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Report ER18

Developing the Concrete Sector's 10 Year Research Roadmap

Joe Gamman and Alistair Russell

Project LR0491
Cement and Concrete Association of New Zealand (CCANZ), funded by the Building Research Levy

1222 Moonshine Rd,
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz

Funded from the Building Research Levy

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Preface

This report aims to consult and document the strategic research needs of the cement and concrete sector over the coming decade. A large number of possible projects were evaluated and generated a short list of candidate project themes for further take-up by the industry.

It sits squarely within the Building a Better New Zealand Industry Research Strategy as being a strategic piece of work that aims to inform and guide research funding for maximum impact and relevance over the long term.

Acknowledgements

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The authors would also like to thank Prof Shaun Hendy and Kannan Ridings of the University of Auckland physics department for their work on bibliometric network analysis in the cement and concrete sector.

Intended Audience

Stakeholders were invited from across the supply chain to have input to the roadmap. As such, it should be of general interest to designers or large asset owners and of particular interest to traditional cement and concrete sector stakeholders.

Specific disciplines that would find the report relevant include materials scientists, cement and concrete suppliers, engineering designers, large asset owners, investors and policy advisors.

Descriptive Title

Developing the Concrete Sector's 10 Year Research Roadmap.

Referencing Guidelines

Gamman and Russell, *Developing the Concrete Sector's 10 Year Research Roadmap* (2016)
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Keywords

Research, Strategy, Cement, Concrete, Structural, Asset, Infrastructure

Peer Review

Advisory Board oversight and sign-off has been secured from the following:

1. NZ Concrete Society – Prof Jason Ingham
2. NZ Ready Mix Concrete Association – Derek Chisholm
3. Precast NZ – Rod Fulford
4. NZ Master Placers Association – Brad Robertson

All members of the advisory board agreed that the process adopted was transparent, open and robust and all were in broad agreement with the results and with the need for a 'living document' such as this to be regularly reviewed.

The following comments are reproduced here without further comment by the authors but should be openly addressed at the first opportunity in the next review by industry. The draft report that the comments were based on has not been amended as this would have placed undue weight on the opinions of the advisory board members without discussion by the wider stakeholder group.

> *I have a question regarding research which is brought about by an event, which may become a high priority for research even though it does not appear in the short or long list. Such events may be research brought about by an earthquake (for instance) requiring prioritised research on retrofit of existing buildings, seating of hollow-core flooring for example. In such a situation the need for information which may not be available, can expose the shortcomings of the industry in the public domain. The research type is not important here but a process to channel such research as a priority may need a specific mention in the Research Roadmap.*

> *A […] possible topic that was not mentioned, although I expect was considered – lifetime costs vs initial costs. As we know so many decisions are made on initial costs but our society would benefit from a longer term view.*

> *Our one comment for future reflection is that of the 5 themes that you list as being commonly encountered throughout the process, the theme associated with the importance of remaining world-leading in seismic design appears to have not been captured within your current short list of candidate projects.*

Abstract

The CCANZ Research Roadmap project has canvassed the opinions of a number of senior practitioners in the cement and concrete sector and from a wide range of stakeholders through use of a supply chain metaphor.

The paper describes the methodology of the roadmap exercise and highlights the finding of 'Resilience in Depth and in Scope' as an over-arching strategy for the coming decade. Further use of the supply chain metaphor to identify plausible scenarios amenable to research projects and their evaluation are also described.

The paper also briefly describes the results of a published literature network analysis that could be used in future to objectively assess the impact of research investment into areas identified as important to the New Zealand cement and concrete sector.

The process adopted has highlighted seven priority project themes and two mechanisms for implementing and supporting long term research.

Introduction

The Research Roadmap project aims to canvas and document the cement and concrete sector's opinion on the research needs and challenges over the next 10 years. Compiling a sector wide view of cement and concrete research needs was a logical outcome of the CCANZ Tertiary Education and Research Strategy first developed in 2012. The 6-1 industry consolidation paper at the 2014 NZCS conference [Gaimster] was a catalyst for development as was the support of BRANZ who were also considering the possibility of how this might be used to inform the development of a sector-neutral template for roadmap development [BRANZ] in general.

There is an old saying in software development dubbed Conway's Law [Conway] that rings true in a project such as this:

> *organisations which design systems ... are constrained to produce designs which are copies of the communication structures of these organisations.*

This is often interpreted to mean that software tends to resemble the organisational chart of the company that built it. How much more difficult it must be to find a consensus opinion of an abstract goal such as research and development spanning businesses, research institutions and multiple representative associations multiple organisation charts!

It is important to note that the research roadmap is not describing research projects about to get underway. The project's goal is to listen to a broad cross section of the cement and concrete sector and reflect back a summary of the opinions and experience in a useable format. It is the authors' hope that the roadmap exercise is merely the first step in lifting the profile of research possibilities and that the outcomes of the project are taken up by sector sponsors.

While some possible structures for delivering research are presented and discussed, the authors note that the R&D system in NZ is complex with multiple institutions involved with many overlapping areas of influence and specialisation. The reader is directed to the NZ Statement of Science Intent for a more comprehensive overview. [MBIE]

Furthermore, we are not aware of a similar methodology being used in any of our peer organisations overseas. After reaching out to Australia, the UK and South Africa via personal networks, we found all countries have an R&D strategy but only at the detailed project level – it proved remarkably difficult to find or infer what process was adopted to capture and evaluate priorities and projects. For that reason, we consider the roadmap project to be forging new ground from a process perspective that we feel would be applicable to other countries and other disciplines.

It should be noted that our Australian counterparts, the Cement, Concrete and Aggregates Association of Australia (CCAA) compile a Technology Plan at 3 yearly intervals which involves consulting CCAA member companies, as well as leading specifiers and industry groups to develop a plan for 3 year increments. While the consultation is more limited than the process adopted in this report, given the relative size of the cement and concrete supply chains in both countries it is likely to be broadly equivalent.

Methodology

A methodology was designed to make it difficult for a small number of opinions or stakeholders to dominate the discussion. Furthermore, in order to stress test some commonly held ideas, the stakeholder group should be wider than tradition expects. Ideally, the process template that this project has designed will be used by BRANZ in other sectors to create a set of construction research roadmaps.

Firstly, a simple supply chain metaphor was used to highlight stakeholders for input, see Figure 1. A number of external stakeholders were acknowledged such as markets, policy and investors.

Figure 1: Supply chain metaphor in the NZ cement and concrete sector

Another common methodology for mapping complex systems is one that highlights feedback loops between actors. Stable systems have inputs, outputs and feedback loops that balance and act to keep the system 'stable' or resistant to often quite large changes in the inputs. Maps of the food chain are a common example [Complex Systems]. This methodology was not adopted purely for the reason that the complexity of the model itself often quickly overwhelms the casual user. A simple linear model, while not correct, was sufficient to guide the thinking of our interviewees and our evaluation process was deliberately kept open enough to allow complexity to be discussed, not mathematically optimised.

Secondly, it was assumed that a small country such as New Zealand would invest time and resources in the descending order of technology adoption, adaptation and finally support of adept individuals operating at the cutting edge of research and development. We termed this the ad-X framework, being ad-opt, ad-apt, ad-ept. Figure 2 shows the relative magnitude of each, increasing from a comparatively small number of areas where New Zealand is adept and considered to be world leading, to a higher proportion of knowledge and practice which is adapted from elsewhere, to the highest proportion which we directly adopt.

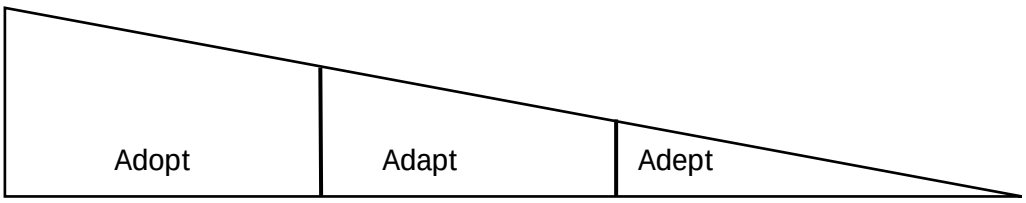


Figure 2: The ad-X framework, (ad-opt, ad-apt, ad-ept)

Invitations to meet were extended to a range of stakeholders. While the discussions were not constrained, some leading questions and boilerplate were covered with each interview to allow some overlap of opinion and common ground.

Ideally, a number of themes would emerge naturally from a diverse range of stakeholders with research projects and pathways flowing naturally from there.

The methodology was discussed and agreed at the first workshop and comments were invited on-line for the project identification and evaluation phase.

Stakeholders

Over the course of the project, over 20 face-to-face interviews were held representing some 550+ years of experience in the cement, concrete and related sectors. Interviews have included materials researchers, structural engineers, ready mix operators, large asset owners, consultants, New Zealand Treasury representatives and related trade organisations. We have also reached out to our peer organisations and personal contacts in the UK, Australia, Japan, South Africa and the US to benchmark our findings.

As anyone who has been involved in an effort like this, after some number of interviews or consultation, the range of opinions starts to converge around a small number of common themes.

It is at this point that the progress thus far is documented and distributed as widely as possible for comment – as Lord Bacon once said:

> *"Truth emerges more readily from error than from confusion".*

It is often the way that progress is made through disagreement with the statement than with the abstract discussion.

Common themes

A number of comments were variations on a handful of observations:

1. New Zealand lacks depth in the materials science of cement and concrete.
2. It is readily acknowledged that the pioneering work of Park, Paulay and Priestley in capacity design, particularly in reinforced concrete, was world leading.
3. By far the topic that was considered essential for New Zealand to remain as world-leading was in seismic design.
4. Demographics of the sector workforce.
5. Transfer of information and knowledge between each of the supply chain elements.

