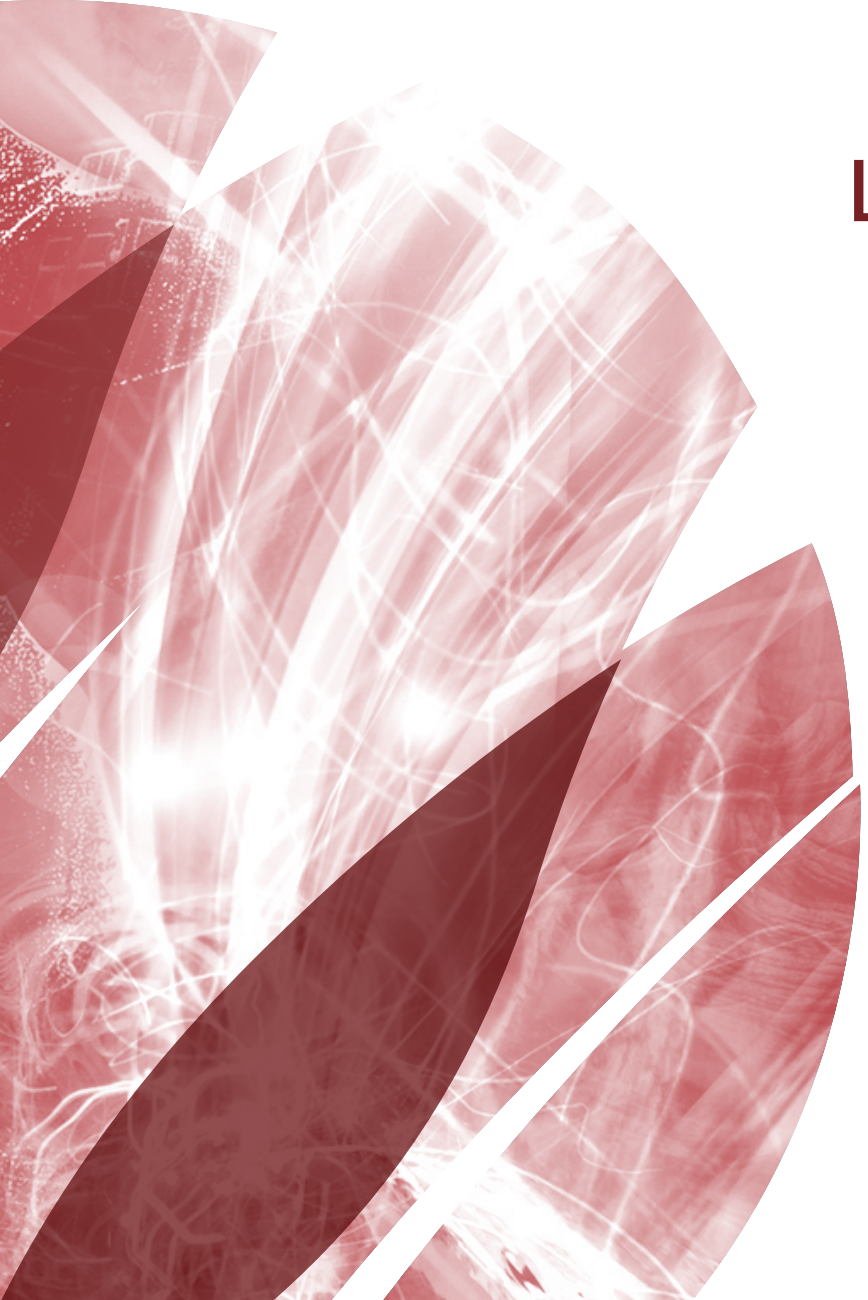
Leveraging R&D Investment for the Australian Built Environment

Project 2.7
Industry Report

December 2012



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Foreword from the Chair and the CEO

John V. McCarthy AO
Chair
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Keith D. Hampson,
Chief Executive Officer
Sustainable Built Environment
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The goal of Australia's Sustainable Built Environment National Research Centre (SBEnrc) is to build a national research and development centre that will add enduring value to the field of sustainable infrastructure and building.

Project 2.7 Leveraging R&D Investment for the Australian Built Environment is a core project for SBEnrc, and each of its four phases will deliver benefits to industry. The first phase, **R&D Investment 1992–2010**, highlighted the significant shift in R&D investment in this sector in the past two decades. It illustrates the need to establish new models for industry, government and researcher engagement to maximise the return on R&D investment. In the second phase, the three **Pathways to Innovation** case studies illustrated the importance to organisations of external innovation linkages and the need for timely, practical research to be available through a range of innovation pathways. The third phase, **Construction 2030** highlighted priority areas for active research including: (i) model-based design/ business models; (ii) intelligent infrastructure and buildings; and (iii) solutions for a more sustainable built environment.

These first three phases have informed the recommendations contained in the policy document **A Vision of R&D Policy Directions**. The document's development is the fourth and final phase of the project. This document outlines a vision for the future defined by a long-term strategic focus; appropriate industry-led R&D priority setting and funding; procurement mechanisms that support innovation; and world-leading interdisciplinary capabilities.

We sincerely thank the industry members who took the time to assist with case study interviews; national workshops for Construction 2030; and honing the policy document. Such industry contribution is vital to more closely aligning funding strategies to industry needs and creating a stronger and more productive industry future.

John V. McCarthy AO
Chair

Keith D. Hampson
Chief Executive Officer

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1 Overview

The overarching goal of this project is to maximise the benefits of R&D to Australia's infrastructure and building industry by matching funding and research strategies to industry needs.

The research aims to increase understanding and knowledge relevant to R&D funding patterns, research team formation and management, future industry needs and R&D strategy.

The four phases and related outcomes of this project are:

Project Phase	Outcomes
1. **Audit and analysis of R&D investment in the Australian built environment since 1990** – access publicly available data relating to R&D investments across Australia from public and private organisations to understand past trends.	• An audit of R&D investment in this sector through interrogating Australian Bureau of Statistics, Australian Tax Office and Australian and state-based data. • A strategic assessment of the above inputs to inform the following project phases.
2. **Examine development and diffusion mechanisms of research and innovation** – investigate specific R&D investments to determine the process of realising research support, direction-setting, project engagement, impacts and pathways to adoption.	• National case studies on specific themes of R&D investment – road construction safety, green buildings, and digital modelling/integrated project delivery – highlighting lessons learned, success criteria and critical challenges.
3. **Develop a strategic road map for the future of this critical Australian industry** – assess likely future landscapes that R&D investment will both respond to and anticipate.	• Planning report for Australia's built environment, updating the CRC for Construction Industry Construction 2020 report published in 2004. • An industry R&D road map, responding to likely future scenarios and recommending research priorities.
4. **Develop policy to maximise the value of R&D investments to public and private organisations** – translate project-acquired knowledge into industry policy guidelines.	• Strategies to allow public and private sector organisations to more profitably engage in research to secure business and industry policy impacts.

2 Phase 1 – R&D Investment 1992–2010

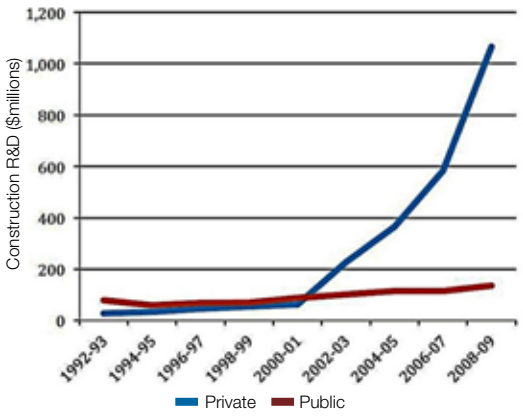
A key outcome of Phase 1 was the report prepared in conjunction with Dr Thomas Barlow R&D Investment Study: 1992–2010. This report identified and reviewed data from Australian government sources (both Federal and State), the private sector and the Organisation for Economic Cooperation and Development (OECD). It provided a snapshot of current R&D investment trends in the built environment in three sectors: (i) the building construction sector, (ii) the heavy and civil engineering construction sector, and (iii) the construction services sector. For full definitions refer p.2 of 2012 R&D Investment Study 1992–2010 – http://www.sbenrc.com.au/research/developing-innovation-and-safety-cultures/leveraging-rad-for-the-australian-built-environment).

2.1 Shifts in Investment

There was a substantial increase in private sector investment between 1992 and 2010, while public sector investment over the same period decreased as a proportion of total spending. In the early 1990s, Australian public institutions were spending three times more on construction related R&D than Australian businesses did. Yet, by 2008 this trend had changed and Australian businesses were spending eight times as much on construction-related R&D as public research institutions. Figure 1 (over page) illustrates this dramatic reversal.

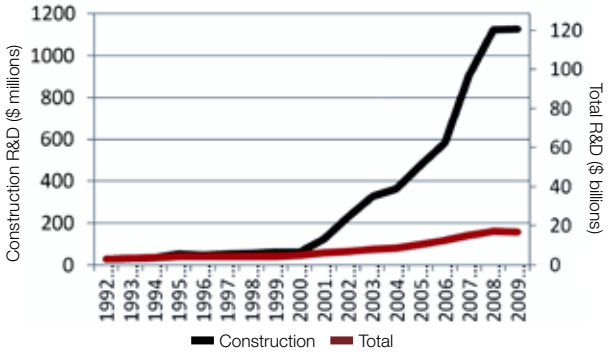
Additionally, a greater percentage of 'construction' research is being undertaken within the built environment sector when compared to total business R&D (Figure 2). Disturbingly, it is also the case that the Australian Government R&D agencies have a reduced emphasis on construction R&D as a proportion of its total spending. Between 1992 and 2008, government agency spending on construction R&D fell from 2.2% to 0.5% of total government sector R&D expenditure (Figure 3).

