Project 2.7 - LEVERAGING R&D FOR THE AUSTRALIAN BUILT ENVIRONMENT

PHASE 2 CASE STUDIES

Part 1 – Overview

To be read in conjunction with:

Part 2 – Road construction safety case report
Part 3 – Green buildings case report
Part 4 – CADD to IPD case report

April 2012

Abbreviations:
AIA – Australian Institute of Architects
AMCA – Australian Mechanical Contractors Association
ARC – Australian Research Council
BEIIC – Built Environment Industry Innovation Council
IAI - International Alliance for Interoperability (now trading as buildingSMART)
IPD – integrated project delivery
PS – Project Services
QDPW – Queensland Department of Public Works
QUT – Queensland University of Technology
SBEnrc – Sustainable Built Environment National Research Centre
QTMR - Queensland Department of Transport and Main Roads
WAG – Western Australian Government

Authors
Dr Judy Kraatz
Professor Keith Hampson
Joe Campana

Project Number 2.7
Project Leader Professor Keith Hampson
Senior Research Fellow Dr Judy Kraatz
Status Final
Date 09/04/12

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1. Introduction

This report provides an overview of the qualitative research comprising three case studies undertaken as a part of the retrospective analysis component of Sustainable Built Environment National Research Centre (SBEnrc) Project 2.7 *Leveraging R&D investment for the Australian Built Environment*. These case studies (see Parts 2, 3 and 4 of this suite of reports) were undertaken to illustrate the nature of past R&D investments in Australia. This was done to complement: (i) the audit and analysis of past R&D investment undertaken by Thomas Barlow (2011); and (ii) the *Construction 2030* roadmap being developed by Swinburne University of Technology and Professor Göran Roos from VTT Technical Research Centre of Finland. These documents will be the basis for the final phase of the present project - developing policy guidelines for future R&D investment in the Australian built environment.

Case 1 – Road Construction Safety - Queensland Transport and Main Roads (QTMR) have taken a leadership role in developing a safer working environment for road construction workers. A range of initiatives have been introduced to contribute to improved performance in this area including: (i) the development and implementation of the *Mechanical Traffic Aid*; (ii) *Thermal Imaging Camera*; and (iii) *Trailer-based* CCTV (camera). A fourth initiative, the *Safety Leadership Training Program* is another major outcome of recent R&D activity. A brief outline of this initiative is provided in Part 2 of this suite of reports.

Case 2 – Green Buildings

The Western Australian Government (WAG) has taken a leadership role for a number of decades in developing *green buildings*. A significant contributor to this process was the formation of the Sustainable Policy Unit within the Department of Premier and Cabinet in 2003. Since that time, a number of initiatives have been introduced to contribute to: (i) greening the stock of government buildings; and (ii) providing leadership in the development of other non-residential buildings developed commercially.

Case 3 – CADD to IPD

This case study explored the evolution of project delivery which has occurred in Project Services (a division of the Queensland Department of Public Works - QDPW) in the last 20 years from: (i) initial implementation of *computer aided design and documentation (CADD)* in the mid-1980's; to the experimentation with *building information modelling (BIM)* from the mid 2000's; to current moves towards *integrated project delivery (IPD).*

2. Research Questions

These case studies in part address the research questions defined for this project:

RQ1: What are the success criteria and critical challenges which impact the industry's ability to realise benefit from R&D investment?

RQ2: What input into, and outcomes from, strategic foresighting and roadmapping are required in order to develop an R&D investment strategy?

RQ3: What policy directions and initiatives are required to promote the pathways identified in the strategic roadmap?

3. Research Methodology

The case study method has been used to undertake studies within three government agencies of innovative initiatives implemented in the past decade, to provide a qualitative understanding of the value of past R&D investment and to inform the next stage of this research project.

3.1. Case study themes

The selection of the case study themes has been made based upon an understanding of:

- where past investment is known to have occurred
- where sufficient knowledge and data exists in order to provide the basis for a comprehensive assessment
- where project partners have expressed an interest in investigating past investments, to learn lessons to better inform future investment and influence industry outcomes
- where an investment is representative of outcomes of the earlier audit and analysis activity