Two topics stood out not for their commonality, but the often diametrically opposed statements associated with them:

1. Climate change, and by extension sustainability in general and carbon pricing – this was either seen as a critical issue or a complete non-issue.
2. Software and IT – this was either seen as an enabler of new business and levels of service and higher profitability or as an aid to established business practices adopted as and when needed from outside the sector.

The authors make no recommendation on either of these two observations other than to point out that the sector should come to a clear and unambiguous position on these issues. Both issues are international in scope and likely to shape government policy and market behaviour. Developments in these areas will be imposed on the sector from external sources such as government policy and/or market competitors. At the very least, our competitor materials may stand to benefit from a wait-and-see position.

Further discussion regarding seismic design often involved the term ‘resilience’ which, while slightly more abstract, is a phrase that resonated across many parts of the supply chain. After discussion with a number of stakeholders, the concept of resilience, within each stakeholder link *and* between links in the stakeholder chain was a concept that all our stakeholders could agree on:

Resilience in Depth: seismic design, future proof design, lifecycle design etc.

Resilience in Scope: collaboration between stakeholders, eliminating foreseeable points of failure and ensuring a smooth delivery of products and services through to the customer.

For this reason, we have adopted the notion of “Resilience in Depth and in Scope” as the sector’s over-arching 10^{+}-year strategy.

Scenarios, projects and evaluation

The roadmap uses the supply chain metaphor to position reasonably foreseeable scenarios as threats or opportunities at the sector level. As a first pass filter, we are looking for a handful of scenarios with a 5% chance of eventuating that would have a sizeable impact on the sector at both operational and/or financial dimensions.

Some examples are indicated in Figure 3. It’s important to note that there are a number of scenarios not included in the simplified supply chain shown such as changing demographics, expectations, ability to pay, national market and building act policies etc. These influence the decision making process up-stream of the supply chain and should not be ignored.

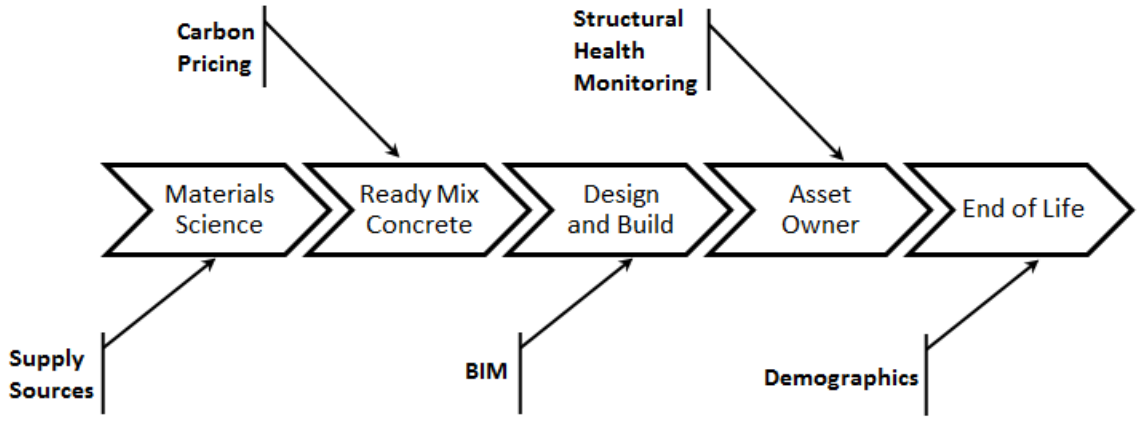


Figure 3: Simplified Scenario Influences on the Supply Chain

As an example, supply sources would include for instance aggregates, cements, sand and admixtures. Scenarios could include the loss of local supply, changes in chemistry and reactivity and new developments overseas adapted for use in New Zealand. Scenarios that are 'up stream' typically have cumulative effects that would flow through the supply chain either as a constraint in physical supply (eg, there is literally no aggregate available for purchase) or force the market to price its supply at prohibitive levels (ie, the market clears the volume available at the highest possible price) which will disproportionately affect some market participants more than others.

Once a scenario is deemed credible, a number of projects could be proposed that would mitigate the risk or create options for further development if needed. Extending the example above, ensuring local aggregate supplies for ready mixed concrete (RMC) production might require some fundamental work in evaluating alkali silica reactivity to ensure that new sources can be confidently used. Addressing a reasonably foreseeable constraint in supply leads to a resilient cement and concrete sector – it is difficult to imagine a resilient supply chain that has supply constraints or single points of failure. At the project level, research projects proposed that facilitate collaboration and understanding between materials science, the RMC sector and say the asset owner would be preferred. The communication needed for collaborative work, as distinct from simply commissioning results, strengthens capability across the supply chain.

Scenario analysis does not lend itself well to matrix style evaluation mechanisms. It is tempting to assign a risk/benefit number to a range of possible projects across a number of dimensions and then multiply the figures out as a ranking mechanism. The authors have purposely steered away from this mechanism and returned to a discussion based prioritisation process. The downsides to a naïve numeric ranking with only the top ranking projects supported is that any system designed can be (will be?) gamed and very quickly. Sector level benefits that we are aiming to foster such as collaboration and resilience in the supply chain would fail to emerge.

Our ideal short list of projects would have the support across the supply chain *irrespective* of whether the project was within a particular discipline with the results becoming openly accessible. Again, using the aggregate supply example, it is reasonable to assume that

design engineers would support a project that maintains the supply of a key construction material and that the results feed into building standards or technical notes that they would use in their day-to-day activities.

The process just described is used to create a short list of priority projects, ideally no more than a handful. The roadmap process will end at this point. Which projects are taken up and in what order will be for sector participants to decide. However, during the roadmap process, the authors found two mechanisms for future use that were generally agreed as potential paths forward and are described in the penultimate section.

Projects and Evaluation

A request to the sector after the first workshop was initiated both by email and as a standard part of the interview process. The actual evaluation is designed to happen by discussion and the following section describes the initial evaluation process prior to discussion.

Of Lists Long and Short

The authors did not constrain the suggested projects in any fashion as part of the interview process other than calling for suggestions as part of the interview conclusion. For our purposes, we have collated all the suggested projects as a "Long Long List".

We filtered these suggestions via two sequential high level Yes/No questions designed to resonate with the themes already outlined before doing some more detailed analysis. A candidate short list of possible projects was then proposed for discussion and comment with the expectation that some or all of the candidate short list would become the sector's short list of priority projects.

It should be noted that some topics will be of intense interest to particular organisations, yet will not feature prominently in this analysis. This is a feature, not a bug. By and large we are looking to identify issues of long term *sector-wide* importance, not single stakeholder concerns (with some due regard to issues of supply that would negatively affect the entire supply chain). There is no conflict in a stakeholder championing sector-wide areas of concern requiring sector-wide support *and* maintaining internal research efforts as part of the expected competition for market share.

Further it should be noted that these scenarios aren't detailed project specifications. It's taken as a given that if the issue is accepted and a project initiated, the project team will generate the detailed project plan for sign-off that addresses an objective informed by the agreed scenario.

Long Long List → Long List: Is There a Reasonably Foreseeable Low Risk, High Impact Scenario?

Long List → Candidate Short List: Does the Project Increase Resilience in Depth &/or Scope?

Candidate Short List → Short List: Comment and Discussion of 1-pager Overviews.

Creating the Long List

The Long Long List is shown in Appendix 2. It is expected that this list will be reviewed and refreshed by the sector at regular intervals and particularly if an unexpected event occurs in the sector that, in hindsight, should have been reasonably foreseeable.

It should be noted that many of the Long Long List scenarios involve complex supply chains. For the purposes of this evaluation, a complex supply chain is assumed to be a core competency of an individual business and the sector's risk is acceptable so long as there are multiple *independent* supply chains. The topic of risk in supply chains, both supply and reputational is however extremely relevant to NZ businesses and is a topic of critical importance. The interested reader is directed to the Resilient Organisations research of Dr Erica Seville for further information and references [[Seville]].

LLL#1 Hollow Core Performance

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

There are multiple suppliers of hollow core products in NZ with a history of performance data to draw on for their current use scenarios.

It is reasonable to assume that any particular company can invest in an increased performance product development to improve their market share or target market. Market competition can be expected to encourage the right kinds of discipline on manufacturers to maintain quality supply to customers.

Conclusion: Remains on the Long Long List.

LLL#2 Floor-Diaphragm Issues

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

There are current limitations in the design and installation of diaphragm floors as highlighted by the Royal Commission. Some development work is currently underway to refine the building codes. Diaphragm floors will continue to be a valid option for structural engineers.

Market competition can be expected to encourage the right kinds of discipline on manufacturers to maintain quality supply to customers.

Conclusion: Remains on the Long Long List.

LLL#3 Building Information Modelling (BIM)

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Building Information Modelling has the potential to increase the efficiency of the design, build and operation of buildings and structures.

Diffusion of the technology into the construction sector is proceeding. Market competition can be expected to encourage the right kinds of discipline on designers to respond to customer demands and constrain costs at the firm level.

Conclusion: Remains on the Long Long List.

LLL#4 Structural Health Monitoring

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Structural Health Monitoring has the potential to increase the efficiency in building and operating buildings and structures, especially with respect to the lifecycle maintenance costs.

Diffusion of the technology into the construction sector is proceeding. Market competition can be expected to encourage the right kinds of discipline on designers to respond to customer demands and constrain costs at the firm level.

Note: a catastrophic failure of a structure such as a bridge would be a high impact scenario but this is not thought to be at 5% level and hence not considered reasonably foreseeable.

Conclusion: Remains on the Long Long List.