Figure 1 – Private versus public R&D on 'construction'



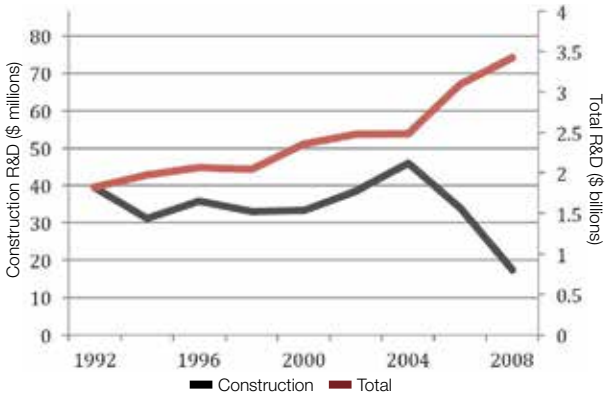
Note (i) Derived from ABS 8112 and Barlow 2011 (refer R&D Investment Study: 1992–2010). (ii) Shows R&D expenditures by sector focused on the socio-economic objective 'construction'. (iii) 'Public R&D' counts R&D from the university sector and from state and federal government agencies.

Figure 2 – Growth in 'construction' R&D relative to total business R&D



Note: (i) Derived from ABS 8109. (ii) Compares business R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total business R&D expenditures (right axis). (iii) The right axis has been adjusted so that the growth rates of both curves from 1992 are comparable.

Figure 3 – Government agency R&D focused on 'construction'



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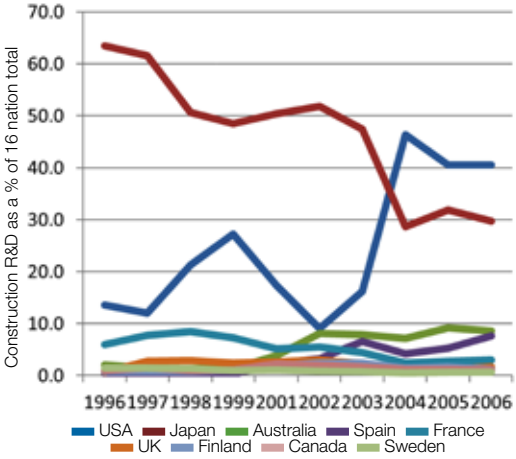
2.2 OECD Comparison

R&D activity within the Australian construction industry has grown in comparison with selected other OECD nations (based on the OECD STAN Database for Structural Analysis). Over the past decade, Australian businesses have dramatically increased their share of global construction R&D. Figure 4 shows comparisons including US and Japan, with Figure 5 excluding these two leaders, emphasising Australia's performance in comparison with other smaller OECD countries.

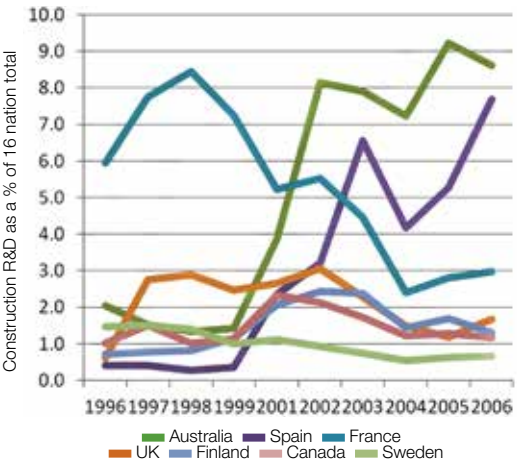
Interestingly, this analysis shows that Australia now outperforms other OECD nations when it comes to construction R&D, especially given the increasing investment from the private sector (Figure 4).

Figure 4 – R&D in the construction industry as a share of 16 OECD nations



Note: (i) Derived from OECD STAN. (ii) R&D expenditures in the construction industry shown as a % of that of 16 OECD nations combined: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Turkey, UK and the USA.

Figure 5 – R&D in the construction industry as a share of 16 OECD nations (excluding USA and Japan)



Note: (i) Derived from OECD STAN. (ii) R&D expenditures in the construction industry shown as a % of that of 16 OECD nations combined: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Turkey, UK and the USA.

3 Phase 2 – Pathways to Innovation

Three case studies of previous significant R&D investment in Australia were undertaken to illustrate the:

- nature of such investments
- drivers, successes and barriers to investment
- organisational capabilities which contributed to outcomes
- outcomes and impacts of these initiatives.

Formal interviews were the primary source of data, along with project and program documentation. Thirty-five face-to-face interviews were conducted between late 2011 and early 2012.

To ensure a cross-section of understandings, interviewees represented: organisational executive; innovation champion; project leader; implementer; supplier; consultant; contractor; industry representative; allied agency representative; and a research representative.

3.1 Overview of Findings

The characteristics found to be in common across the three case studies included:

- *Drivers*: government drivers for change; enhancing best-practice; increased efficiency; and making use of new tools and technologies.
- *Implementation activities*: developing new skills; updating processes to align with innovations; and investing in relationships.
- *Process needs*: training; better communications and collaboration; new work practices and processes.
- *Impacts on values and culture*: the need for behavioural, work-practice and cultural change.
- *Supply chain impacts*: the need for integration of new skills and knowledge.
- *Key successes*: improved strategic and project outcomes, work environment and deliverables, and improvement in supply chain knowledge and outcomes.
- *Barriers*: business process and procurement practices; an entrenched resistance to change; improving awareness of initiatives and benefits.
- *R&D engagement*: R&D needs to be focused and practical; each agency reviewed had links with external R&D providers which complemented internal efforts.

Key Findings

External innovation linkages are essential

Timely and practical research should be a priority

Agencies need access to a range of innovation pathways

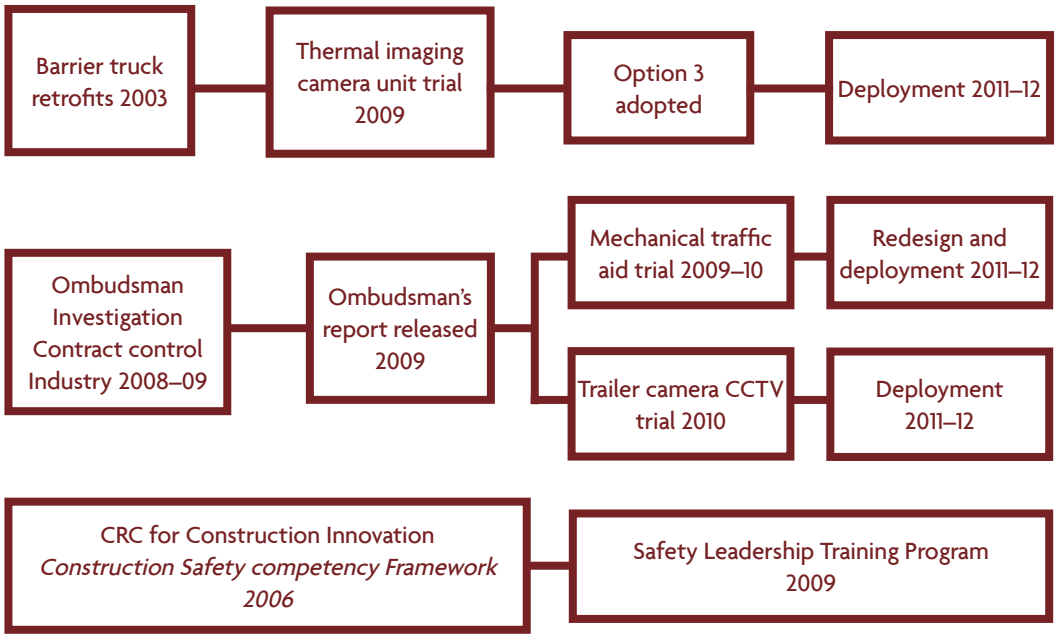
Case Study 1: Road Construction Safety

Queensland Transport and Main Roads (QTMR) are committed to ensuring a safe working environment for road construction workers in Queensland. They were a core partner in the Construction Safety Competency Framework project (CRC for Construction Innovation, 2006) and other safety research activities. Recent initiatives have further contributed to enhanced performance in this area including the development and implementation of the:

- mechanical traffic aid
- thermal imaging camera
- trailer-based CCTV (camera).

These three initiatives formed the basis of this case study, which had a formal R&D management process within QTMR (Figure 6) that included trials, options analysis and deployment.

Figure 6 – Road construction safety pathway to innovation



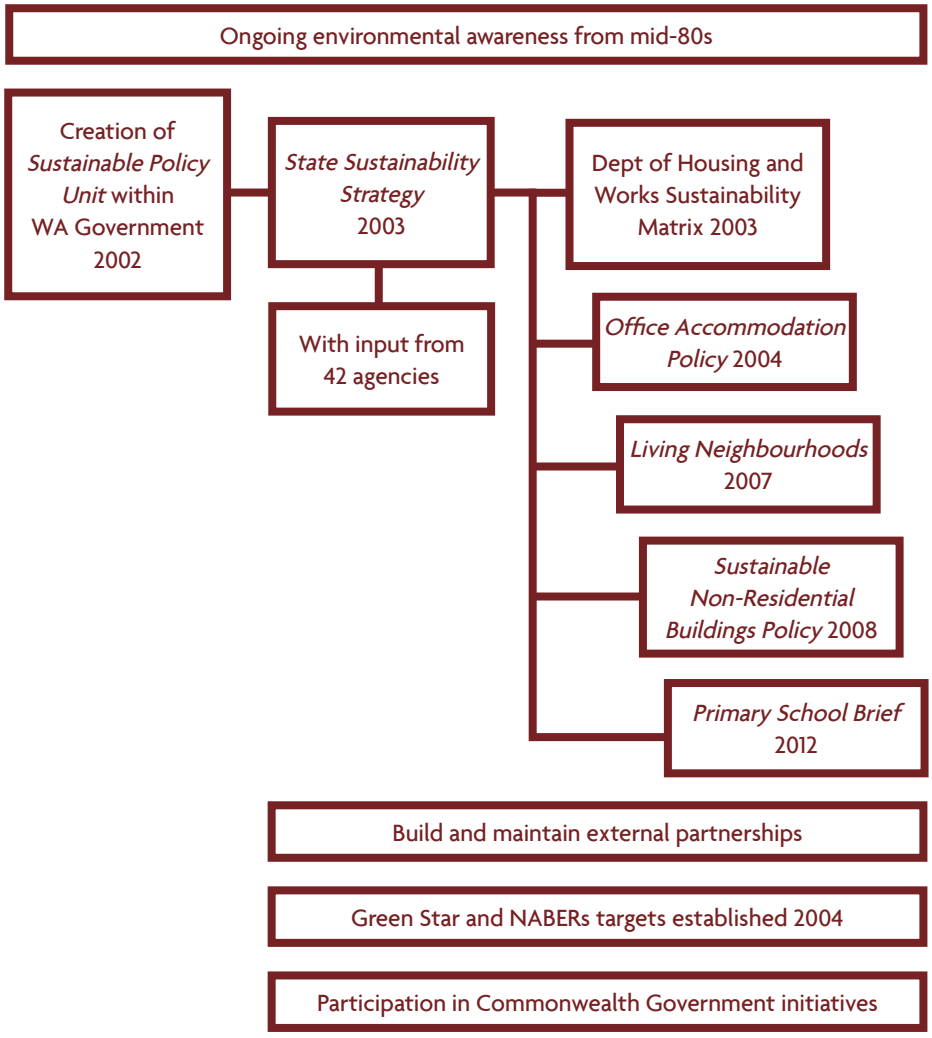
Case Study 2: Green Buildings

The Western Australian (WA) Government has taken a strategic leadership role for three decades in developing policies, guidelines and regulations to green the built environment. In the past decade a number of key initiatives have been introduced to contribute to:

- greening the stock of government buildings
- providing leadership in the development of other non-residential commercial buildings.

Figure 7 illustrates the pathway taken in this case study. It includes a key investment in the formation of the Sustainable Policy Unit in 2002, along with a focus on policy development, building external relationships and establishing targets for green commercial building outcomes.

Figure 7 – Green buildings pathway to innovation



Case Study 3: Digital Modelling/Integrated Project Delivery

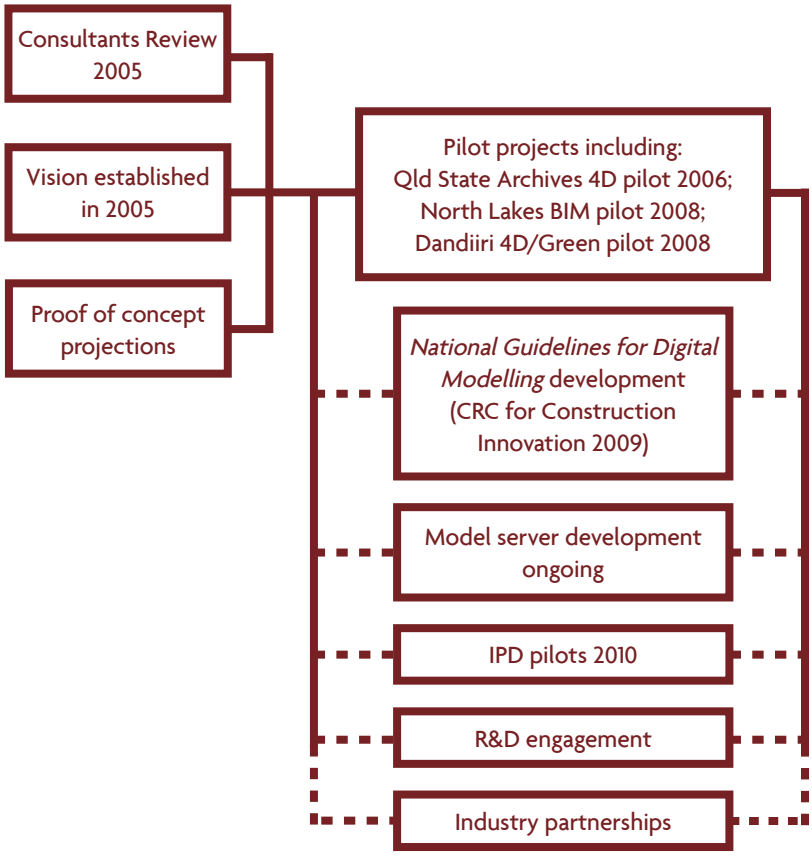
This third case study explored the evolution of digital project delivery processes in Project Services (a division of the Queensland Department of Public Works (QDPW)) from initial implementation of computer aided design and documentation (CADD) in the mid-1980s to experimentation with and implementation of building information modelling (BIM) from the mid-2000s; to current moves towards integrated project delivery[1] (IPD).

Project Services has provided acknowledged national and international leadership in this field, characterised by strong research partnerships, industry consultation and engagement.

Figure 8 illustrates the steps taken by Project Services to advance the digital supply chain of its building projects. This was characterised by a focus on developing more efficient delivery mechanisms through the use of new technology enablers, coupled with process changes including pilot projects, strong researcher engagement, targeted industry leadership and partnerships.

1. IPD requires team collaboration across the project supply chain, including design consultants, contractors and subcontractors (CRC for Construction Innovation (2009) National Guidelines for Digital Modelling).

Figure 8 – Digital modelling pathway to innovation



3.2 Research Benefits

Road construction safety case study

Recent trials in QTMR explored in the current case study responded to both an internal drive to improve safety for road construction workers and the travelling public, and the 2009 Queensland Workplace Rights Ombudsman Report on Traffic Control. Assessments of the trials were carried out with the following outcomes:

- thermal imaging cameras – 27 installed in Barrier Trucks across QTMR's fleet throughout 2011–12
- mechanical traffic aid – redesigned for use in Queensland conditions including development of specifications and deployment guidelines. Scheduled for deployment in 2011–2
- trailer-based CCTV cameras – approved for implementation with supporting deployment guidelines. Scheduled for deployment in 2011–12.

Green buildings case study

Impacts have been achieved through a combination of informal, formal and integrated R&D activities. The establishment of the WA Sustainable Policy Unit was pivotal. This led to the publication of the WA State Sustainability Strategy (2003), which has informed subsequent policy documents. Additional leverage has been achieved through the establishment of relationships with external organisations including: other state and local planning authorities; research institutions; supply chain partners; and industry associations including the Green Building Council of Australia (for example, WA Department of Finance, Building Management and Works supported the development of the GBCA Green Star – Public Building Rating Tool – 2010).

As well as resulting in a growing number of significant green buildings in WA, outcomes of this research have been embedded in policies, regulations and guidelines including the:

- Office Accommodation Policy (2004)
- Department of Housing and Works Sustainability Matrix (2003)
- Liveable Neighbourhoods Policy (2007)
- Sustainable Non-Residential Buildings Policy (2008)
- Primary School Brief (2012).

Digital modelling/integrated project delivery case study

QDPW Project Services have an ongoing integrated informal R&D process with the incremental adoption of new technologies and work practices. Internal proof of concept, achieved on a project-by-project basis, has been complemented by formal R&D engagement through core involvement with the CRC for Construction Innovation from 2001 to 2009, and now with SBEnrc. Project Services has also been involved with a number of Australian Research Council (ARC) Industry Linkage projects led by universities QUT and RMIT. Key industry outcomes include:

- Mareeba Court House and Police Station (2006) – first BIM pilot
- Queensland State Archives (2006) – 4D model developed
- North Lakes Police Station (2008) – BIM approach further developed
- structural steel design provided to the fabricator from Project Services
- Dandiiri Contact Centre (2008) – 4D model developed including energy modelling – building awarded the highest environmental performance of any Australian building under construction at that time
- development of National Guidelines for Digital Modelling (2009) through the CRC for Construction Innovation.

Impacts on the industry include QDPW Project Services being acknowledged as a national and international leader in this field with extensive dissemination of leading work-practices to other industry researchers, external contractors, suppliers and vendors. This has led to significant productivity benefits for the industry as highlighted by the Built Environment Industry Innovation Council in their 2010 report (Allen Consulting 2010)[2] .

2. Allen Consulting Group. (2010). Productivity in the buildings network – Assessing the impacts of Building Information Models. BEIIC. Canberra.