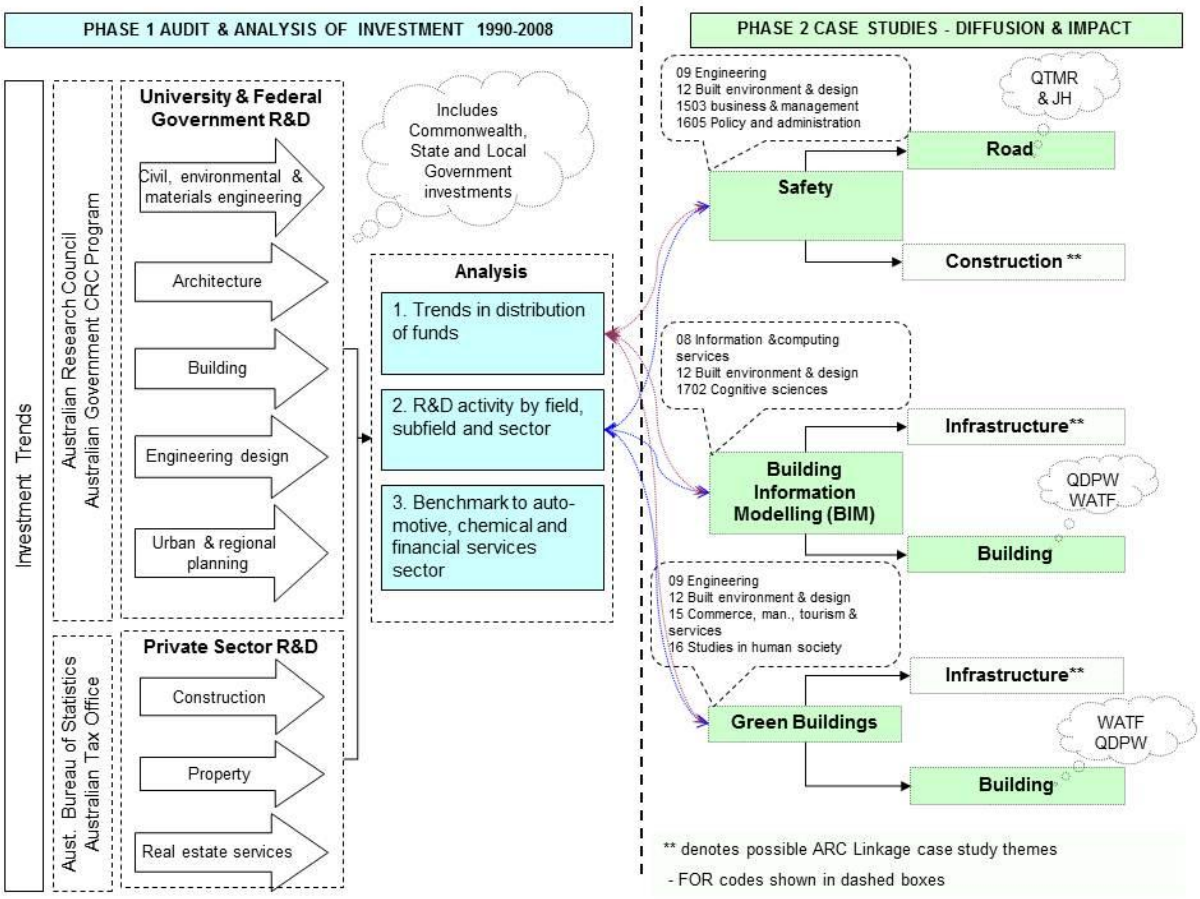
The three selected themes for investigation are:

- Case 1 – Road construction safety (RCS)
- Case 2 - Green buildings (GB)
- Case 3 – CADD to BIM to IPD (CADD IPD)

Construction 2020 (Hampson and Brandon, 2004) identified nine key visions for the future of this critical Australian industry. These three themes for these case studies directly reflect four of these visions (i.e. environmentally sustainable construction, welfare and improvement of the labour force, information and communications technologies for construction and virtual prototyping).

Figure 1 clarifies the links between the previous audit and analysis phase of this project and selected theme.

Figure 1 – Overview of selection



3.2. Case study method

Through targeted case studies, the current research seeks to illustrate the context for investments including:

- mechanisms and processes through which R&D was translated into practical outcomes
- drivers, successes and barriers to delivery of R&D outcomes
- organisational capabilities such as internal and external linkages

3.3. Theoretical framework

Reference is made to three areas of academic theory to contextualise gathered data and to position the research team to add to the body of knowledge in this field. These are: (i) dynamic capabilities; (ii) absorptive capacity; and (iii) open innovation.

Teece, Pisano and Shuen (1997) discuss *dynamic capabilities* 'as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments' (p.516). Criteria for providing evidence of an organisation's dynamic capabilities have been drawn from papers in this field including Lawson and Samson (2001), Teese and Pisano (1994), Eisenhardt and Martin (2000), and Davis and Walker (2009).

Cohen and Levinthal (1990) introduce the concept of *absorptive capacity* as a 'firm's ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends' (p.128). They argue that absorptive capacity is 'largely a function of prior related knowledge' (p.131) that has been accumulated through effort, as prior knowledge facilitates the assimilation of new knowledge. Zahra and George (2002) propose absorptive capacity is a dynamic capability and discuss four dimensions of this capability, namely: knowledge acquisition, assimilation, transformation and exploitation (p.186). These capabilities are represented as two complimentary yet distinctive subsets: (i) potential capacity as the firm's ability to acquire and assimilate knowledge, and (ii) realised capacity as the ability to transform and exploit knowledge. Key criteria which shed light on the absorptive capacity of an organisation have been drawn from key literature in this field. The following measures of absorptive capacity have been derived from Cohen and Levinthal (1990), Zahra and George (2002), Nieto and Quevedo (2005), Flatten et al. (2011).