LLL#5 Autonomous Vehicles

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Autonomous vehicles are likely to have a big impact on those parts of the supply chain with significant logistics needs such as the transport of materials or Ready Mix Concrete. It is not expected to impact significantly on other parts of the supply chain.

Market competition can be expected to encourage the right kinds of discipline on distributers to maintain quality and price.

Conclusion: Remains on the Long Long List.

LLL#6 3D Printing

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

3D printing has the potential to increase the range of shapes available for the final finish presumably at less cost and/or time than traditional concrete formwork processes. This flexibility, assuming cost and time are at least comparable with existing techniques could promote more use of concrete by designers. Market competition can be expected to encourage the right kinds of discipline on designers to respond to customer demands.

Conclusion: Remains on the Long Long List.

LLL#7 Overseas Concrete Formulations/Practices

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Overseas developments becoming standard practice have very little opportunity to migrate to NZ even from as close as Australia. A high impact event could see the sector branded as price gouging NZ customers or providing an inferior product with respect to our typical overseas benchmark economies.

Conclusion: **Proceed to the Long List.**

LLL#8 Carbon Pricing

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

The NZ Emissions Trading Scheme (ETS) is currently pricing CO2 at approx. $17/tCO2 up from around $3/tCO2 over the last decade. A number of countries have an ETS in place with Sweden having a price of $150/tCO2 with some industry concessions. Given the trajectory of environmental concerns around the world over the last 10-20 years, it seems reasonably certain that carbon prices will increase and a 5% chance of a $50/tCO2 price in NZ by 2026 is a reasonably foreseeable risk. The consequence is that concrete can become un-competitive as a construction material.

Conclusion: **Proceed to the Long List.**

LLL#9 Demographics

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Where the population centres in NZ are going to grow and the typology of their dwellings in the period 2020 – 2050 are likely to be very different from say, the 1970 – 2000 period. Planning documents such as the Auckland Unitary Plan are likely to favour higher density dwellings. Concrete could become a preferred construction material due to acoustics, precast options, ease of construction, acoustic amenity etc.

Conclusion: **Proceed to the Long List.**

LLL#10 Investor Incentives

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Changes in the procurement and maintenance of government assets are already in play and are far more advanced in overseas markets. Investor vehicles such as Public Private Partnerships (PPP) that incorporate construction and on-going provision of the service for extended periods via the contract may have a positive or negative view on traditional construction practices. A scenario where a PPP prefers an competitor material due to the performance or ease/price of maintenance over a 25 year contract period is a reasonably foreseeable risk.

Conclusion: **Proceed to the Long List.**

LLL#11 Specific Single Points of Failure in the Market

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

There are multiple suppliers of all sectors in the supply chain with predictable barriers to entry for new entrants. Market competition can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#12 Buildings v Infrastructure

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

The market for concrete is broadly even across residential, commercial and infrastructure. Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#13 High Mass Walls

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#14 Increasing expectations &/or Declining Ability to Pay

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#15 Stranded Assets

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Long lived durable assets that can be moved to meet changes in demand or usage ie, Reusable prefab components for school buildings etc.

Conclusion: **Proceed to the Long List.**

LLL#16 Prefabrication vs Bespoke

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

A library of prefab components with detailed BIM models freely available may make the design of assets using them easier/quicker/robust. The possibility exists that medium term, prefabrication and storage of these components turns provision into a ‘warehousing and distribution’ problem as opposed to a time sensitive ‘manufacture and deliver’ problem. This could help smooth boom/bust cycles.

Connection to LLL#15: Stranded Assets.

Conclusion: **Proceed to the Long List.**

LLL#17 New vs Retrofit

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Existing concrete assets could have their life extended by retrofitting with new technology. A case in point is PolyEthylene formed internally to installed concrete pipes via robotics.

Conclusion: **Proceed to the Long List.**

LLL#18 High Insulation Floor Systems

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition and mandatory minimums in the Building Codes can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#19 Wall-Floor Connections

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition and mandatory minimums in the Building Codes can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#20 Cladding Panels

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition and mandatory minimums in the Building Codes can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#21 Post Installed Anchors

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Any change in customer preferences is likely to be seen in a clear trend and would not be expected to affect multiple stakeholders in the supply chain. Market competition and mandatory minimums in the Building Codes can be expected to encourage the right kinds of discipline on suppliers to meet demand.

Conclusion: Remains on the Long Long List.

LLL#22 Cement Supply

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

There are four major suppliers of cement in NZ, two of which are $B dollar companies. All 4 companies are part of international supply chains for feedstock or final product.

It is reasonable to assume that any particular company can have supply issues but market competition can be expected to encourage the right kinds of discipline on cement suppliers to maintain quality supply to customers.

Conclusion: Remains on the Long Long List.

LLL#23 Concrete Curing

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Curing plans can have dramatic long term effects on the asset. The handover between quality fresh concrete supply and long term durable asset is in the hands of a diverse range of contractors with a wide distribution of skillsets and experience.

A market based assumption that quality suppliers will be supported long term isn't valid with typically a one-off purchase, especially in the residential sector. The impact of low quality builds affects consumer's confidence in concrete as a construction materials and hence impacts the entire supply chain resulting in concrete becoming un-competitive as a construction material in some instances &/or locations.

Conclusion: **Proceed to the Long List**.

LLL#24 Concrete Ageing

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

A market based assumption that quality suppliers will be supported long term isn't valid with typically a one-off purchase, especially in the residential sector. The impact of low quality builds affects consumer's confidence in concrete as a construction materials and hence impacts the entire supply chain resulting in concrete becoming un-competitive as a construction material in some instances &/or locations.

Connection to LLL#23: Concrete Curing.

Conclusion: **Proceed to the Long List**.

LLL#25 Alternative Cements

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Policy and/or market shifts make Portland Cement less desirable and alternative formulations more attractive. There is a need to have field validated data on alternative cement formulations with NZ aggregates.

Connection to LLL#23: Concrete Curing

Connection to LLL#24: Concrete Ageing

Connection to LLL#26: NZ Pozzolans

Connection to LLL#22: Cement Supply

Connection to LLL#8: Carbon Pricing

Connection to LLL#31: NZS3104

Conclusion: **Proceed to the Long List.**

LLL#26 New Zealand Pozzolans

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Policy and/or market shifts make Portland Cement less desirable and alternative formulations more attractive. There is a need to have field validated data on alternative cement formulations with NZ aggregates.

Connection to LLL#25: Alternative Cements

Conclusion: **Proceed to the Long List.**

LLL#27 Supplementary Cementitious Materials

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Policy and/or market shifts make Portland Cement less desirable and alternative formulations more attractive. There is a need to have field validated data on alternative cement formulations with NZ aggregates.

Connection to LLL#25: Alternative Cements

Conclusion: **Proceed to the Long List.**

LLL#28 Aggregate Supply

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Aggregate supplies are domestically sourced and quarries are subject to changing Resource Management Act consents over a 10 year period. There are subtle chemistry effects such as Alkali Silica reactions that are specific to both the aggregate and the cement that can have deleterious effects on the long term durability of structures. Conservative limits can force concrete suppliers to source aggregate from long distances which can have significant price impacts which will flow through the supply chain. Concrete can become un-competitive as a construction material in some instances &/or locations.

Conclusion: **Proceed to the Long List**.

LLL#29 Admixture Supply

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

There are multiple major suppliers of admixture in NZ, many of which are ultimately sourced from multi-$B dollar global companies. While all companies are part of international supply chains it is reasonable to assume that market competition can be expected to encourage the right kinds of discipline on admixture suppliers to ensure quality supply to customers.

Conclusion: Remains on the Long Long List.

LLL#30 Policy Shift

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Policy shifts on say, carbon pricing or building codes is a reasonably foreseeable risk and is addressed in other projects which create options or upper/lower bounds on the effects.

It is not easy to see what research the concrete sector could do mitigate the risk of an external event other than to maintain a watching brief and make sure that research efforts are closely aligned with policy.

Conclusion: Remains on the Long Long List.

LLL#31 NZS 3104 Constraints

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

Manufacture of concrete is a single stakeholder issue and while it may be desirable for NZS3104 to move from a prescriptive approach to a more operationally proven functionality approach, this is best left to the suppliers to discuss and agree the risk/reward trade-offs.

However, it is acknowledged that allowing a shift to a performance based philosophy is likely to lead to more innovation as standard practice to reduce costs. In principle, from a long term research perspective, this sort of policy should be supported.

Conclusion: Remains on the Long Long List.

LLL#32 Specific Single Points of Failure in the Workforce

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Our understanding of fundamental materials science in concrete is limited to a small number of individuals in a small number of institutions. Retirement, employer or research topic changes by just one or two individuals could severely impact the sector's ability to source authoritative neutral advice. In the absence of high quality independent advice, there is substantial 'naive purchaser' risk – the cost/benefit risk of relying only on the advice of suppliers.

Connection to LLL#25: Alternative Cements

Conclusion: **Proceed to the Long List**.

LLL#33 CPD of Design Engineers

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? No

There are multiple suppliers of design engineering services in NZ. It is reasonable to assume that market competition can be expected to encourage the right kinds of discipline on design engineering firms to ensure quality supply to customers.

It should also be noted that even senior design engineers can be sourced internationally, albeit with some difficulty. Once again, market pressures can be expected to create the incentives needed to ensure that offers of employment are attractive to overseas candidates.

Conclusion: Remains on the Long Long List.

The Long List

The Long Long List of 33 project and theme suggestions from the interviews was narrowed down to 14 via the first filter question: Is There a Reasonably Foreseeable Low Risk, High Impact Scenario?