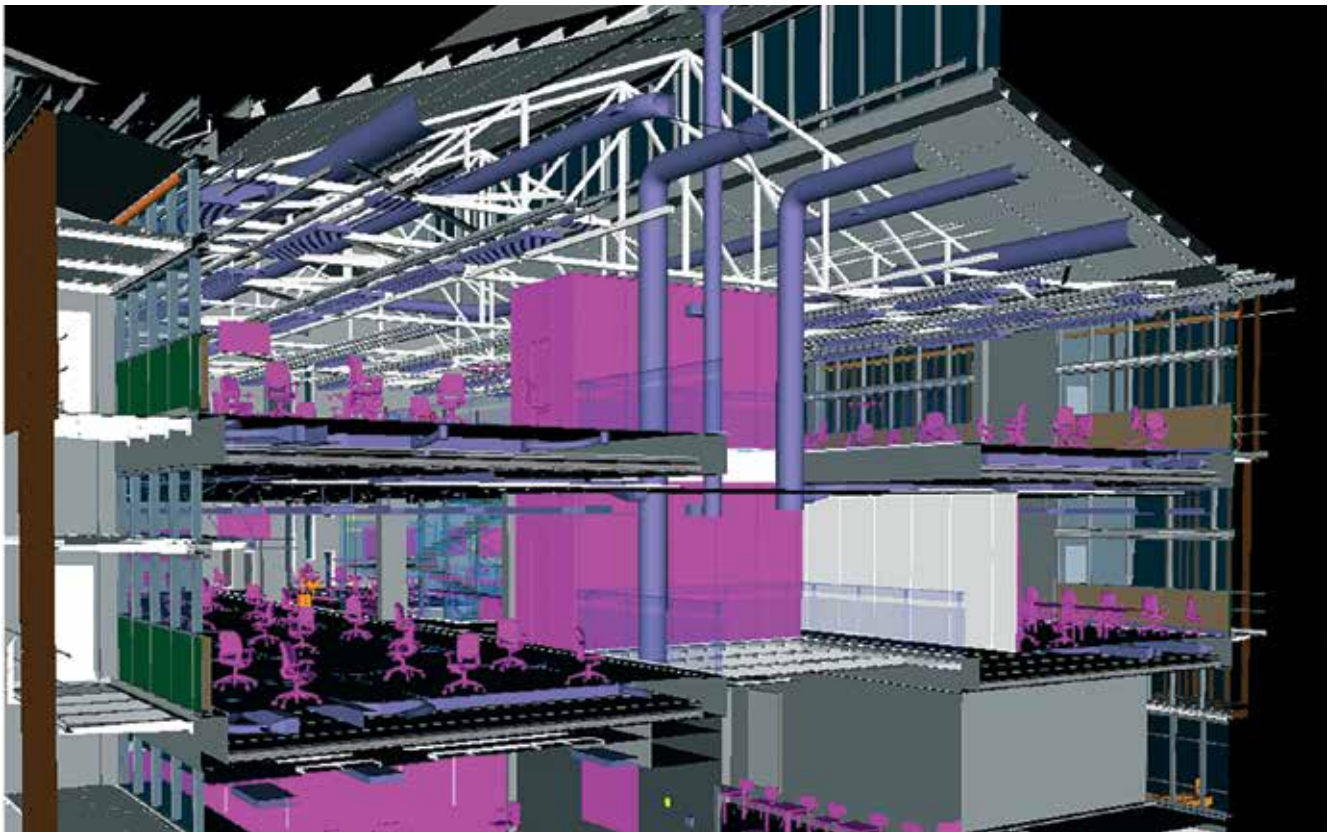
3.3 Conclusions

The analysis of these case studies highlights the:

- different pathways available for agencies to implement innovation
- importance of lateral communications structures with external organisations
- incremental nature of implementation coupled with technology and process change
- need for practical and timely research through existing relationships
- need for ongoing and complementary skills development.

Questions and challenges raised that may be the focus of future research include:

1. How does an organisation determine the most appropriate pathway to innovation?
2. How to most effectively develop relationships with researchers and industry?
3. How can industry accelerate the uptake of BIM to improve productivity?
4. How can organisations become more agile given the rate of change of technology?
5. What are the most effective mechanisms to facilitate practical and timely research?
6. How best to deliver training and skills to an industry dominated by small and medium enterprises in an environment of ongoing technological change?



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- Road Construction Safety Case – All interviewees; and key personnel in QTMR including Dianne Heenan, Jeff Abbott, Keith Butler, Anthony Hoiberg and Graham Fraine
- Green Building Case – all interviewees; and key personnel in WA Finance, Building Management and Works, especially Carolyn Marshall and Anna Evers (who undertook the WA-based surveys)
- Digital Modelling/Integrated Project Delivery Case – all interviewees; and key personnel in QDPW, especially Tom Fussell.

4 Phase 3 – Construction 2030

A Roadmap for R&D Priorities for Australia's Built Environment

The property and construction industry is the foundation of the Australian economy and is responsible for the development, construction and maintenance of infrastructure that supports Australian society. Understanding the likely future landscape of this industry will be of strategic benefit to the industry future and our society.

4.1 Visions for the Future

Implementing visions of the future requires establishing robust priorities …

In 2004, following extensive national consultation, the *Construction 2020* report was delivered by the CRC for Construction Innovation. It identified nine industry visions for future practice. The overall vision was that the Australian industry would take more responsibility for leading and investing in R&D through tripartite industry, government and research collaboration. The need to build industry's capacity and ability to undertake robust and viable national research and innovation in order to deliver real value to property and construction businesses was also identified.

In 2012, the successor to the CRC for Construction Innovation – the Sustainable Built Environment National Research Centre (SBEnrc) progressed this industry development initiative to create the basis of an industry R&D road map to establish priorities that respond to likely industry futures. Earlier project phases revealed significant growth in engagement between industry, government and researchers and described R&D case studies in road construction safety, green buildings and advanced ICT and procurement. The road map can shape decisions as to how to more profitably engage in research to secure business advantages and industry development.

Construction 2030 identifies:

- areas that will need research for adaptation to local conditions or partnering with other industries to produce usable results for the Australian construction industry
- areas where the construction industry must direct specific research action. This is necessary because of the potential future benefits and because these areas are unlikely to progress without construction industry attention.

Visions for the future help provide a focus for industry when clarifying its investment priorities. However, aspirations must be cast within realistic assessments of the future conditions under which they will have to be achieved. The *Construction 2030* research team undertook this assessment to generate a map of key drivers of the large-scale social (macro-social) environment to which the industry may need to adjust.

The *what-if* map of key sectors of the Australian future landscape captures the greatest inherent uncertainties of the macro-social environment. The map includes a broad range of future applications of emergent trends relevant to the industry. The map was used to generate decision scenarios that covered combinations of likely future uncertainty settings including: climate change, skills, economy, attitudes, policies/governance, energy and technology. The scenarios were tested with industry representatives in a series of national workshops. Participants then selected the possible technology capabilities that best matched the scenario conditions.

4.2 Construction 2030 Priorities

The list of technology capabilities was subjected to expert review regarding the timing and likelihood that the technologies were to emerge. Some technologies might be expected to emerge from existing research in construction or in other industries. However, other technologies will not emerge within a practical time frame, if at all, unless the property and construction industry itself conducts the research.

Research that requires adaptation to local construction industry conditions or that requires partnering with other industries to produce usable results for construction has been identified. This includes areas that are likely to be critical to the industry and which are not currently receiving sufficient research effort. It will be necessary to strengthen existing research capacity and organisational relationships for industry-wide issues that do not respond to direct market forces.

All research areas must be continuously monitored for unplanned innovation and unexpected developments in the macro-social environment.

Table 1: Summary of R&D priorities for Australia's property and construction industry

Research Area	Description	Industry Need	Action Focus
1. Model-based facility lifecycle business models	Model-based information technologies have the potential to facilitate profound changes in the way business is structured and value captured across the built environment life cycle. Enabling alternative business models will be crucial to commercialising critical technologies and solutions.	• A key link between the capital asset and more effective asset delivery and management. • Collaborative processes supported by robust facility lifecycle management tools.	Conduct active research
2. Intelligent infrastructure and buildings	Electronics, sensor and communication, analysis and network applications that improve the control, comfort, security, management and optimisation of infrastructure and buildings to improve occupant welfare and sustainability across the full lifecycle. Nano-scale sensors may be embedded in the structure itself.	• To enhance control, automation, integration and communication of facility durability, performance and sustainability along the entire property and construction value chain using long-life sensor systems. • To enable a longer view of investment and planning with reduced lifecycle costs.	Conduct active research
3. Solutions for a more sustainable built environment	Different types of solutions can make the built environment more sustainable – through concept, design, construction and ownership. To create incentives for their development and use, many of these solutions are dependent on novel systems, standards, tools, and financial and business models.	• To adapt to changing business conditions including the market and regulatory environment. • For greening the existing and future built environment and adapting to climate change	Conduct active research
4. Information and communications technology (ICT) for radical re-design	ICT is critical to facilitate improved conceptual and detailed design taking into account the need to disseminate information on and support new materials and trends, construction processes and asset management. Predictive tools and optimisation techniques for integrating product and process design at a single asset level to intermediate scales of urban or network level are required.	• To respond to climate change at multiple levels of design – facility, precinct, and regional. • To find new energy balances in the design of built environment systems brought about by changes to energy generation.	Conduct research for local conditions

Research Area	Description	Industry Need	Action Focus
5. Biotechnology for tree-based materials	Considerable research is being conducted into materials, products and processes based on trees for structural and non-structural applications. These range from UV, moisture and decay resistance to increased insulating or conduction performance, through to new nano-cellulose-metal composite materials.	• To respond to societal expectations, climate change and skills shortages. • Possibilities for new materials with customised properties and more effective processes such as modular construction.	Conduct research for local conditions
6. Educational curricula	The need for lifelong learning, shifts in business models, advanced ICT and sustainability presents challenges and opportunities to curricula. This includes initial and continuing education in the technical, operational and management aspects of the industry.	• Integrated teaching in the use of new approaches and technologies. • Stronger integration of research and teaching and customised career-long education.	Conduct research for local conditions

Acknowledgements

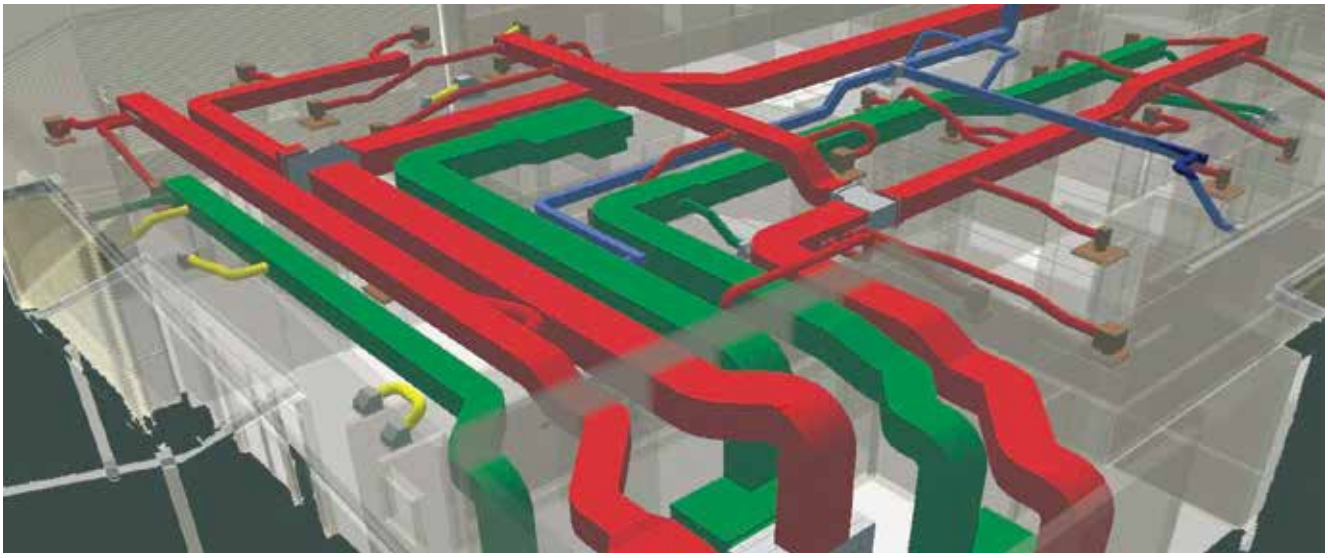
The research team acknowledges the contribution of workshop participants from Perth, Brisbane, Sydney and Melbourne who were involved in the foresighting workshops throughout November 2011.

