom and Ireland was poor quality housing as there was no incentive for innovation.

At a general level: Auckland is experiencing a boom, and, due to its size the effects can be felt throughout New Zealand. One consequence of this is that builders are busy and there is very little incentive to innovate. This market environment needs to be addressed significantly - and it cannot be addressed simply. Within this context, we refer to the report’s findings on Amsterdam. Amsterdam is a city of high housing prices and a strong reliance on tourism - another factor that elevates the cost of living. In this regard it is not unlike Auckland. However, the municipality of Amsterdam has focused on stimulating innovation and is rolling out a long-term strategy to make the city and country supportive of innovation in an attempt to attract creative thinkers.

At a more specific level: NZ3604 - although highly innovative when launched - has now become the default means of construction. This causes other modern methods of construction to be considered ‘alternative solutions’ (AS). We are seeing some significant problems around this:

1. An alternative solution that is approved by one local council needs to go through the same approval process by other councils. Making an alternative solution costly both in terms of time and money.
2. There are no processes by which an alternative solution will or can eventually be considered not ‘alternative.’
3. There are many robust modern methods of construction that have been used for decades around the world but are not accessible to New Zealanders because of the cost of approval.
4. There are only a small number of equivalents (CodeMark) meaning excellent products from Europe and North America need to go through extensive local testing - which is cost prohibitive for most.

There is a clear need for a cross-disciplinary working group or consultancy process aligned with the government looking at both the general and the specific legislative, economic and political obstacles outlined above. Within this report eu|te|ma, who are experts in strategic technology management, have proven successful in advising the European Commission on strategies in the building sector. Contracting a similar group in New Zealand would help in gathering relevant information and people to make informed recommendations to the government. Additionally, more detailed case-studies of cities tackling this problem and making quantifiable progress - like Amsterdam - are required and could be the mandate of the new working group. A long-term strategy aligned to the 10 year programme of the National
Science Challenge 11 to create an operational environment in New Zealand would likely provide the best chance for success that will allow for steady and long-term change and monitoring to support and grow innovation in the building sector in New Zealand.

Item 2. The need for leadership and guidance addressing new and emerging technology for the industry, where the future of the industry will be, and how to prepare for it.

A number of local research support entities exist at the time of writing. The Building Research Association of New Zealand (BRANZ) who funded the AECFutures think tank and commissioned this report, the Building Information Modelling (BIM) Acceleration Committee and the Auckland Tourism, Events and Economic Development (ATEED) to name a few. In some capacity these organisations separately support research, economic development and technology support for the industry. Their groups are also separately investigating or funding research into BIM, automation, fabrication and performance - but not necessarily specific to the holistic approach to combining these to improve the performance of the AEC sector. Because these groups all have very individual mandates and operate in different sectors it has not been possible to have a coordinated approach to these various streams of research in the building sector, but that is exactly what is needed. A new group focused on contemporary tools and processes in the building industry is necessary to develop a leadership strategy for innovative building in New Zealand. This organisation will be required to evaluate the construction sector as a whole and not as separate entities that arbitrarily come together as the AEC industry.

Within this report there are two pragmatic examples of this (1) Centres such as Träcentrum become clear public icons and provide services that industry can easily find. With an influential board of advisors, The Wood Centre is able to liaise closely with government and industry to effectively provide reliable leadership that helps the industry prepare for tomorrow with continuous support for the present. Träcentrum is highly industry focused, aimed at working with them to understand their short term need over three to five years. They develop programmes that deliver skilled people with the required knowledge. Importantly within the context of leadership - it listens to industry and then provides guidance to ensure there is a plan being enacted to keep industry prepared for future change. (2) The newly created NCCR for digital fabrication at ETH in Zurich is another approach. It tackles cutting edge research and becomes a global icon for innovation. This type of centre attracts the best researchers and students from all over the world bringing unparalleled knowledge into the country adding to its creative capital. In different ways both of these types of centres benefit their respective countries. One by directly servicing the industry and the other by attracting world class industry knowledge and skill into the country. This shared knowledge then indirectly benefits the local industry who in turn publically represents the country as a world leader in this area.

New Zealand already benefits greatly from the work of the Building Research Association of New Zealand (BRANZ) both in terms of the work they do and the external work and research they fund through investment of the Building Research Levy. Having an entity such as BRANZ provides the opportunity of possibly expanding its scope and establishing a specific division focusing on innovation and industry leadership or externally fund an advisory group to establish a place of excellence and leadership in emerging technologies.
Item 3. The need to upskill workers in emerging technologies and a place where organisations can exchange knowledge.

There is significant expertise in New Zealand in and around the types of technology and changes that the industry is facing. The New Zealand high-value manufacturing sector is world recognised as punching well above its weight. This sector is using automation technology that is already finding its way into the building sector. The marine sector has significant capability in material and performance testing and simulation - something which is increasing in importance with the uptake of BIM. America’s Cup Yachts are fabricated in New Zealand, and some of this expertise has already been applied to building, such as the Marsden Cross Heritage Centre.