The resulting Long List:

1. LLL#7 Overseas Concrete Formulations/Practices
2. LLL#8 Carbon Pricing
3. LLL#9 Demographics
4. LLL#10 Investor Incentives
5. LLL#15 Stranded Assets
6. LLL#16 Prefabrication vs Bespoke
7. LLL#17 New vs Retrofit
8. LLL#23 Concrete Curing
9. LLL#24 Concrete Ageing
10. LLL#25 Alternative Cements
11. LLL#26 New Zealand Pozzolans
12. LLL#27 Supplementary Cementitious Materials
13. LLL#28 Aggregate Supply
14. LLL#32 Specific Single Points of Failure in the Workforce

It is clear that a number of project suggestions were topics generally associated with Materials Science. These include understanding cement chemistry, aggregate-cement chemistry and long term performance. Additionally, Materials Chemistry will be needed to validate alternate cement formulations as future options in a carbon pricing scenario. This is all within a risk of a very small number of materials science experts in NZ.

For that reason, we are grouping LLL#23, 24, 25, 26, 27 and 28 into a single Materials Science project labelled LL#100.

The final Long List to be carried through for evaluation:

1. LL#1-7 Overseas Concrete Formulations/Practices
2. LL#2-8 Carbon Pricing
3. LL#3-9 Demographics
4. LL#4-10 Investor Incentives
5. LL#5-15 Stranded Assets
6. LL#6-16 Prefabrication vs Bespoke
7. LL#7-17 New vs Retrofit
8. LL#8- 32 Specific Single Points of Failure in the Workforce
9. LL#9-100 Materials Science

Note: the numbering scheme is [Current_List_Acronym]#[Current_List_Number]-[Previous_List_Number] and is carried through the evaluation process to give some context back through to the original Long Long list of research project or theme suggestions.

Example: the candidate short list name “CSL#2-2-8 Carbon Pricing” was the 8th project identified from the interviews, the 2nd project to make it onto the Long List and also the 2nd project to make it onto the candidate short list.

Creating the Candidate Short List

Take the Long List above and apply the second filter question: Does the Project Increase Resilience in Depth &/or Scope?

LL#1-7 Overseas Concrete Formulations/Practices

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

The sector is branded as price gouging NZ customers or providing an inferior product or service with respect to overseas benchmark economies.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Depth & Scope

Resilience in Depth:

More concrete mix designs are available as standard products in NZ. Concrete formulations are developed worldwide from businesses responding to market needs. Many of these businesses are multi-billion dollar organisations with target markets, such as SE Asia, going through multi-decade periods of 10+% growth. An active programme of assessing developments overseas in the NZ context is prudent.

Resilience in Scope:

Strong collaboration potential between materials scientists, ready mix sector, designers and construction. New products can allow new services or processes to develop. A case in point is the slow adoption of Self Compacting Concrete over the last 2 decades in say, the precast sector.

Conclusion: **Proceed to Candidate Short List.**

LL#2-8 Carbon Pricing

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

A $50/tCO2 price in NZ by 2026 is a reasonably foreseeable risk.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Depth & Scope.

Resilience in Depth:

The cement manufacture process can be studied in greater depth to accelerate low carbon manufacture efforts and alternate cements can become financially viable requiring field testing verification and validation.

Resilience in Scope:

Carbon pricing will impact financially on every single aspect of the supply chain as well as being viewed negatively by consumers especially in response to campaigns by competitor materials such as timber.

Conclusion: **Proceed to Candidate Short List.**

LL#3-3 Demographics

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

As Medium Density Housing typology increases, concrete seen as the preferred construction material due to acoustics, precast options, ease of construction, acoustic amenity etc.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Scope.

Resilience in Depth:

Some minor aspects in the disciplines associated with the amenity value being studied.

Resilience in Scope:

Potential for increased collaboration between suppliers, designers, contractors and developers to develop robust solutions and communicate the long term advantages to potential residential owners.

Conclusion: **Proceed to the Candidate Short List.**

LL#4-10 Investor Incentives

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

PPP developers comes to view concrete as a preferred material due to the performance or ease/price of maintenance over a 25 year contract period.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Scope.

Resilience in Depth:

Some minor aspects in the disciplines associated with the amenity value being studied.

Resilience in Scope:

Potential for increased collaboration between suppliers, designers, contractors and developers to develop robust solutions and communicate the long term advantages to potential infrastructure owners.

Conclusion: **Proceed to the Candidate Short List.**

LL#5-15 Stranded Assets

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Long lived durable assets that can be moved to meet changes in demand or usage as a unique selling point.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Scope.

Resilience in Depth:

Resilience in Scope:

Potential for increased collaboration between suppliers, designers, contractors and developers to develop robust solutions and communicate the long term advantages to potential infrastructure owners.

Conclusion: **Proceed to the Candidate Short List.**

LL#6-16 Prefabrication vs Bespoke

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Prefabrication and storage of these components turns provision into a 'warehousing and distribution' problem as opposed to a time sensitive 'manufacture and deliver' problem.

Does the Project Increase Resilience in Depth &/or Scope? No.

Resilience in Depth:

Better understanding of the value in the use of standard components by designers.

Resilience in Scope:

Potential for strong collaboration between design and precast suppliers. Some potential for collaboration with asset owners or investors. However, it is unclear that asset owners or investors are primarily making purchasing decisions based on life time costs as distinct from initial construction costs.

Conclusion: Remains on the Long List.

LL#7-17 New vs Retrofit

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Existing concrete assets could have their life extended by retrofitting with new technology.

Does the Project Increase Resilience in Depth &/or Scope? No.

Resilience in Depth:

Some increase in Depth for a particular product offering. The ability to directly transfer any increase in understanding to other products and services is limited.

Resilience in Scope:

Some increase in Scope is possible by increasing dialogue between asset owners and service providers. It's also not obvious that the original supplier will be the provider of retrofit technologies.

Conclusion: Remains on the Long List.

LL#8-32 Specific Single Points of Failure in the Workforce

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes

Retirement, employer or research topic changes by one or two individuals could severely impact the sector's ability to source authoritative neutral advice.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Scope and Depth.

Resilience in Depth:

Authoritative advice is only sourced from domain experts. Any project addressing the mitigation of a loss in capability in the workforce must by extension be investing in expertise, albeit in a narrow range of disciplines.

Resilience in Scope:

Supporting expertise will require clear communication from across the supply chain regarding needs and issues. There needs to be a connection between depth in expertise and the ability to translate this expertise into advice for the wider industry.

Conclusion: **Proceed to Candidate Short List.**

LL#9-100 Materials Science

Is There a Reasonably Foreseeable Low Risk, High Impact Scenario? Yes – multiple.

Does the Project Increase Resilience in Depth &/or Scope? Yes: Depth and Scope.

Resilience in Depth: Increasing the materials science understanding of cement use in NZ, cement behavior with NZ aggregate sources and local Alkali Silica chemistry, effect of curing on durability and performance long term, NZ sourced materials, options for alternatives under a change in carbon pricing policy scenario.

Resilience in Scope: This project can benefit from a multi-discipline team comprised of cement suppliers, RMC producers, materials chemists and economics/markets.

Conclusion: **Proceed to Candidate Short List.**

The Candidate Short List

The Long List of 9 projects was narrowed down to 7 via the second filter question: Does the Project Increase Resilience in Depth &/or Scope?

The resulting Candidate Short List:

CSL#1-1-7 Overseas Concrete Formulations/Practices

CSL#2-2-8 Carbon Pricing

CSL#3-3-3 Demographics

CSL#4-4-10 Investor Incentives

CSL#5-5-15 Stranded Assets

CSL#6-8-32 Specific Single Points of Failure in the Workforce

CSL#7-9-100 Materials Science

Creating the Short List

The Candidate Short List was confirmed via an invitation to all stakeholders (who were welcome to forward the invitation on via email) via an online comment form.

On the following pages we have generate 1-page overviews of the Candidate Short List projects for discussion. We have consciously tried to not use a weighting metric system for the evaluation as the topics are far too complex.

Ultimately, we are striving for a handful of priority projects that would be well supported from all stakeholders in the cement and concrete sector. If an error must be made it should be to eliminate a topic for consideration on the understanding that it would be better to have a small number of strongly support projects go through than a larger number of less well supported projects.

Note: the radar diagrams are indicative only and are trying to indicate visually where the tradeoffs are in any particular project. Ideally, a portfolio of projects would overlap to form a large circle which would indicate broad acceptance across all stakeholders and focus on a range of macro-scale objectives. Also note that the two major drivers expected to be imposed externally on the sector (sustainability and Information Technology) are placed at the 9 and 3 o'clock positions respectively. This is to easily highlight that a research portfolio that shows a figure-8 display is likely to be too focused on internal concerns and is not 'looking out over the horizon'.

CSL#1-1-7 Overseas Concrete Formulations/Practices Overseas Concrete Formulations

Low risk, high impact Scenario: The sector is branded as price gouging NZ customers or providing an inferior product or service with respect to overseas benchmark economies.

Indicative Project Title: Evaluating Overseas Best Practice for the NZ Market

Market Segment: Materials, Supply, Design

Single Point of Failure Possible? No

Effect on Supply Chain: Cumulative. Once validated, it is expected to benefit the full supply chain.

Exogenous Influences: No. Some risk from new entrants to the market transferring overseas BAU but this can be expected to occur over reasonable time frames.

Ad-opt, Ad-apt or Ad-ept: Ad-opt

Requires new knowledge or new practice? Yes

Worst case scenario: Sector branded as price gouging or providing sub-standard product/services.

Best Case scenario: Better ways of working, higher profitability and customer expectations regularly exceeded → increase in market share with respect to competitor materials.

Resilience in Depth: Yes.