5 Phase 4 – A Vision of R&D Policy Directions

5.1 The Challenge

Several challenges are highlighted by this report including:

1. *Government spend* – Between 1992 and 2010, government agency spending on construction R&D fell from 2.2% to 0.5% of total government sector R&D expenditure. This has occurred despite the Australian construction industry growing in terms of gross value added significantly faster than the Australian GDP in the last two decades.
2. *Time frames* – There is a mismatch in the nature of research objectives sought from the public (often medium to long term) and the private sector (often short-term). **Implication: A mechanism to encourage/enable public organisations to build greater long-term strategic capabilities is required.**
3. *Fragmented nature of the industry* – Historically, there has not been coherent strategic planning within the industry due to: fragmentation; the project-centred nature of the industry; and little capacity for organisational or industry learning. **Implication: Industry will only act strategically to define their common problems if they have a clear incentive to contribute and if there is a well-defined structure to define such problems.**
4. *Industry structure in the building sector* – The small and medium enterprise (SME) nature of the industry restricts the capacity of most firms to invest directly in long-term R&D. Furthermore, SMEs lack channels to access new ideas when not directly involved in research. **Implication: There is a need to shift some of the levy funds to both R&D *and* training.**
5. *Government risk aversion* – Public sector clients are often risk averse, seeking the lowest priced conforming tender with the least possible risk. Where alignment between research and procurement is lacking this can also restrict innovation in asset construction and maintenance. **Implication: Governments need to: encourage innovation through the procurement process; establish generic standards for 'public good' and industry outcomes; and introduce an R&D component to all projects.**
6. *Public sector expertise* – In most cases there is greater technical excellence in industry than in the public sector, partially due to the level of R&D investment in the respective sectors. Furthermore, there is little incentive for researchers to engage in industry collaborations due to the greater prestige offered by national competitive grant-funded research and lower perceived value from industry-relevant research. **Implication: An opportunity exists for practitioner/researcher exchange – to build a shared understanding of a culture of innovation unhindered by traditional models. This would lead to: a rise in interdisciplinary approaches; and potentially unorthodox solutions to industry challenges.**



5.2 Models for Industry R&D Engagement

Several models for engagement have been considered in detail.

Industry-sponsored research councils – Globally, several industries have formed their own research funding bodies. Typically such bodies have started as industry initiatives without government funding or leadership, but often go on to leverage government funds. A key feature of this model is the research focus on strategic, pre-competitive research of the sort that would benefit all members of a consortium collectively, rather than individual firms.

These consortia may also broker research partnerships between individual companies and research providers in the public sector to address a specific challenge faced by a particular company. This activity is enhanced by the existence of a broad capability and an established relationship built up through the sponsorship of previous strategic, pre-competitive research.

Government-mediated industry R&D – Australia has a strong tradition of assisting industries with high SME involvement in fund-raising for R&D through levies on industry activity, with funds distributed according to priorities determined by an industry board. The Building and Construction Industry Training Fund (BCITF) is one such model which invests in skills development. This fund could theoretically be modified through legislative amendments in order to foster a viable and industry-responsive research fund.

Government can also play a role in encouraging industry-based organisations to associate and develop a shared vision. One such example is the Built Environment Industry Innovation Council (BEIIC) which has been tasked with advising the Australian Government on innovation challenges. A smaller and more focused group such as this, led by the industry, could play a significant role in driving a future Australian public-private research agenda.

Government agency research – Traditionally, governments have maintained internal R&D capabilities related to the built environment. However, as governments have progressively reduced their internal design and construction activities, they have also reduced the internal investment in R&D. Within the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's largest state-owned industrially oriented research organisation, the realignment of internal priorities has led to an additional steep reduction of such R&D. Other countries offer examples of government agencies that have prioritised construction research as being integral to economic growth, and used the strength of their national institutions to reinforce the capabilities of their local construction industry.

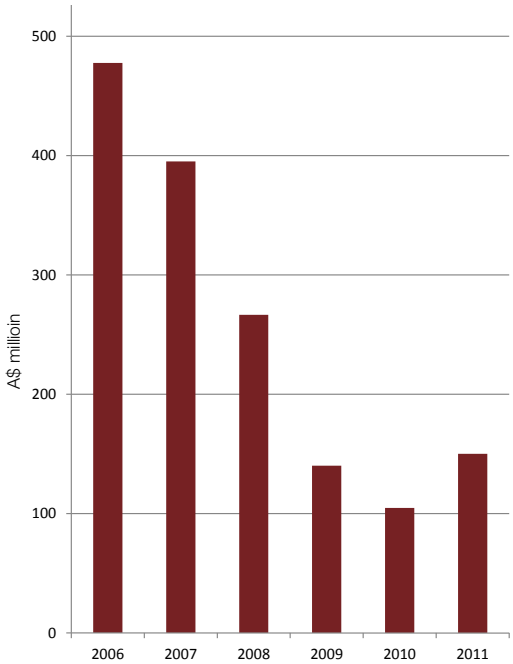
Government R&D tax programs – The Australian Government offers R&D tax concession and incentives to promote innovation.

A tax concession to encourage Australian industry to undertake R&D activities was first introduced in 1986. Its aim was to make eligible companies more internationally competitive by encouraging innovative products, processes and services through the promotion of technological advancement and strategic R&D planning. It was replaced on 1 July 2011 by the Australian Government's $1.8 billion R&D Tax Incentive which provides tax offsets to encourage more companies to engage in R&D.

The Australian government has also announced that it will introduce quarterly credits for SMEs from 1 January 2014 (ATO, 2012).

Government grants – Historically, Australian governments have sought to build partnerships between industries and public sector researchers via long-standing public grant schemes. The Australian Research Council (ARC) Linkage program and the Cooperative Research Centres (CRC) program are two such schemes. Recently, these schemes have failed to foster substantial public-private partnerships, despite the extremely strong growth in private sector internal investment on R&D. For example, there is currently no CRC that serves the strategic needs of the construction industry as a whole.

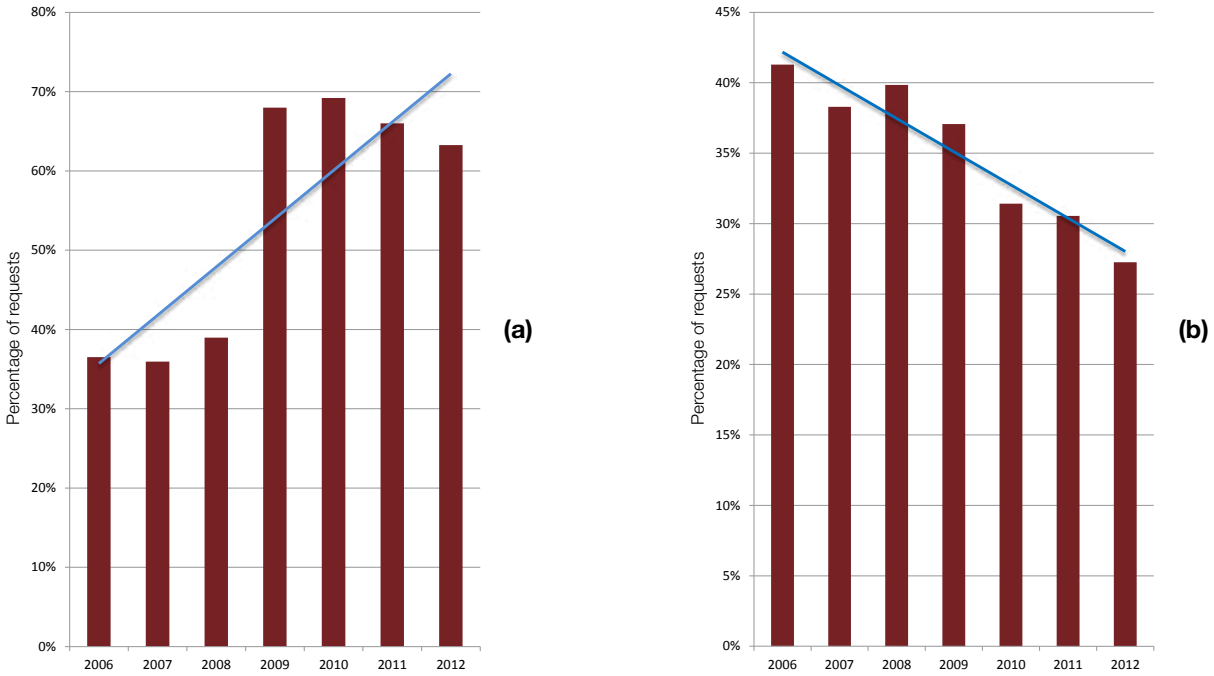
Figure 9 – Total CRC funds granted between 2006 and 2011 (A$ millions adjusted for inflation to June 2012) (CRC 2011)



The ARC linkage program has also experienced a steady decline in the funds granted (funds granted in 2012 were 25% lower than in 2006 in June 2012 dollars) and success rates after the peer review process remain relatively low (average 43% success rate over the last 7 years).

This becomes a significant disincentive to industry participation if grant applications with willing industry partners are rejected, potentially reinforcing a culture of poor engagement.

Figure 10: ARC Linkage projects funds allocation as a percentage of request (2006–2012) for: (a) all successful applications (b) discipline panels under which Built Environment applications are classified (ARC, 2012)



Note: Derived from ARC (2012) Linkage Projects Funding Outcomes. Discipline categories used for (b) containing built environment, architecture and civil engineering were: PME = Physical, Mathematical and Information Sciences an Engineering, HCA = Humanities and Creative Arts, HSE = Humanities and Creative Arts, Social, Behavioural and Economic Sciences, EMI = Engineering, Mathematics and Informatics, EE = Engineering and Environmental Sciences.