Chesbrough (2004) defines the *open innovation* paradigm as assuming 'that firms can and should use external as well as internal ideas and internal and external paths to market, as they look to advance their technology. Open Innovation assumes that internal ideas can also be taken to market through external channels, outside a firms current businesses, to generate additional value (p.23). Chesbrough proposes that this increases the number of possible sources of innovation. This approach better enable an organisation to deal with the unknowable, and manage the risks associated with experimentation. Chesbrough et al. (2005) was used as the source for the *features* of 'open innovation' presented in these case reports. Huizingh (2011) was the source for the criteria used to illustrate the *nature* of open innovation exhibited in the delivery of initiatives. Categories of *factors resulting in benefit from innovation* for project and team have been drawn from Ling (2003). Bossink (2004) discusses an extensive array of *drivers for construction innovation*. These have been used to derive categories of drivers from the interviews, within each case study organisation.

Data from interviews was coded by the research team against criteria selected and developed from above papers to build an understanding of the organisational capabilities evident in the implementation of the focus initiatives (and highlighting those not evident which may contribute to enhanced outcomes in the future).

4. Data collection

Multiple sources of information were used to inform these case studies including: (i) meetings with key agency staff; (ii) project, program and organisational documentation (Section 7.1); (iii) formal face-to-face interviews; (iv) academic literature in the field; and (v) industry reports and presentations. The key source of data was the formal interviews.

4.1. Formal interviews

Data gathered, coded an analysed in these reports has been compiled from a series of formal interviews carried out from May to October 2011 with a duration of 30mins to 1 hour.

Interviewees were identified by the research team in conjunction with each agency. To ensure a cross-section of inputs and understandings to inform this research, interviewees from each of the following categories were targeted (Box 1).

Box 1

(i) Organisational executive – i.e. typically CEO or Director General.

(ii) Innovation champion – of the initiative with medium to long-term corporate knowledge if possible.

(iii) Project leader – responsible for overseeing the transition of the initiative into practice.

(iv) Implementer – involved in the day-to-day implementation of the initiative in practice.

(v) Supplier – external entity such as a software vendor, property agent taking facility to market.

(vi) Consultant – working with the lead agency to deliver project integrating the initiative.

(vii) Contractor – external entity working with the lead agency to deliver project integrating the initiative.

(viii) Industry representative – from a relevant industry association.

(ix) Allied agency – such as the client agency.

(x) Research representative – a researcher with a strong and active history in the field.

The coverage of 8-10 interviewees for each case was considered sufficient to uncover the key issues (Guest, Bunce et al., 2006). Table 1 details the break-down of these by category for each case.

Table 1 - Interviewees

Role	Case 1	Case 2	Case 3
Executive (internal)	1	1	1
Champion (internal)	1	-	1
Project Leader (internal)	1	1	1
Implementer (internal)	1	1	1
Allied Agency (internal)	2	2	-
Supplier (external)	2+	1	1
Contractor (external)	-	1	2
Consultant (external)	-	3	1
Industry Rep. (external)	1	1*	2
Researcher	1	2	1
	11	13	11

* Previously in WAG

\+ One supplier specific to safety leadership program – data not included in analysis for the 3 target initiatives.

Interview questions
Generic interview questions were:

1. In your opinion what were the main drivers for these initiatives undertaken by the agency?
2. Who drove this project?
3. From your perspective, who are the people responsible for delivering this initiative both strategically and at a project level?
4. Are you aware if these initiatives are a part of or the result of the agency's R&D activities?
5. Do you know of any external researchers involved in this initiative?
6. What was involved in implementing this initiative?
7. Were there any barriers to its successful implementation?
8. What new processes were required to implement this initiative?
9. Were there any cultural or values-based changes needed to implement this initiative?
10. Did the initiative need to be adjusted due to any major internal or external changes throughout its implementation?
11. What were these adaptations?
12. What was successful about this initiative (both processes and outcomes)?
13. What have been the impacts on (i) your supply chain and (ii) your industry?
14. Has this experience made you more or less likely to do research again?

The same researcher was responsible for all interviews within each case. Responses were documented within 24 hours of the meeting, and a transcript was prepared (all interviewees agreed to their interview being recorded)[1].

Interview data analysis
Thematic coding and analysis was undertaken of data gathered from interviews for each case study. This was a two-step process:

(i) The researcher established key themes based on an analysis of the interviewees' direct responses to each questions to identify drivers, barriers, successes and the like for each of the cases.

(ii) The researcher coded responses against criteria derived from dynamic capability, absorptive capacity and open innovation theory. The thematic grouping and coding was verified (via random sampling) by an alternate research team member to ensure the reliability and trustworthiness of the assessment.

5. Findings and discussion

Attention is drawn to each of the three case reports which along with this document make up the suite of research reports as outcomes of Project 2.7.

Section 5.1 provides a summary and brief analysis of the key themes identified from interview responses relating to drivers, barriers, successes and the like. Section 5.2 provides a brief analysis of the criteria coded by researchers from interview responses (see Section 7.2 for a detail breakdown)

[1] The valuable assistance of Anna Evers (WAG) in conducting the green buildings interviews is acknowledged.