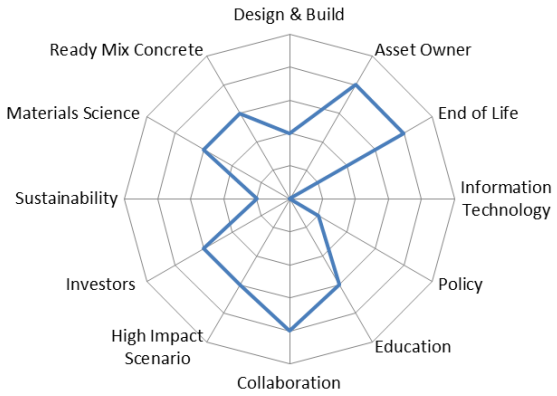
Resilience in Scope: Yes.

Collaboration: Yes

Funding Scale: $x00,000 over 3-5 years per project.

Timeframe: Continuous but likely several years from initiation before the first results start to filter through to the sector at large.

Expected Outcome: High degree of collaboration. At least 1 or 2 overseas developments transferred to NZ earlier than expected.



CSL#2-2-8 Carbon Pricing

Low risk, high impact Scenario: A $50/tCO2 price implemented in NZ by 2026.

Indicative Project Title: Evaluating Concrete Sector Options in a High Price Carbon Market

Market Segment: Materials, Supply, Design, Asset Owners, Information Technology, Markets, Investors, Customers, Public Perceptions

Single Point of Failure Possible? No

Effect on Supply Chain: Cumulative. A high price on carbon emissions is expected to have a significant, step-change effect on the entire supply chain. This will be compounded by the simultaneous efforts of our competitor materials.

Exogenous Influences: Yes. Highly likely that NZ is a fast follower and there is demand overseas for carbon pricing. If a significant trading partner implements a strong carbon price, they are likely to impose an equivalent price on NZ imports. NZ would do the same.

Ad-opt, Ad-apt or Ad-ept: Ad-opt, Ad-apt and Ad-ept.

Requires new knowledge or new practice? Yes.

Worst case scenario: Concrete priced out of contention in major traditional markets.

Best Case scenario: Better ways of working, higher profitability and customer expectations regularly exceeded → increase in market share with respect to competitor materials.

Resilience in Depth: Yes.

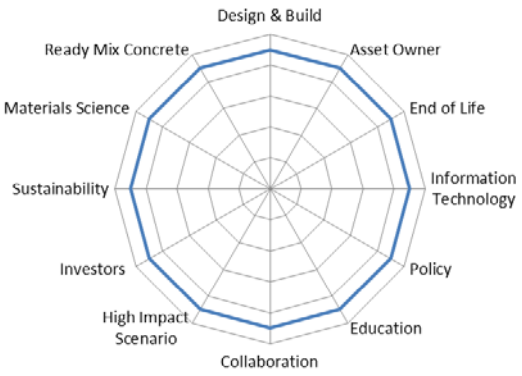
Resilience in Scope: Yes.

Collaboration: Yes

Funding Scale: $x0,000 over 1-2 years per project. Note: these are options based studies, not implementation. Individual stakeholder(s) would then need to invest in implementation studies.

Timeframe: Continuous but likely several years from initiation before the first results start to filter through to the sector at large.

Expected Outcome: High degree of collaboration. At least 1 or 2 obvious options scoped in full within 5 years.



CSL#3-3-3 Demographics

Low risk, high impact Scenario: Concrete is the preferred construction material for Medium Density Housing due to acoustics, precast options, ease of construction, acoustic amenity etc.

Indicative Project Title: Understanding the Amenity Value Proposition in MDH

Market Segment: Design, Asset Owners (Residential), Markets, Public Perceptions

Single Point of Failure Possible? No

Effect on Supply Chain: Supportive. Increased demand.

Exogenous Influences: Possible. Urban planning and quality design/build of MDH as a life-long dwelling for all types of ages and families may be expressed as building WOFs or more stringent design criteria placed on developers.

Ad-opt, Ad-apt or Ad-ept: Ad-opt. Multiple high quality examples exist overseas.

Requires new knowledge or new practice? Yes. Change will require more demanding *purchasers*.

Worst case scenario: Concrete priced out of contention in the MDH market or consumer perceptions are influenced by competitors or concrete constructions not meeting expectations.

Best Case scenario: Customer expectations regularly exceeded → increase in market share wrt competitor materials.

Resilience in Depth: Minor.

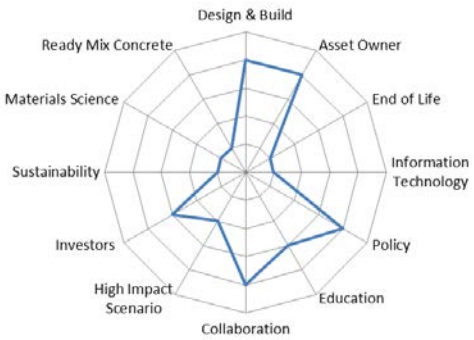
Resilience in Scope: Yes.

Collaboration: Yes

Funding Scale: $x00,000 over 3-5 years per project. Note: This assumes that exemplar projects are supported for research purposes. Earlier work has indicated that there can be expected benefits that are not realized in place. This expectation gap will negate any potential gains we could make in market share.

Timeframe: Continuous but likely several years from initiation before the first results start to filter through to the sector at large.

Expected Outcome: High degree of collaboration. At least 1 or 2 exemplar MDH projects delivered within several years. Substantial amounts of follow up social research enabled.



CSL#4-4-10 Investor Incentives

Low risk, high impact Scenario: PPP developers comes to view concrete as a preferred material due to the performance or ease/price of maintenance over a 25 year contract period.

Indicative Project Title: Understanding the Long Term Value Proposition for Investors

Market Segment: Design, Asset Owners (Infrastructure, Commercial), Markets, Policy

Single Point of Failure Possible? No

Effect on Supply Chain: Supportive. Increased demand.

Exogenous Influences: Possible. Public Private Partnerships as a vehicle for government infrastructure are likely to grow.

Ad-opt, Ad-apt or Ad-ept: Ad-opt.

Requires new knowledge or new practice? Yes. Change will require more demanding *purchasers*.

Worst case scenario: Concrete priced out of contention in the PPP market.

Best Case scenario: Customer expectations regularly exceeded → increase in market share wrt competitor materials.

Resilience in Depth: Minor.

Resilience in Scope: Yes.

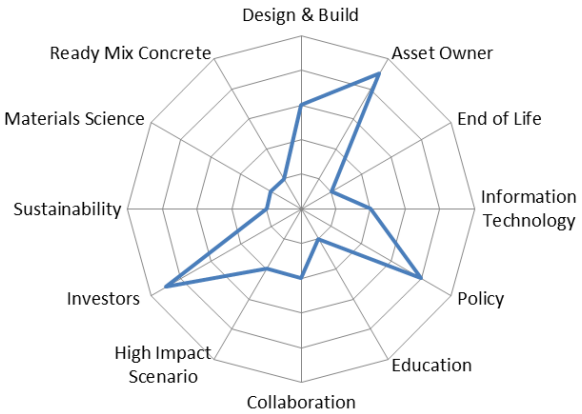
Collaboration: Yes

Funding Scale: $x0,000 over 1-2 years per project. Note: these are options based studies, not implementation. It's not clear what, if any, options could be subsequently developed.

Timeframe: Continuous but likely 2-3 years from initiation before some level of understanding on the feasibility of more targeted research/development.

Expected Outcome: High degree of collaboration. Increased understanding of purchaser incentives.

Note: similarities to CSL#3-3-3 Demographics



CSL#5-5-15 Stranded Assets

Low risk, high impact Scenario: Long lived durable assets that can be moved to meet changes in demand or usage as a unique selling point.

Indicative Project Title: Eliminating Stranded Asset Risk

Market Segment: Design, Asset Owners particularly government (Infrastructure, Commercial), Markets, Policy

Single Point of Failure Possible? No

Effect on Supply Chain: Supportive. Increased demand.

Exogenous Influences: No.

Ad-opt, Ad-apt or Ad-ept: Ad-apt.

Requires new knowledge or new practice? Yes. Change will require re-thinking construction away from a supply chain to an indefinite lifecycle. Will require purchasers with very long operating timeframes such as government schools.

Worst case scenario: Status quo.

Best Case scenario: Customer expectations regularly exceeded → increase in market share wrt competitor materials.

Resilience in Depth: Yes.

Resilience in Scope: Yes.

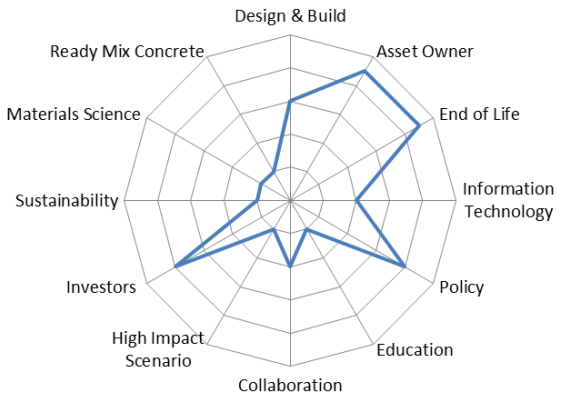
Collaboration: Yes

Funding Scale: $x0,000 over 1-2 years per project. Note: these are options based studies, not implementation. It's not clear what, if any, options could be subsequently developed.

Timeframe: Continuous but likely 2-3 years from initiation before some level of understanding on the feasibility of more targeted research/development.

Expected Outcome: High degree of collaboration. Increased understanding of purchaser incentives.

Note: similarities to CSL#4-4-10 Investor Incentives



CSL#6-8-32 Specific Single Points of Failure in the Workforce

Low risk, high impact Scenario: Retirement, employer or research topic changes by one or two individuals could severely impact the sector's ability to source authoritative neutral advice.