5.3 Recommendations

For Industry (including government as a developer and asset manager) – it is in the best interest of the construction industry to engage with public research, and lead and invest in its own research and innovation. The following actions could provide a link between industry and public-sector priorities, and to serve the long-term interests of the industry itself:

- Establish a national industry steering body to define long-term (5–10 year) R&D priorities for the construction industry, to be revised annually.
- Disseminate these priorities throughout government and public-sector research organisations to help align the research priorities and capacity building activities with the long-term strategic interests of the industry.
- Provide a new funding stream (derived in part from industry sources) to be distributed directly by the proposed industry steering body in order to provide incentives to public research organisations to grow capacity that is aligned with the long-term industry needs.

For Government (as a client, regulator, and investor) – all levels of government must actively ensure that the public infrastructure investment is effectively delivered:

- Public procurement should establish systematic and internationally consistent standards that will drive innovation in the industry and public investment in infrastructure. These activities should be paralleled by investment in relevant R&D capability.
- State governments, through existing mechanisms funding trade training (industry training levies), to allocate a proportion of these funds towards long-term strategic R&D determined by the state chapters of the proposed national industry steering body.
- Federal funding for Centres of Excellence, CRCs, ARC Linkage funding, and CSIRO internal funding should: reflect the long-term strategic priorities identified by the proposed national industry steering body; and offer incentives for public research bodies to align their research capabilities with the needs of regional industry.

For Public Research Organisations – Universities and government research agencies are highly reactive to external financial incentives. Recognising this constraint, public organisations can nonetheless provide leadership through:

- Senior decision-makers in government agencies and universities integrating industry priorities and regional industry capability into their internal investment allocation in order to ensure that capabilities within public organisations match long-term industry needs.
- Public research organisations building ongoing strategic partnerships with members of the construction industry while retaining a focus on leading-edge practice and driving transformational change.
- Public research organisations building outstanding centres emphasising interdisciplinary models (social as well as technical), to ensure results are globally connected.

Acknowledgements

The SBEnrc research team acknowledges the contributions of:

- Professor Andrew Reeves – for providing valuable insights into the history and structure of current R&D mechanisms in Australia.
- Professor Ian Chubb AC, Chief Scientist, Australia; and his State counterparts Dr Geoff Garrett AO, Queensland; Professor Mary O'Kane, New South Wales; Professor Don Bursill AM, South Australia; and Professor Lyn Beazley AO, Western Australia – for their assistance in focussing policy guidelines on national and state issues as an important element of developing the final guidelines.

Our Vision for the Future

1. A national industry steering body which defines long-term strategic industry R&D priorities, and funds associated research in public organisations.
2. Government procurement equipped to support construction innovation and supply matching funds for strategic R&D.
3. Research institutes with world-leading interdisciplinary capabilities to provide expertise relevant to the goals of the Australian construction industry.
4. This vision is underpinned by a culture of self-improvement, mutual recognition, respect and support.

6 CIB Task Group 85: R&D Investment and Impact

This influential international Task Group, established in 2011 has arisen directly from this Sustainable Built Environment National Research Centre Project 2.7 and has been supported through significant interest from 35 members across 15 countries.

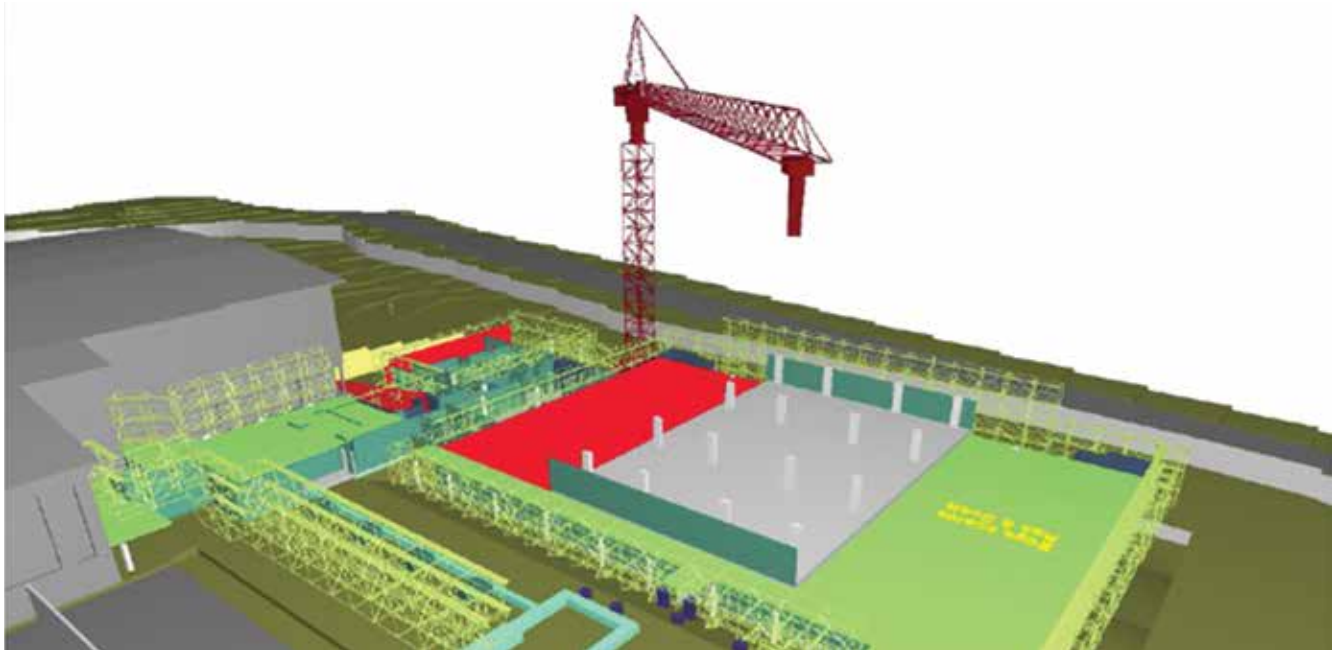
The International Council for Research and Innovation in Building and Construction (CIB) was established in 1953 to stimulate and facilitate international cooperation and information exchange between research institutes in building and construction. CIB has since developed into a world-wide network of over 5,000 experts from about 500 member organisations across 100 countries active in the research community, in industry or in education, who cooperate and exchange information in building and construction related research and innovation.

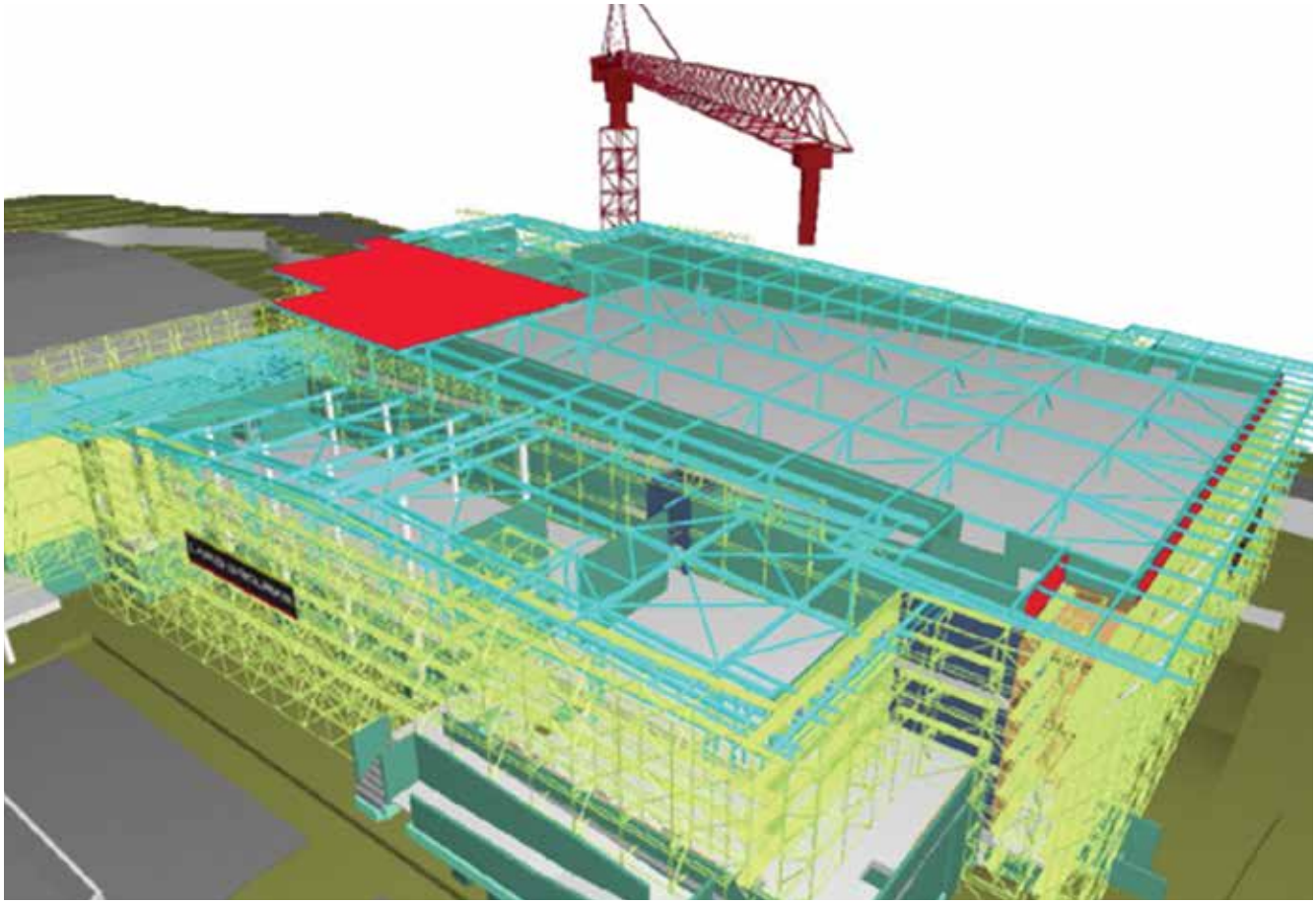
TG85 is coordinated by Professor Keith Hampson – Sustainable Built Environment National Research Centre (SBEnrc), Australia; Professor Aminah Robinson Fayek – University of Alberta, Canada; and Dr Judy Kraatz – Queensland University of Technology (QUT), Australia.