These however are only a very small number of unusual examples, what is more common is:

1. Organisations investing in equipment and finding it very difficult to find someone with the skill to fully utilise the equipment outside of older industry conventions. These organisations are unable to find a resource to upskill existing staff with the knowledge that would allow for innovative practices.
2. Organisations understanding that they could be doing more but not being able to find the expertise necessary to accomplish it.
3. Organisations finding that their expensive, highly technical machines sit idle. These findings are also repeated in New Zealand with the same result – machines are used a fraction of the time they were intended to run.

There could be immediate addressing of this issue through establishing an innovation network, similar to that of the food innovation network that has already been created in New Zealand. The food sector has assembled a national network of facilities and people with in-depth knowledge around supporting the Food and Beverage Industry of New Zealand. Like the building sector, the food sector is made up of a large proportion of SME’s (small to medium size enterprises with a lot of knowledge and facilities scattered all across the country. Some of this equipment is not being used to its full capacity or is particularly specialised and thus only operational for 50% - 70% of the time. Establishing an innovation network for the building industry would connect the scattered expertise and resources to share knowledge and facilities that would help grow capability in the sector. One successful example to build from is in the organisation highlighted in this report. ‘Robots in Architecture’ provide on-call help for its members and provides a place for sharing knowledge and tools in the innovative use of robots. They also run regional industry workshops introducing new technology to organisations and stakeholders in the building sector, all of which supports and grows a culture of innovation within the industry.

An innovation network features internal transparency and direct communication. Members of a network collaborate and share knowledge directly with each other, rather than through hierarchies. They come together with a shared vision because they are intrinsically motivated to do so and seek to collaborate in some way to advance an idea.

The five essential elements of collaborative innovation networks (what Gloor calls their "genetic code") are as follows:

1. Evolve from learning networks
2. Feature sound ethical principles
3. Based on trust and self-organisation
4. Make knowledge accessible to everyone
5. Operate in internal honesty and transparency

They rely on modern technology such as the Internet, e-mail, and other communication vehicles for information sharing. Creativity, collaboration, and communication are their hallmarks although they existed well before modern communication technology enabled their creation and development.

RECOMMENDATIONS & ROADMAP

In summary, there is a lot of potential, knowledge and existing skill in New Zealand to have a dynamic and vibrant innovation culture in the building sector. The conclusions of this report have summarised three key obstacles to innovation and approaches to overcoming them. The first issue, regarding the operating environment, is a long-term issue that will require a long-term strategy that will require government involvement. The second issue, regarding leadership, can be addressed in the near-term. New Zealand is well placed with organisations like BRANZ, for example, where an entity or group could be established or contracted to provide support while in the long-term working toward the viability of a centre for innovation. The third issue, on knowledge exchange, could be quickly addressed in the near-term through supporting an innovation network to create an atmosphere of innovation and collaboration amongst industry partners. The findings of this report confirm that the facilities, knowledge and willingness to share exists within the industry and academia, although it is distributed throughout the country. A formal innovation network would be a strong move to immediately mobilise and provide access to methods of innovation within the industry. These initiatives are aligned into the 'innovation roadmap' in Figure 9 (larger image can be found in the Appendix.

Figure 9. Innovation Roadmap
In summary, there is a lot of potential, knowledge and existing skill in New Zealand to have a dynamic and vibrant innovation culture in the building sector. The conclusions of this report have summarised three key obstacles to innovation and approaches to overcoming them.

1. **Issue: Operating environment**  
   **Timeframe:** Long term (10 year)  
   **Recommendation:** Establish a cross-disciplinary working group aligned with the government looking at both the general and the specific legislative, economic and political obstacles. Additionally, more detailed case-studies of cities tackling this problem and making quantifiable progress - like Amsterdam - are required and could be part of the mandate of the new working group. A long-term strategy aligned to the 10 year programme of the National Science Challenge 11 to create an operational environment in New Zealand would likely provide the best chance for success to allow for steady and long-term change and monitoring to support and grow innovation in the building sector in New Zealand.

2. **Issue: Leadership**  
   **Timeframe:** Mid term (3 year)  
   **Recommendation:** Establish a “Centre for Innovation” within or funded through BRANZ or the government to provide the leadership, space and resources to encourage innovation in the building industry. The Centre should be a collaborative effort of government, industry and education.

3. **Issue: Knowledge exchange**  
   **Timeframe:** Near term (1 year)  
   **Recommendation:** Create an innovation network that provides workshops and access to technology and experts through existing resources already established in the country. The innovation network would also serve to better inform both the public and industry stakeholders about emerging technology and its capability. This will also have the effect of increasing demand for better buildings and innovation by informing customers and industry stakeholders of the benefits.

Within this roadmap the Innovation Network develops the market that creates demand for, and utilises, the Centre for Innovation. These two initiatives mean when the government strategy of consultancy and implementation improves the Operating Environment, there are innovative industry stakeholders ready to transform construction in New Zealand.
## APPENDIX

### Advisory Panel

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<th>Name</th>
<th>Organisation</th>
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<td>Mark Battley</td>
<td>Centre for Advanced Composite Materials</td>
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<td>Ewan Brown</td>
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<td>Grant Carter</td>
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<td>Owen Griffiths</td>
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<td>Kevin Sweet</td>
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