5.1. Illustrating the cases

The following tables (Tables 2 to 10) provide a combined summary of the key themes which were identified in interview relating to the various drivers, implementation activities, new processes, impacts, success, barriers and R&D outcomes for each case.

Key drivers (Table 2) which emerged across the three case studies include: government drivers for change; enhancing best-practice in each specific field; increased efficiency; and making use of new tools and technologies.

Table 2 – Key drivers

Case 1 - RCS	Case 2 – GB	Case 3 – CADD IPD
Risks to workers & public	Right thing to do	Improved business outcomes
Safety – workers and vehicles	Reducing water & energy consumption	Production efficiency & outcomes
Current research projects	Rating schemes	Better communication & collaboration
Implementation of new technology	Industry awareness	New technology
Work operations & efficiency	Cost savings & economic benefits	Provide industry leadership
Government reports & initiatives	Gov. initiatives, policies & regulations	Stimulating & smart work environment

Implementation activities (Table 3) shared across the three cases include: developing new relevant skills; updating processes to align with innovations; and investing in relationships.

Table 3 - Key implementation activities

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Deployment & implement guidelines	Application to project life cycle	Incremental adoption / experimentation
Communication & stakeholder participation	Monitoring & quantifying benefits	Establish a shared vision & plan
Procurement requirements	Cultural alignment	Invest in technology & relationships
Alignment to Acts, regulations, policies & codes	Develop & apply new skills & processes	Patronage of executive management
Funding requirements	Develop a strategic approach	Training
Legal & privacy issues & implications	Relationship building	Updating processes & manuals
Staff education & training	Capacity building	Alliance with researchers

Table 4 highlights key processes across the three case studies. Those in common across the cases include: the need for training; better communications and collaboration (ranging from the public, stakeholders or within the delivery team); implementing new work practices and processes. Both the *green buildings* and *CADD to IPD* case studies also highlighted the need for broadening the delivery team to include the contractor.

Table 4 - Key processes

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Education & training	Aligning budget & requirements	**Current**
Communication within industry & public	Enhancing processes	Use & sharing of 3D & 4D models
Project management	Training	Enhanced collaboration
Work practices and guidelines	Use ratings tools, benchmarks & reporting mechanisms	Develop shared vision
MUTCD[2] & TRUM[3] updates	Embed in core values	**Required**
Traffic management & IT requirements	Leadership	New procurement methods & fee splits
Collaboration, coordination & stakeholder engagement	Collaboration, coordination & stakeholder management	New style of training
Governance & program management	Contractor involvement at early stage	Application tweaking
	Getting exemplar projects built	Embed in other business processes
		Workflow documentation
		Industry-wide data support/ conventions
		Rationalisation of standards
		Model server development & use
		Better identification of value
		Focus on what is needed to build

In terms of impacts on the values and culture of an organisation, the need for behavioural, work-practice and cultural change were apparent across all three cases (Table 5).

Table 5 - Impact on values and culture

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Cultural change program	Behavioural change	Move from engaging consultant to a consultancy team
Benefits of new technology	Breaking down silos	Change in contractor culture
Work site deployment; work patterns; contractor expertise	Getting triple bottom line (triple bottom line) benefits	Builders in design process/office
Build awareness & understanding through communications	Build awareness & understanding	New way of dealing with contracts & copyright
R&D initiative processes	Foresight	Change in business & delivery processes
Education & training	Dealing with change	Shared team values; greater trust
Budgets for new technology	Valuing sustainability 'aesthetic'	Use as design/doc. tool

Table 6 summarises impacts that are apparent across the supply chain. The need for integration of new skills and knowledge (and the implications thereof) were important in all three cases.

[2] QTMR Manual of Uniform Traffic Control Devices
[3] QTMR Queensland Traffic and Road Use Management Manual

Table 6 - Impact on supply chain and industry

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Shared knowledge	Improved knowledge & skills	Sharing models
Workforce & union implications	Better needs definition	Develop national BIM guidelines
Availability of technology locally	Recognition of commercial & competitive advantage	Changing relationships
Industry funding	Proof of concept achieved	Feedback loop to vendors & suppliers
Better site management		Improvement in upfront inefficiencies

For each of the cases major external changes impacted upon the implementation of initiatives (Table 7). This ranged from the implications of external report findings to changes in government to the impacts of changing technology (both hardware and software).

Table 7 - Major changes impacting on initiative

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Regs, Acts, codes, & policy updates	GFC – both positive & negative	Reduction in workload due to reconstruction
Implementation, deployment, process documents	Carbon tax discussion & move to green economy	CAD vendors pushing next-gen software
Training & education	Change in government	Stalling of enabling technologies
Funding for trials	Introduction of NABERS[4]	GFC focus on cost-effective delivery
Design changes	Commonwealth Government initiatives	Governments mandating use of BIM

Key successes (Table 8) were highlighted both: (i) within the organisation implementing the initiatives (improved safety, project outcomes, work environment and deliverables); and (ii) across the respective sectors (greater awareness of safety issues, access to consultants with relevant skills, and risk taking by government to improve sector-wide knowledge and outcomes).