Indicative Project Title: Investing in Capability

Market Segment: Materials Science, Design, Asset Owners, Consultants

Single Point of Failure Possible? Yes

Effect on Supply Chain: Supportive. Risk mitigation.

Exogenous Influences: No.

Ad-opt, Ad-apt or Ad-ept: Ad-ept.

Requires new knowledge or new practice? Yes. Change will require re-thinking how the sector supports fundamental knowledge and access to expertise.

Worst case scenario: Loss of NZ based authoritative expertise.

Best Case scenario: Two or three layers of redundancy spread across multiple institutions in critical areas of expertise with strong ties to industry needs.

Resilience in Depth: Yes.

Resilience in Scope: Yes.

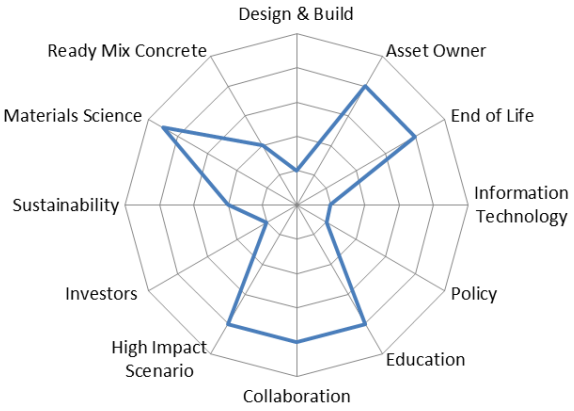
Collaboration: Yes

Funding Scale: $x0,000 per annum long term. Note: This assumes that some level of matching support from institutions.

Timeframe: Continuous but likely 2-3 years from initiation before an expert can be considered to be aware of national issues and develop strong working relationships.

Expected Outcome: High degree of collaboration and an adequately supported fundamental science capability.

Note: overlap with CSL#7-9-100 Materials Science



CSL#7-9-100 Materials Science

Low risk, high impact Scenario: Multiple resulting from changing needs and expectations of end customers. Scenarios are predominantly focused on mitigating risks associated with concrete curing, ageing, alternative cements, NZ Pozzolans and SCMs and Aggregate Supply either singly or in combination, especially in connection with a significant driving force in the market such as Carbon Pricing.

Indicative Project Title: The Concrete Materials Science Programme

Market Segment: All but predominantly Materials Science, Design, Asset Owners, Consultants.

Single Point of Failure Possible? Yes

Effect on Supply Chain: Supportive. Risk mitigation.

Exogenous Influences: Possible.

Ad-opt, Ad-apt or Ad-ept: Ad-ept.

Requires new knowledge or new practice? Yes.

Worst case scenario: Sector cannot respond to changes in customer expectations or market policy.

Best Case scenario: A commitment to continuous improvement and the expertise locally available to deliver.

Resilience in Depth: Yes.

Resilience in Scope: Yes.

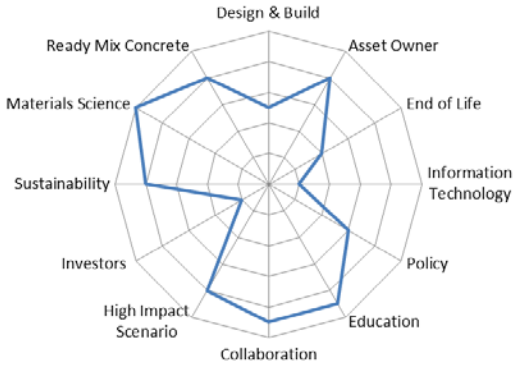
Collaboration: Yes

Funding Scale: $x0,000 per annum long term. Note: This assumes that some level of matching support from institutions.

Timeframe: Continuous but likely 2-3 years from initiation before the first results are seen by industry.

Expected Outcome: High degree of collaboration and an adequately supported fundamental science capability.

Note: overlap with CSL#6-8-32 Single Points of Failure in the Workforce



The Short List

After the second round of discussion and comment, all candidate short list project themes were carried through to the Short List without change.

The resulting Short List:

SL#1-1-1-7 Overseas Concrete Formulations/Practices

SL#2-2-2-8 Carbon Pricing

SL#3-3-3-3 Demographics

SL#4-4-4-10 Investor Incentives

SL#5-5-5-15 Stranded Assets

SL#6-6-8-32 Specific Single Points of Failure in the Workforce

SL#7-7-9-100 Materials Science

Some Notes on the Short List

There are 3 ad-opt candidates, 1 ad-apt candidate and 2 ad-ept candidates with 1 candidate, Carbon Pricing, spanning all three Ad-X categories. This is broadly aligned with the assumption that ad-opt, ad-apt and ad-ept should be in a decreasing order of focus (although not necessarily decreasing order of funds).

It is interesting to note that over half of the short list candidates are not from the 'traditional' areas of concrete research – there are a number of risks/opportunities from directions not typically on the day-to-day radar of the concrete industry.

Two Short List projects (Investor Incentives and Stranded Assets) could conceivably be combined, at least in the initial fact finding and investigating phases as there is likely to be significant areas of common interest between investors and public asset ownership, particularly in PPP developments.

A simple sum of the Short List radar values shows that the portfolio of the Short List projects is broadly applicable to most of the areas identified as important albeit with Information Technology and Sustainability still somewhat under-represented. As expected, in a linear supply chain, upstream projects tend to accumulate benefits to downstream stakeholders so we see Asset Owners receiving a lot more benefit from the portfolio of research projects than would be expected based on the topics themselves.

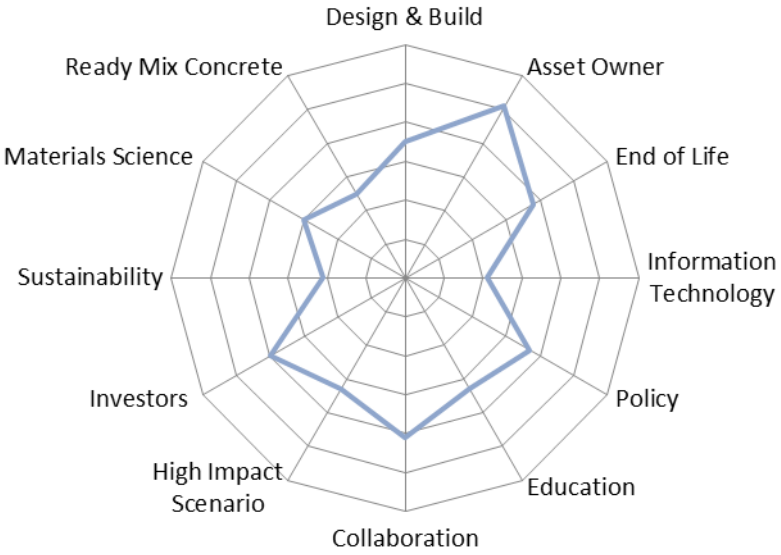


Figure 4: Overlay Summary of all Short List Radar Diagrams

The Challenge Ahead

Regardless of the outcome of the project, the primary challenge for the sector is to make progress on facilitating action. Most participants interviewed generally agreed that our sector does not invest in research at the levels of our competitor materials and certainly not at the levels of our colleagues overseas.

From our discussions, we propose two mechanisms that were well received at the conceptual level.

The Cement and Concrete Sector Technical Development Fund

A long term fixed amount for best practice development within the university sector. A sum of $50k per annum was generally felt to be large enough to be useful. The aim is to connect industry more deeply with academia by funding small sections of standard development work at a premium price so that the academics could spend the remainder on blue sky publishable research of their own.

Ideally, the academic would leverage the results into independent government funding in areas of interest to the sector (ie, using the industry funds as 'seed' capital). The grants would be overseen by a board of industry representatives with day-to-day experience of the building standards of relevance to our sector.

The important feature of the fund is that it is a long term commitment by the sector into research and forces the discussion of funding away from a cost:benefit calculation and toward an allocation of funds discussion. This change in focus is expected to change and strengthen collaboration over the medium term.

The Cement and Concrete Sector Overseas Technology Adoption Fund

The creation of a commons funding pool for projects aiming to field test the use of standardised overseas technology in New Zealand. In essence, it is formalising the process of ad-opting technology from overseas.

Self-Compacting Concrete (SCC) is the example of choice. It has been in widespread use overseas since the 1980s but did not reach New Zealand until relatively recently. Adopting overseas technology incurs risk and the free rider effect is very real – if someone else accepts the risk and proves that it works, they are then unable to maintain a price premium! This is an active disincentive to innovation and change.

We propose a competitive pool that invites projects from industry participants *and their clients* to de-risk the transfer to New Zealand on the proviso that the techniques and learnings from its use in an actual project are then freely disseminated to the community. It is a straightforward knowledge-commons type play. If we can't ad-opt and critically evaluate technology from overseas, how are we going to ad-apt it?

The obvious next question is where would one or both of these initiatives receive funding? The authors have no definitive answer – we can only suggest that by focusing R&D on sector wide benefits it would make the most sense to be funded via a transparent sector wide process with governance, transparency and a commitment to open data the preferred business-as-usual default. There are obvious connections to the current efforts in the sector to combine 6 distinct organisations into a single organisation. The authors believe that a commitment to a single representative organisation will have a parallel commitment to undertake research support on behalf of the sector and ensure skills and experience are maintained in New Zealand.

Overseas Priorities and Projects

The draft report was sent out to a number of senior colleagues and peers overseas for comment in particular Australia, South Africa and the UK.

By and large, all comments received confirmed that the process was robust and easily accessible for all stakeholders.