The Task Group is focussed on building a better understanding of R&D investment practice globally, including retrospective analysis of past investments and their impact; and building prospective considerations for improved mechanisms in developing, disseminating and encouraging uptake of R&D outcomes.

The objectives of this Task Group include:

- Establish an international network to exchange knowledge and contribute to new understandings and knowledge related to leveraging R&D investment in the building and construction industry. A key aspect of this is the focus on collaboration between private sector organisations and public sector agencies to maximise outcomes.
- Establish an international research agenda across countries to facilitate discussion and debate (based upon comparable data), the intent being to further develop the knowledge-base and theory relevant to this field.
- Potentially build a consensus of metrics to enable the ongoing exchange of knowledge and findings relating to R&D investment.
- Promote publication in this field to enable greater global dialogue regarding R&D investment and its impacts (both academic knowledge-base and industry outcomes).
- Strengthen collaboration between private firms, government agencies and research institutions to deliver better policy and programs to achieve enhanced investment outcomes.





6.1 Program of Work

The following schedule outlines the activities of the Task Group.

Year 1 – May 2011 to April 2012

Start-up meeting at 6th Nordic Conference on Construction Economics and Organisation, Copenhagen, April 2011.

Establish electronic community for the Task Group through:

- website
- bi-monthly Webex meetings including country presentation by members.

Task Group meeting SB11 Helsinki, World Sustainable Building Conference, October 2011:

- discuss research methodology
- identify opportunities for knowledge exchange
- report on Australian activities and preliminary findings.

Year 2 – May 2012 to April 2013

Bi-monthly Webex meetings continue.

Ten Abstracts submitted for TG85 stream at CIB World Building Congress 2013, Brisbane (jointly hosted by QUT and SBEnrc).

Book outline 'R&D Investment and Impact' submitted and approved for publication by international publisher Taylor and Francis.

Year 3 – May 2013 to April 2014

CIB World Building Congress May 2013, Brisbane, Australia:

- TG85 stream
- TG85 Industry publication promoting global industry benefits of applied research.

CIB TG85 R&D Investment and Impact book to be published by Taylor and Francis (early 2014).

6.2 Membership

As at September 2012, this Task Group has 35 members representing 15 countries.

Australia	Seokho Chi Keith Hampson (Coordinator) Naomi Herron Judy Kraatz (Coordinator) Karen Manley Adriana Sanchez (Commission Secretary)
Brazil	Francisco Cardoso Lucia Helena de Oliveira Mercia Maria Semensato Bottura de Barros
Canada	Aminah Robinson Fayek (Coordinator)
Peoples Republic of China (including Hong Kong)	Dongping Fang Pin-Chao Liao Geoffrey Shen Roine Leiringer
Denmark	Kim Haugbølle
Finland	Miimu Airaksinen Suvi Nenonen Tuomo Poutanen Liisa Lehtiranta
France	Frédéric Bougrain
Germany	Gregor Neusse
India	Anil Sawhney Arun Kashikar
Ireland	Ken Thomas
New Zealand	Suzanne Wilkinson
Norway	Marit Støre Valen
Portugal	Francisco Branco
South Africa	Rodney Milford Ntebo Ngzowana
Sweden	Anna Kadefors Jan Bröchner
The Netherlands	Wim Bakens Geert Dewulf Emelia Van Egmond-de Wilde de Ligny
USA	Alexandra Staub Sarah Slaughter

7 Dissemination of Project Findings

7.1 Industry Presentations

- 5 September 2012 – Presentation by Keith Hampson to Western Australian industry stakeholders, WA Department of Finance, Building Management and Works and Australian Institute of Architects. *Report on project progress,* Perth.
- 6 July 2012 – Presentation to BEIIC by Keith Hampson. *Report to BEIIC on project progress*. Complemented by Catherin Bull (BEIIC and Project 2.7 PSG Member), Canberra.
- 12 June 2012 – Presentation by Keith Hampson and Judy Kraatz to Queensland Transport and Main Roads. *Report on Road Construction Safety case*. Opened by Dr Graham Fraine, Deputy Director General, Brisbane.
- 18 April 2012 – Keynote Address by Keith Hampson to International Workshop on Integrated Design and Delivery Solutions (IDDS) by Keith Hampson. *Building BIM in Australia: A Retrospective and Prospective Analysis,* Washington DC, USA.
- 23 August 2011 – Workshop presentation by Keith Hampson to Australian Academy of Technological Sciences and Engineering (ATSE), *Increasing the Innovation Dividend from Emerging Technologies* forum, Brisbane.

7.2 Industry Publications

- July 2012 – *Construction 2030: A Roadmap for Australia's Built Environment Industry*. Voros J., Hayward P., Roos G., and Bok B.
- May 2012 – *Pathways to Innovation Case Study Reports Parts 1, 2, 3 & 4*. Kraatz J., Hampson K., and Campana J.
- July 2012 – *SBEnrc Project 2.7 Update #2*
- October 2011 – *SBEnrc Project 2.7 Project Update #1*
- May 2011 (Updated June 2012) – *The Built Environment Sector in Australia – R&D Investment Study*. Thomas Barlow

7.3 Refereed Journal Papers

- Building Research and Information (BRI). Paper accepted for publication Feb 2013. Kraatz, J.A. and Hampson K.D., *Brokering Innovation to Better Leverage R&D Investment*.
- Foresight. Practitioner paper to be submitted. Bok, B., Hayward, P., Voros, J. and Roos, G, *Morphological Scenarios and Technology Roadmapping*.
- Construction Management and Economics. Findings paper to be submitted. Bok, B., Roos, G, Hayward, P., and Voros, J. *Emergent Technology for the Built Environment – Technology Roadmapping Extended*.
- Foresight (to be confirmed). Methodology paper to be submitted. Bok, B., Voros, J., Hayward, P., and Roos, G, *Morphological Analysis – The Ideal Meets the Practice*.

7.4 Refereed Conference Papers

- 6–18 November 2012. Asia-Pacific Foresight Conference (Perth, Australia). Bok B., Hayward P., Voros J., and Roos G., *Morphological Scenarios and Technology Roadmapping*.
- 8–12 July 2012. Healthy Buildings 2012 Conference (Brisbane, Australia). Hampson K.D. and Kraatz, J.A., *R&D Investment in Green Building Initiatives in Western Australia*.
- 19 October 2011. SB11 World Sustainable Building Conference (Helsinki, Finland). Hampson K.D. and Kraatz J.A., *Retrospective Evaluation and Prospective Value-add: A Review of R&D Investment in Australia*.
- 21–26 June 2011. Modern Methods and Advances in Structural Engineering and Construction, The Sixth International Structural Engineering and Construction Conference (ISEC-6) (Zürich, Switzerland). Hampson K.D. and Kraatz J.A., *Leveraging R&D to Advance Digital Modelling Practice in Australian Construction.*
- 13–15 April 2011. 6th Nordic Conference on Construction Economics and Organisation (Copenhagen, Denmark). Hampson K.D. and Kraatz J.A., *Leveraging R&D Investment for the Australian Built Environment*.

8 Benefits

8.1 Contribution to Industry Practice

Project 2.7 has delivered a number of tangible industry benefits including:

The ***audit and analysis of past R&D investment in Australia*** which has highlighted the significant shift in R&D investment in this sector in the past two decades. This highlights the need to establish new models for industry/researcher/public sector engagement to maximise the return on R&D investment. These findings have then informed each subsequent project phase.

The three ***case studies*** highlight the importance of:

- external innovation linkages
- timely and practical research as a priority
- the need for government agencies to have access to a range of innovation pathways.

In addition each case study has revealed the beneficial outcomes of past investments and the mechanism of securing those benefits in examples including:

- Thermal imaging cameras being installed in 27 Barrier Trucks across QTMR's fleet; Mechanical Traffic Aids being redesigned for use in Queensland conditions; and Trailer Cameras now approved for implementation throughout the State of Queensland.
- WA Government's Office Accommodation Policy (2004); Liveable Neighbourhoods Policy (2007); Sustainable Non-Residential Buildings Policy (2008); and the Primary School Brief (2012) as outcomes of their R&D focus in this area.
- The integration of BIM-related R&D activities into built assets in Queensland with tangible environmental (Green Star ratings) and safety (construction rehearsal) benefits.

Construction 2030 has highlighted three priority areas for active research in the built environment including:

- Model-based design/business models – to provide a key link between the capital asset and more effective asset delivery and management.
- Intelligent infrastructure and buildings – to enable a longer view of managing facility investment and planning with reduced life cycle costs.
- Solutions for a more sustainable built environment – to adapt to changing business conditions including market and regulatory environment.

These phases have then informed the recommendations contained in the ***Phase 4 Policy Guidelines***. These guidelines outline a vision for the future defined by a long-term strategic focus with: appropriate industry-led R&D priority setting and funding; procurement mechanisms which support innovation; and world-leading interdisciplinary capabilities.

8.2 Contribution to Theory

Phase 1 – R&D Investment 1992–2010 – provides an empirical basis from which further knowledge can be derived.

Phase 2 – Pathways to Innovation – made explicit use of criteria related to theories of organisational capabilities and open innovation in case study analysis. This has provided tangible examples of the role played of dynamic capabilities, absorptive capacities and open innovation for public sector agencies working in the built environment industry specifically.