Table 8 – Key successes

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Better risk identification & early warning system	Green outcomes embedded in budgets & projects	Department taking risk to introduce new methods to industry
Greater awareness within industry	Consultants on board	Clear vision & sticking to it
Changed driver behaviours	Better educated industry & market	Incremental change approach
Improved safety around work sites	Better understanding of issues	More effective delivery
	Better guidelines, tools, monitoring & reporting	Clearer communication, collaboration, honesty & openness
	Reduced resource consumption & costs	Green building outcomes
	Improvement in best practice	Model quality
		Better collaboration tools
		Motivated team

[4] NABERS is a performance-based rating system for existing buildings. NABERS rates a building on the basis of its measured operational impacts on the environment, and provides a simple indication of how well you are managing these environmental impacts compared with your peers and neighbours - see www.nabers.com.au.

A significant list of barriers were also identified (Table 9). These were more comprehensive for both the *green buildings* and *CADD to IPD.* This can be attributed to these initiatives having a longer history of development and being much more widespread in their implementation to date. The need for research to be focussed on practical and commercial outcomes was common across all three cases, as were business process and procurement-related issues; an entrenched resistance to change; improving awareness of initiatives and benefits (including political). The continuity in the knowledge base and resources were also highlighted as important in two of the three cases.

Table 9 – Key barriers

Case 1 - RCS	Case 2 - GB	Case 3 – CADD IPD
Lack of time & resources	Better budget setting & business case writing required	Indifference & lack of knowledge
Internal awareness of initiatives	Cost issues & perceptions	Building a shared vision
Speed of research	Whole of gov. leadership & mandate	Entrenched old business processes (esp. procurement)
Broad concerns over technology deployment	Lack of funding & split between agencies	Resistance to change
Internal delays; procurement requirements	Legislation & regulations outdated, lack of incentives & clarity	Vendor focus on graphics rather than workability & object data
Design & manufacturing issues	Industry resistance to change; capacity	Commercial realities
MUTCD[5] requirements	Adapting research to practicalities	Lack of political understanding of need
	Accounting & monitoring	Continuity of knowledge and support
	Loss of key people	Education & training to address gaps
	Lack of foresight; awareness/knowledge	Capable software & technology
	Management issues	
	Trade-based industry	

In relation to the interview questions regarding R&D engagement, Table 10 summarises the key issues identified from interviews. These questions related to: identifying if these initiatives are a part of current R&D activities; the involvement of external researchers; and the likelihood for future R&D engagement. The benefits and relationship to the industry are highlighted in each case study. Each agency involved in this research drew upon external R&D sources along with their own internal resources (both formal or informal).

Table 10 - R&D engagement

Case 1 - RCS	Case 2 - GB	Case 3 – CADD to IPD
Role of WHS Senior Advisor	Dept. funds university links	Proof of concept via informal process
Better tech. solutions & outcomes	R&D by other agencies, unis. & industry	Several formal R&D links
Benefits for industry	Several existing avenues in Gov.	Abundant underlying international R&D
Better innovation	Need to tailor benefits to practice & industry	Industry links via assoc., vendors & suppliers
Greater role for academics	Can be slow & costly	
R&D can increase safety	More required to maintain leadership	

[5] QTMR Manual of Uniform Traffic Control Devices

This knowledge, along with that gained from meetings and documents provided by each agency, has informed an understanding of the pathways each of the initiatives has undertaken. Each of the three case studies has undertaken different pathways to implement these initiatives.

Case 1 *Road construction safety* is characterised by a formal R&D process with a strong process focus through which three specific technology-based safety related trials have been undertaken, assessed and implemented (Figure 2).

Figure 2 – Road construction safety pathway

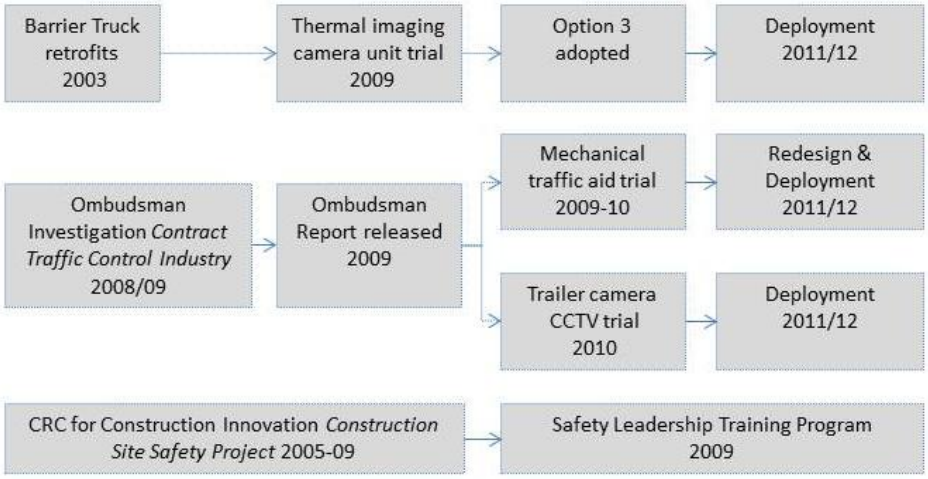


Figure 3 illustrates the pathway taken by the Western Australian Government in developing and implementing *green building* initiatives in that state. This included: both formal and informal R&D activities; a key investment in the formation of the Sustainable Policy Unit in 2003, along with an on-going focus on policy development, building external relationships and establishing targets for green outcomes in line with industry and community expectations.