Some selected comments:

> *Your association has clearly put a considerable amount of thought and effort into this exercise which is commendable because this will help to avoid misallocation of scarce research funding.*
>
> *I am pleased to see several of the topics I supported have been given priority on your lists – particularly rehabilitation and retrofitting of existing RC structures. Most of our inherited infrastructure was built subsequent to the Second World war and is now way beyond its original design life (typically 30 to 40 years old).*
>
> *This body of work makes a worthwhile contribution to the direction of industry resourcing for research. It provides academics with clear issues valued by the concrete and allied industries for new research efforts. Further, it provides a basis for periodic review of industry thinking. Many of the issues identified in the short list resonates in the Australian industry and may offer opportunities for Trans-Tasman collaboration*

It was gratifying to see that the process was robust enough that all of our overseas colleagues could see that the same process would likely yield a different set of priorities in their country or region.

It is recommended that regular reviews of the Research Roadmap by the sector would take advantage of overseas colleagues being in country on sabbatical or as an invited speaker for other reasons.

Conclusions

This report outlines a robust methodology and process for compiling and defining several project themes for further development in the cement and concrete sector based on a simplified linear supply chain for goods and services.

A number of interviews were held with senior representatives across the stakeholder chain and the draft results were presented and discussed in person in a workshop format and via an on-line invitation for comment.

The final short list of project themes:

SL#1-1-1-7 Overseas Concrete Formulations/Practices

SL#2-2-2-8 Carbon Pricing

SL#3-3-3-3 Demographics

SL#4-4-4-10 Investor Incentives

SL#5-5-5-15 Stranded Assets

SL#6-6-8-32 Specific Single Points of Failure in the Workforce

SL#7-7-9-100 Materials Science

The report does not prioritise the short list of project themes any further. Implementation and priority order of investment are left to the sector stakeholders themselves.

Furthermore, the report describes a viable mechanism for objectively measuring capability development in R&D investment, outlines a simple framework for categorising R&D investment and suggests two mechanisms for ongoing implementation of research and development in the short listed themes.

The draft report has been endorsed by the Ready Mix Concrete Association (RMCA), PrecastNZ, the Master Concrete Placers Association (MCPA) and the NZ Concrete Society (NZCS).

Appendix 1 – Capability Indicators

As a consequence of considering the ad-opt, ad-apt, ad-ept framework, the question arose about how exactly a change in capability could be objectively assessed. One possible route to measure the ad-ept capability was via network analysis of published research. A collaboration with the physics department at the University of Auckland verified a proof-of-concept approach that highlighted which subject areas could be considered as ad-ept [Ridings]. As the analysis is based on published data sets from the primary literature, the methodology could in theory be used to monitor long term investments in research capability.

Using Scopus, a number of different research topics were searched for and the top 20 - 30 keywords and number of publications of those keywords were recorded. Keywords that are mentioned with different search terms are considered to 'overlap'. These overlapping keywords can then be considered 'topics' and a graphical network can then be constructed linking them together.

For instance, when searching the Scopus database for *cement* 14,202 articles are found and the word *concrete* is listed as a keyword in 1,937 of those articles. The two topics 'cement' and 'concrete' are then joined by a line (in the jargon of graph theory, this is an edge joining two nodes in an adjacency matrix). Software can be used to automate this process somewhat and a visual representation of the results is generated whereby the size of the topic circle is proportional to the number of articles and hence represents in some sense 'expertise'.

This work compared the same topic map for articles that list a NZ based author vs non-NZ based authors. The differences in the network structure can be then used to infer how influential certain topics are in concrete and cement research in NZ relative to the research community overseas.

For example, if NZ based researchers did the same absolute quantity of research in the same subject areas as the rest of the world, the size of the circles (which represent the proportion of publications with that as a subject) in each network map would look identical. It is obvious that this will not be the case as NZ does not do research in *all* possible areas of concrete therefore the difference in size between the circles in the NZ network vs the worldwide network should indicate where the NZ science investment has been preferentially deployed. This should not be taken to mean that NZ is deficient in the remaining areas. As outlined in the Ad-X framework, the NZ science system will (and should) adopt overseas findings where appropriate and invest scarce resources in areas that are specifically of interest to NZ. We should expect to see larger circles in subject areas that broadly reflect the needs of NZ.

Comparisons of the subject networks, as shown in Figures 5 and 6, clearly show that New Zealand has chosen to develop and support capability in seismic performance, capacity design and engineering geology. This is entirely consistent with the expectations just described.

While the work was preliminary and targeted a proof-of-concept threshold, the results are promising enough to warrant the claim that in theory, further investments in research and development could be objectively measured, at least in subject areas that are published in the primary literature. The authors believe this may be of particular interest to funding agencies.

Worldwide Network

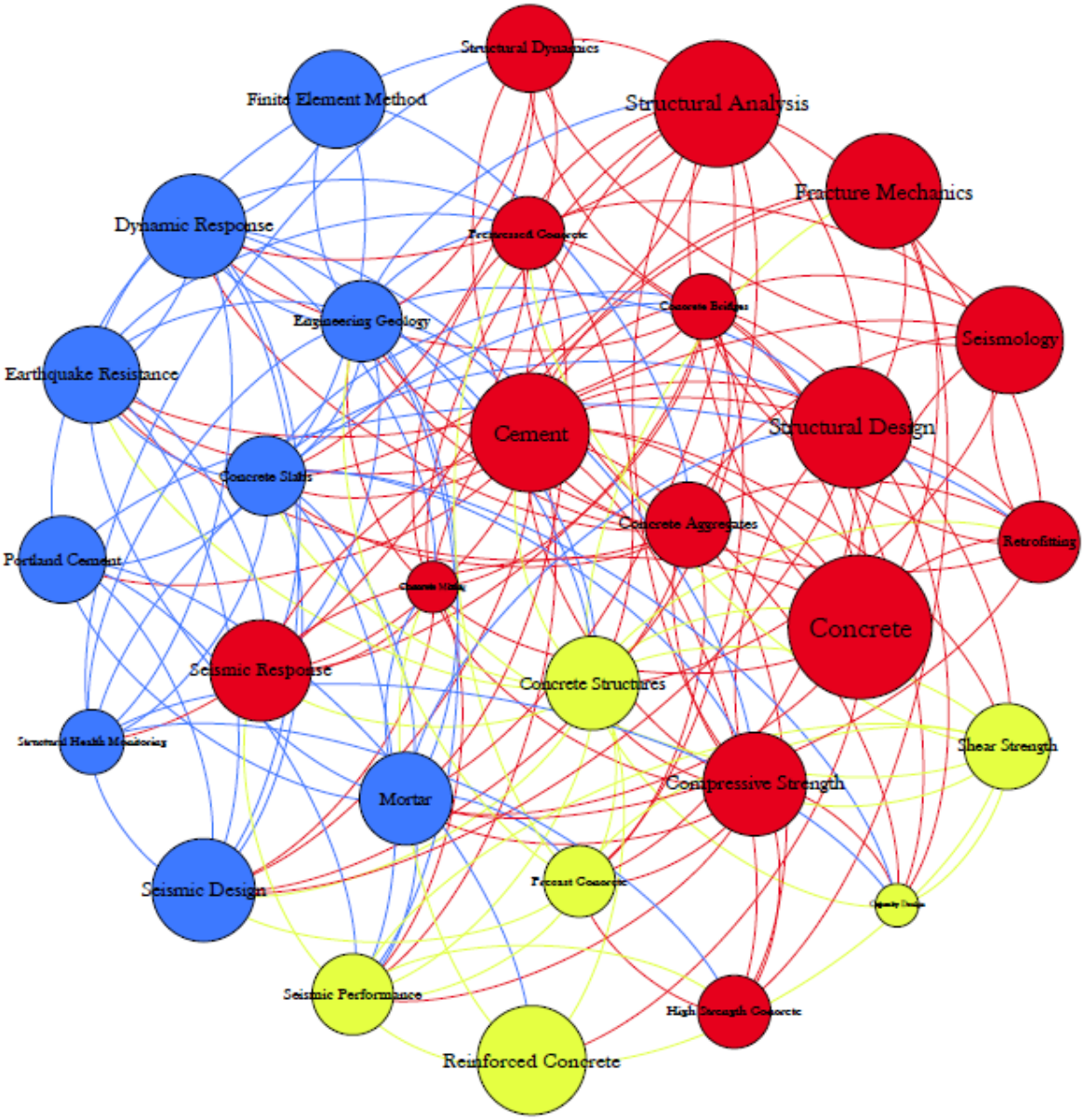


Figure 5: Published Subject Network Maps for the World in Cement and Concrete Research