Phase 3 – Construction 2030 – this research (by Swinburne University of Technology and VTT Finland) has demonstrated that morphological scenarios can be used with expert-produced technology roadmaps to arrive at defensible results for a client with strong user participation and honouring a 15-year industry vision. The benefits to theory are:

- The team considers this to be the first time that a normative industry vision has been integrated with the production and use of plausible future scenarios in Australian industry; these are typically viewed as incompatible objectives requiring different methods.
- Scenario workshops were undertaken to bring industry-thought leadership and expertise to the selection of R&D priorities. This was done through the novel use of a 'technology wall' that reverses thinking which typically views technology as a push factor or a driving force which helps to bring about a desired future. Rather, the future acted as a 'pull' factor which guided the choice of technologies.
- The use of a 'traffic light' decision making framework for selection of industry priorities was made to facilitate transition of the workshop results to the decision making processes, and to develop judgements and follow-up processes.

9 Project Team

9.1 Project Steering Group

The Project Steering Group (PSG) was established at the initiation of this project and has met five times to date. This group has provided a valuable forum for:

- ensuring relevant and practical links to industry practice
- maintenance of strategic direction
- re-shaping specific project activities as required
- discussion of research methodology, findings and dissemination.

Links to both the Built Environment Industry Innovation Council (BEIIC) via Professor Catherin Bull, and the Office of the Chief Scientists' national network have provided an important avenue through which to maintain the project's strategic direction and senior national support and profile.

Members of the Project 2.7 Project Steering Group were:

SBEnrc	Keith Hampson
Queensland University of Technology	Judy Kraatz Rachel Parker Joe Campana Seokho Chi
Swinburne University of Technology	Peter Hayward Joseph Voros Barbara Bok Russell Kenley Toby Harfield
VTT Technical Research Centre of Finland	Göran Roos
Queensland Department of Public Works	Don Allan Ross Smith
Queensland Transport and Main Roads	John Gordon Dianne Heenan Jeff Abbott
WA Finance Building Management and Works	Michael Pearson Carolyn Marshall Anna Evers Graeme Lockhart
John Holland	Silva Crocker Lea Slade
Barlow Advisory	Thomas Barlow
Built Environment Industry Innovation Council	Catherin Bull
Queensland Office of the Chief Scientist	Nicole den Elzen Melanie Gray
Aalto University, Finland	Liisa Lehtiranta

9.2 Research Team

Phases 1, 2 and 4 Research Team Members

Professor Keith Hampson (Project Leader and Chief Investigator) has over 30 years of industry, government and research leadership. He has international experience and scholarship, operating in multi-disciplinary environments in design, construction and maintenance functions in infrastructure and building. Keith has a Bachelor of Civil Engineering (Hons), an MBA, and a PhD from Stanford University focusing on innovation and competitive performance in infrastructure design and construction processes. He is also an acknowledged national and international leader in construction research, committed to building a more internationally competitive industry by promoting better education, applied technology and innovative practices. He has been recognised by awards of Fellow – Institution of Engineers Australia, Fellow – Australian Institute of Company Directors and Fellow – Australian Institute of Management. Keith is currently CEO of the *Sustainable Built Environment* National Research Centre (SBEnrc), successor to the CRC for *Construction Innovation*, of which he was CEO for its nine years of operation.

Dr Judy Kraatz (Senior Research Fellow) brings 25 years of professional activity in the built environment to inform business solutions, project delivery and research undertakings. Her career has spanned design architecture, leading a team of professionals delivering city-wide solutions for public buildings and parklands and integrating sustainability into regional endeavours; design practice and business process solutions. Judy's doctoral studies investigated how project objectives can be better aligned with an organisation's corporate objectives and responsibilities. The outcome of this research is a value-mapping framework which tracks project performance back to existing organisational objectives, outcomes and values. Judy has been responsible for the management of this project; and day to day academic direction of team members.

Joe Campana (Research Assistant) – Joe has over twenty years of professional activity in the telecommunications, project management, and education environments. His career spans from being a telecommunications specialist; to leading ICT project teams; to teaching and consulting in the vocational education sector. Joe has a Master of Education (QUT) and is currently a PhD candidate at QUT. Joe has provided a significant day-to-day contribution to project outcomes. In particular, Joe was responsible for data collection and analysis (with the assistance of Seokho Chi) for the Road Construction Safety case study.

Anna Evers – holds a BA (Hons) in Biological Sciences from the University of Oxford and an MA in Ecologically Sustainable Development from Murdoch University, where she wrote her thesis on community gardens. After graduating from Murdoch, she worked as a Research Officer for the WA State Government in Building Management and Works, Department of Finance. Anna made a substantial contribution to the Green Building case study through: assisting in the compilation of interviewees; undertaking the 12 WA-based interviews; and providing documentation on green building initiatives in that state.

Dr Thomas Barlow – has made a significant contribution to Phase 1 of this project. He is highly respected within the Australian research community for his analyses of the Australian R&D system and for his strategic work with research-intensive organisations. He is the author of the essential book about Australian innovation, The Australian Miracle. He has also been a policy advisor within the Howard Government, a columnist with the Financial Times in London, and a Fellow of Balliol College, Oxford.

Professor Rachel Parker (Chief Investigator) – Rachel's research focuses on comparative business systems and the institutional foundations of innovation and industrial competitiveness. Her work has contributed to improved understandings of the way in which Australian and international public policy programs affect firm and industry behaviour and therefore industrial development and transformation. She has published fifty articles and three books and her publications appear in leading international journals in the field including Entrepreneurship Theory and Practice, Organization Studies, Political Studies, International Journal of Cultural Policy and Work, Employment and Society. She has been the lead Chief Investigator on 4 ARC Grants (including 3 ARC Discovery Grants) and has been involved in numerous ARC grants totalling $2 million. She has recently worked as a consultant/advisor on knowledge transfer activities for the Department of Innovation, Industry, Science and Research; Queensland Rural Industry Training Council; QMI Solutions and Australian Institute for Commercialisation.

Professor Andrew Reeves – works at Monash University as a Professorial Fellow and Senior Advisor for Collaboration and is attached to the National Centre for Australian Studies. Andrew trained as a historian at the University of Melbourne and La Trobe University and has worked for two decades in Australian museums. He has published on subjects as varied as the history and material culture of Australian trade unionism, goldmining in nineteenth century Victoria and museum studies. Most recently Andrew was senior policy advisor to the former Federal Minister for Innovation, Industry, Science and Research, Senator Kim Carr. It is in this context he has made a significant contribution to the final phase of this project.

Phase 3 Research Team Members

Ms Barbara Bok (Research Assistant) is a PhD Candidate and Researcher at the Faculty of Business and Enterprise, Swinburne University of Technology, where she is establishing a profile in transformative education and foresight. She has taught on the Master of Strategic Foresight and Micro-economics program at Swinburne. Barbara holds degrees in operations research and statistics, business administration, and strategic foresight. Prior to her work at Swinburne, Barbara worked in her own management consulting business after a career in the manufacturing and mining-related industries in roles that facilitated management and engineering decision making.

Dr Peter Hayward (Chief Investigator) – is a trained accountant and economist with over 25 years of experience in taxation and public policy. Peter studied systems theory under the mentorship of consultants such as Richard Hames and Richard Bawden and has experience in the application of it to public policy initiatives. He completed a Graduate Certificate of Science in Strategic Foresight in 2001 and this has allowed him to integrate his passions for change management, organisational viability, sustainable futures and cultivating the leadership that makes all that possible. In 2005 he completed his PhD, examining the development of foresight in individuals and also became the Program Director of the Masters of Strategic Foresight, a role he is still proud to perform. Peter has consulted to a range of organisations in the use of foresight methods, and is the author of the inaugural monograph in the School's Monograph Series, Foresight in Everyday Life. He is the author of the journal articles 'Facilitating Foresight', 'The Moral Impediments to Foresight Action' and 'Futures Thinking as a Catalyst for Change'.

Professor Göran Roos (Chief Investigator) – chairs the Advanced Manufacturing Council in Adelaide and is a member of the Board for VTT International in Finland; Honorary Professor at Warwick Business School in the UK; Visiting Professor of Intangible Asset Management and Performance Measurement at the Centre for Business Performance at Cranfield University in the UK; Professor in Strategic Design in the Faculty of Design at Swinburne University of Technology in Melbourne; Adjunct Professor at University of South Australia in Adelaide; Adjunct Professor at University of Adelaide; Adjunct Professor at University of Technology Sydney; Adjunct Professor at Nanyang Business School, Nanyang Technological University in Singapore and Senior Advisor to QMI Solutions in Brisbane and Aalto Executive Education Academy in Helsinki. Göran was named one of the 13 most influential thinkers for the 21st century by the Spanish business journal 'Direccion y Progreso' and was appointed Thinker in Residence by the South Australian Premier for 2011.

Dr Joseph Voros (Chief Investigator) – began his career as a scientist. During his PhD in theoretical physics he worked on mathematical extensions to the General Theory of Relativity. After that he spent several years in Internet-related organisations (including Netscape Communications in Silicon Valley), before becoming a professional futurist. Prior to becoming an academic, he worked as a consultant analyst and practitioner. He now teaches into most of the units in the Master of Strategic Foresight at Swinburne University of Technology in Melbourne. He also designed the Swinburne MBA unit on corporate strategy and taught it for several years. For over a decade his research has focused on developing a rigorous process–method view of foresight, and three of his research articles have won excellence awards, including an Outstanding Paper award in 2010. He is a member of the World Futures Studies Federation, the Shaping Tomorrow Foresight Network, a professional member of the World Future Society, and is a founding member and board member of the International Big History Association. In February 2012, he was one of 42 world experts selected to present at the Global Future 2045 International Congress in Moscow.

Sustainable
Built Environment
National Research Centre

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations for the built environment industry.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of SBEnrc outputs. The SBEnrc integrates research across the environmental, social and economic sustainability areas in programs titled Greening the Built Environment; Developing Innovation and Safety Cultures; and Driving Productivity through Procurement.

Among the SBEnrc's objectives is collaboration across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

SBEnrc Core Partners:

Government of Western Australia
NSW Transport Roads & Maritime Services
Queensland Government
Parsons Brinckerhoff
John Holland
Curtin University
QUT
Swinburne University of Technology

For further information:

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