Figure 3 – Green buildings pathway

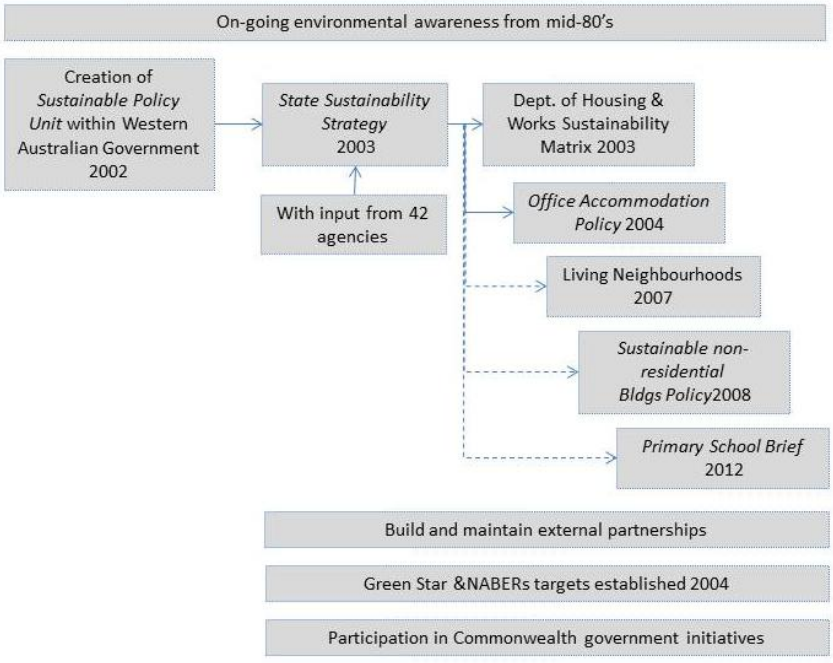
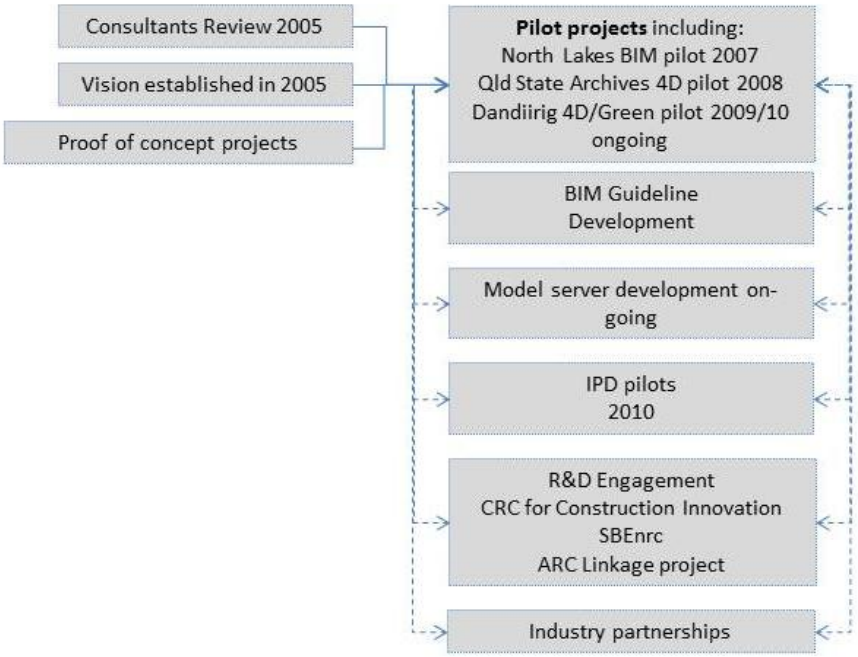


Figure 4 illustrates the recent steps taken by the Queensland Department of Public Works Division of Project Services in implementing initiatives which started in the mid 1980's around CADD, BIM and IPD. This has been characterised by: a highly motivated focus on developing more efficient delivery mechanisms through the use of new technology enablers, coupled with process change; and an informal and integrated R&D process including pilots. Leadership of and engagement with the supply chain throughout has been critical.

Figure 4 – CADD to IPD pathway



5.2. Understanding organisational capabilities through links to theory

This section provides an overview comparison of the data derived from interview, relevant to organisational capabilities. This information can be used to identify those organisational characteristics which are apparent in each agency, and may be enhancing delivery of initiatives. Table 11 provides a summary of the key capabilities most frequently coded by researchers from interviewees responses.