New Zealand Network

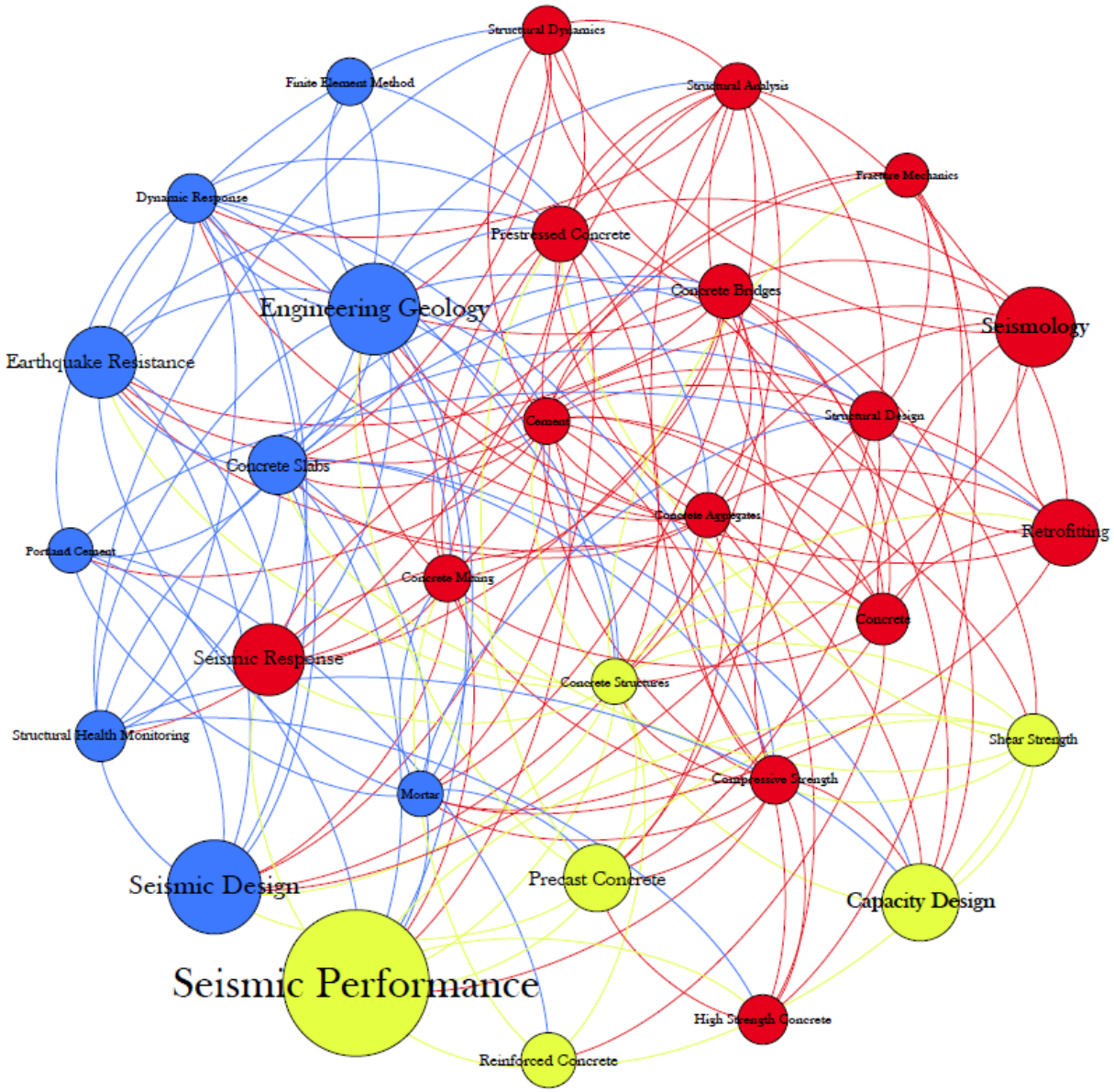


Figure 6: Published Subject Network Maps for New Zealand
in Cement and Concrete Research

Appendix 2 – The Long Long List

The Long Long List is a list of projects or topics suggested for evaluation in our interviews. While it is not expected that the list is exhaustive, we feel confident that given the seniority and cumulative experience of the interviewees that it represents an adequate starting point.

The authors' expectation is that the list is reviewed and amended regularly as part of the ongoing research programme, especially in light of an unexpected turn of events that does not have a Long Long List entry as a root cause.

	Theme	Project or Topic
LLL#1	Design	Hollow Core Performance
LLL#2	Design	Floor-Diaphragm Issues
LLL#3	Information Technology	Building Information Modelling (BIM)
LLL#4	Information Technology	Structural Health Monitoring
LLL#5	Information Technology	Autonomous Vehicles
LLL#6	Information Technology	3D Printing
LLL#7	Market	Overseas Concrete Formulations
LLL#8	Market	Carbon Pricing
LLL#9	Market	Demographics
LLL#10	Market	Investor incentives such as PPPs etc
LLL#11	Market	Specific Single Points of Failure
LLL#12	Market	Buildings v Infrastructure
LLL#13	Market	High Mass Walls
LLL#14	Market	Increasing expectations &/or declining ability to pay
LLL#15	Market	Stranded assets
LLL#16	Market	Prefabrication vs Bespoke
LLL#17	Market	New vs Retrofit ie, PE formed internal to concrete pipes via robotics
LLL#18	Market	High Insulation Floor Systems
LLL#19	Market	Wall-Floor Connections
LLL#20	Market	Cladding Panels
LLL#21	Market	Post Installed Anchors
LLL#22	Market	Cement Supply
LLL#23	Materials Chemistry	Concrete Curing
LLL#24	Materials Chemistry	Concrete Ageing
LLL#25	Materials Chemistry	Alternative Cements
LLL#26	Materials Chemistry	New Zealand Pozzolans
LLL#27	Materials Chemistry	Supplementary Cementitious Materials
LLL#28	Materials Chemistry	Aggregate Supply

LLL#29	Materials Chemistry	Admixture Supply
LLL#30	Policy	Policy Shift
LLL#31	Policy	NZS 3104 Constraints
LLL#32	Workforce	Specific Single Points of Failure
LLL#33	Workforce	CPD of Design Engineers

Appendix 3 – List of Interview Participants

The authors would like to thank everyone that made time available for the interviews and the workshops and the thoughtful comments given in response to the advance pre-reading material.

Our thanks to:

Des Bull	Holmes Consulting Group
Alessandro Pallermo	University of Canterbury
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Rick Henry	University of Auckland
Jason Ingham	University of Auckland
Jim Bentley	University of Auckland
Sue Freitag	Opus International
Sheldon Bruce	Opus International
Chris Munn	Allied Concrete
James McKechnie	Allied Concrete
Anthony Wilson	Wellington City Council
Barry Wright	NZTA
Roger Fairclough	Treasury (NIU)
Dene Cook	Firth
Rod Fulford	PreCast NZ
Neil Milestone	VUW
Morten Gjerde	VUW
Andrew Charleson	VUW
Jeff Matthews	NZCS
Ruth Berry	BRANZ
Tianhe Yang	BRANZ
Matt Sharp	Callaghan Innovation
Conrad Lendrum	Callaghan Innovation

And the many others who have provided comments or expressed support for the process or provided feedback but were unable to meet in person.

Appendix 4 – Interview Questions

1. Name, Area of expertise, Experience (years, NZ, other?)
2. Currently representing which industry sector? (supplier, consultant, end user, contractor/construction, asset holder, R&D)
3. Is there a recurring persistent problem in your sector that you are aware of? (attempting to identify an existing 'pain point')
    a. Would you classify that problem as 'operational' or 'fundamental' (operational being more along the lines of NZ Standards, market operations, pricing etc of existing products whereas fundamental would require some sort of development to meet an unfulfilled need)
    b. What timeframe of 'urgency' would you place on this issue? (<2 years, 5+years, 10+ years)
4. Our working assumption is to break the sector into the following major groups:
    a. Cement manufacture and supply
    b. Ready Mix Concrete supply
    c. Design and Construction
    d. Asset Maintenance
    e. End of life
    f. Procurement Processes, Standards, Government Policy etc

    With the assumption that both R&D and IT innovation can and will occur across all of these and that concepts of environmental stewardship will continue to develop.

    Would you agree or disagree that this is a valid, albeit broad brush and ignoring vertical integration, grouping of the sector? If not, how would you modify it? Does viewing the sector like this promote silo-thinking &/or encourage efficiency?
5. Do you have any comments on the likely 'mega-trends' that the sector should be aware of?
6. How would you estimate or describe the current level of R&D or innovation in the sector? ($$, people, institutions)
    a. How would you compare this to the traditional competitor materials of steel and timber?
    b. How would you compare this to our overseas colleagues?
7. By any metric NZ is a small player on the international scene – what area would you like to see NZ acknowledged as world-leading in the concrete sector?
8. Do you have any comments on the distribution and skillset of the sector workforce, especially over the next 10 years? (ie, many engineering disciplines will see a disproportionate level of retirement by 2020 and a misalignment of skillsets)

Appendix 5 – Methodology

The methodology adopted in this report is briefly described below.
Assumptions:

1. NZ will adopt, adapt and become adept in different subjects areas – research investment is expected to support all 3 areas of interest as sources of innovation.
2. A simple linear supply chain, that extends from suppliers to owners is agreed in advance that can be used to frame discussions with multiple stakeholders.

Process:

1. Interviews with stakeholders from across the supply chain. Where possible, aim for a weighted distribution of interviews in the 'traditional' areas of expertise. In this report, those areas are broadly in the ready mix concrete supply sector and the structural design sector. The interviews were a mix of standard questions and freeform discussion. Request projects or topics that the stakeholder would like to see in the roadmap (ie, creating the Long Long List). It is important that this step is not a simple questionnaire survey as this will tend to reinforce the subjective bias of the authors.
2. Identify a number of common themes and actively listen to your stakeholders in subsequent interviews. The intent is to reflect their discussion back to them using your proposed theme and seek their agreement that it is/is not an example of the theme. This should be happening for the second half or third of your interviews hence it is important to have the entire supply chain represented as interviewees as early as possible.
3. Identify a strategy for the roadmap that should naturally support the themes identified above.
4. Workshop 1: Round table discussion with stakeholders on the common themes and strategy.
5. Continue with interviews and collection of project ideas and topics if needed. Make a decision on when the Long Long List is closed.
6. Filter the Long Long List using high level Yes/No questions that reflect the objectives of strategy outlined previously. Short term projects or stakeholder specific concerns should not make it through to the Long List. There should be no more than 9 topics, and preferably fewer presented as Candidate Short List options.
7. Create 1-pager discussion notes for the Candidate Short List options. Actively discourage numerical ranking systems.
8. Workshop 2: Candidate Short List discussed and the final Short List agreed.

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