Table 11 – Summary of most frequently coded capabilities

Most frequently coded capabilities	Case 1	Case 2	Case 3
Product and process development	***	***	***
Organisational learning	***	***	***
Knowledge acquisition and exploitation	***	***	***
Outbound flows of knowledge	***	***	***
External R&D engagement	**	***	***
Abundant underlying knowledge landscape	***	**	***
Integrated and informal R&D function		***	***
Technology transfer	***		***
Capacity for technological development/ adoption from other sources	***	**	**
Internal R&D activity	***	**	**
Alliances (incl. programs promoting collaboration)	***	**	**

Most frequently coded capabilities	Case 1	Case 2	Case 3
Lateral communications structures	**	**	***
Strategic decision-making		**	***
Empowerment of innovation leaders &/or champions		**	***
Innovations from suppliers	**		***
Maximising use of technology	**		***
Customer/Client focus and involvement	***	**	
Industry push	***		**
New metric for assessing innovation		***	**
Decreasing risks	***		
Broad view of risk	***		
Coordination of innovation process (and participating groups)	**	**	**
Converting R&D into business value	**	**	**
Gov. clients with innovative demands	**	**	**
Product or service differentiation	**	**	
Economies of scale	**		**
Cost advantage through decreased waste		**	**
Mechanism for financial risk sharing and benefits	**		
Rise of innovation intermediaries		**	
Awareness of competitors' technologies	**		
Programs promoting access to technology	**		
High level of technical specialisation			**
Innovation stimulating regulation		**	
Coupled activities (incl. creation of knowledge networks)		**	
Financial benefits		**	
Effort put into cost reduction		**	
Access to new markets	**		
Financing pilot projects			**

*** Majority (i.e. >80%) of respondents mention issues related to these capabilities
** Several (i.e. >50% but <80%) respondents mention issues related to these capabilities

Table 12 shows those criteria for which there was little or no coding related to that particular capability. This may be due to a number of factors including: that this criterion is not relevant at a given time (e.g. the trial nature of the initiative); or that additional focus on this area may improve impact (e.g. market subsidies to support uptake).

Table 12 – Criteria least or not coded

	Case 1	Case 2	Case 3
Cost advantage through increased market intelligence	X	minority	X
Gov. guarantee for markets for innovative firms	X	some	X
Subsidies for innovative applications and materials	X	some	X
Product evaluating institutions	X	some	X
Non pecuniary inbound innovation	several	X	X
Proactive and nuanced role of IP	X	X	X

Note – 'X' indicates criteria not coded by researchers based on interviewee responses.

6. Conclusions

The analysis of these three illustrative industry case studies highlights:

1) different pathways available to agencies to implement innovation in specific fields
2) the importance of lateral communications structures with external organisations
3) the incremental nature of the implementation in each case
4) the coupled nature of both technology and process change
5) the need for practical and timely industry research
6) the need for on-going skills development

Each of these issues raises a series of further questions and challenges for future research including:

1) How can an organisation determine a better pathway to implement innovation?
2) How to most effectively and efficiently develop relationships with researchers and industry? (especially given current procurement practices for the latter)
3) How can industry accelerate the uptake of BIM to improve productivity?
4) How can government agencies and private businesses become more agile in business processes 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 a fragmented industry dominated by SMEs in the environment of on-going technological change?

7. Appendices

7.1. Case study documentation

Case 1 – Road construction safety

Documents provided by QTMR included:

- Brief for Decision: Funding Strategy for Safety Leadership Project. (2008)
- Application of Imaging and Recording Technologies as a method of early collision detection, incident reduction and evidence recording on-board Main Roads Barrier Trucks: Final Report. (2009)
- Application of Reversing Camera Technology aboard Main Roads mobile plant: Final Report. (2010)
- Research and development of new proximity technologies: Project Proposal. (2010)
- Stop-Think-Go: Communication and Action Plan. (2010)
- Trial application of LED Speed Indicating Device (SID) Signage at Road Works: Project Outline. (2010)
- Trial application of Trailer-Based CCTV systems and associated road signage: Project Outline. (2010)
- Zero Harm: Communication and Action Plan. (2010)
- Fatigue Glasses Trial: Project Plan. (2011)
- Mechanical Traffic Aid: Trial Report. (2011)
- Review and Implementation of Harmonised WHS Legislation for QTMR: Project Plan (Lite). (2011)
- Workplace Health and Safety Management System: Project Plan (Lite). (2011)

Case 2 – Green buildings

Documents provided by WAG included:

- Government Office Accommodation Guidelines
- details of quality criteria in tendering for buildings and architectural services
- Sustainable Non-Residential Buildings Policy (2008)
- Sustainable Non-Residential Government Buildings Guidelines
- Sunlight Design Guide (section)
- Energy Management in the Design of New Buildings (section)

Case 3 – CADD to IPD

Documents provided by QDPW included:

- Internal documentation was limited to the *Vision* diagram which was prepared in 2005, and has guided the direction of development since that time.
- A presentation prepared by Laing O'Rourke and Project Services '*extraordinary*' and presented at the 2007 buildingSMART conference
- The *National BIM Guidelines* – prepared by the CRC for Construction Innovation in conjunction with its national and international partners including QDPW Project Services

7.2. Links to theory

The following tables (Table 13 - Table 23) provide a more detailed break-down of the criteria as coded by researchers from interview responses.

Table 13 - Evidence of organisational dynamic capabilities

	Case 1 - RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Product or process development Organisational learning Customer focus Alliancing Technology transfer Internal R&D engagement	Product or process development Organisation learning External R&D engagement	Product & process development Organisational learning External R&D engagement Strategic decision-making Technology transfer
Several	External R&D engagement Product or service differentiation	Internal R&D engagement Product or service differentiation Cost advantage through less waste Strategic decision making	Internal R&D engagement Alliancing
Some	Strategic decision making	Technology transfer Alliancing Customer focus	Cost advantage through less waste Product/service differentiation
Minority		IP creation Cost advantage through increased market intelligence	IP creation Customer focus
None	Cost advantage through increased market intelligence Cost advantage through less waste IP creation		Cost advantage through increased market intelligence

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 14 - Evidence of inbound absorptive capacity

	Case 1 – RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Exploitation of knowledge Assimilation of knowledge into organisation Transfer of knowledge	Exploitation of knowledge Assimilation of knowledge into organisation Transfer of knowledge Knowledge acquisition from external sources Knowledge acquisition – internally generated	Exploitation of knowledge Assimilation of knowledge into organisation Transfer of knowledge Knowledge acquisition from external sources
Several	Knowledge acquisition – internally generated Knowledge acquisition from external sources		Knowledge acquisition – internally generated

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 15 - Measures of absorptive capacity

	Case 1 - RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Effort put into development of new products Staff skills - Investment in training Awareness of customer needs Capacity for tech. development		Effort put into development of new products
Several	Awareness of competitors' technologies Noteworthy economies of scale	Awareness of customer needs Effort put into development of new products Capacity for tech. development Effort put into cost reduction	Capacity to adapt technologies from other sources Noteworthy economies of scale Capacity for tech. development High level of tech. specialisation
Some	Range of staff training Capacity to adapt technologies from other sources	Staff skills - Investment in training Capacity to adapt technologies from other sources	Staff skills - Investment in training Awareness of customer needs Effort put into cost reduction
Minority	High level of tech. specialisation	High level of tech. specialisation Noteworthy economies of scale Range of staff training	Awareness of competitors' tech.
None	Effort put into cost reduction	Awareness of competitors' technologies	Range of staff training

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 16 - Features of open innovation

	Case 1 - RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Abundant underlying knowledge landscape Purposive outbound flows of knowledge & tech.	New metrics for assessing innovation capability and performance Purposive outbound flows of knowledge & tech.	Abundant underlying knowledge landscape Purposive outbound flows of knowledge & tech.
Several	Business model focus on converting R&D into commercial value Equal importance given to external knowledge, in comparison to internal knowledge	Business model focus on converting R&D into commercial value Abundant underlying knowledge landscape Rise of innovation intermediaries	Business model focus on converting R&D into commercial value New metrics for assessing innovation capability and performance
Some		Equal importance given to external knowledge, in comparison to internal knowledge	Equal importance given to external knowledge, in comparison to internal knowledge Rise of innovation intermediaries
None	Proactive and nuanced role of IP management Rise of innovation intermediaries New metrics for assessing innovation capability and performance	Proactive and nuanced role of IP management	Proactive and nuanced role of IP management

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 17 - Nature of open innovation - inbound innovation (internal use of external knowledge)

	Case 1 - RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Exploitation	Exploitation Knowledge Acquisition	Exploitation Knowledge Acquisition
Several	Outbound innovation (external exploitation of internal knowledge Retention Non-pecuniary Knowledge Acquisition	Outbound innovation (external exploitation of internal knowledge Retention Coupled activities	Outbound innovation (external exploitation of internal knowledge Retention
Some	Pecuniary criteria such as acquiring, sourcing, selling, and revealing		Coupled activities
Minority		Pecuniary such as acquiring, sourcing, selling, and revealing	
None	Coupled activities	Non-pecuniary	Non-pecuniary Pecuniary such as acquiring, sourcing, selling, and revealing

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 18 - Nature of open innovation - effectiveness

	Case 1 - RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Nonfinancial benefits Decreasing risks		Enhancing tech. effectiveness
Several	Enhancing technological effectiveness Access to new markets	Financial benefits	Number of innovations Less waste
Some	Less waste	Less waste Decreasing risks Lower costs Enhancing tech. effectiveness Access to new markets Stimulating growth	Financial benefits Decreasing risks Lower costs Nonfinancial benefits Access to new markets
Minority		Shorter time to market Other measures Number of innovations Nonfinancial benefits	Shorter time to market Other measures Stimulating growth
None	Shorter time to market Number of innovations Other measures Lower costs Stimulating growth Financial benefits		

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 19 - Categories of factors resulting benefit from innovation for project team and project

	Case 1 - RWS	Case 2 – GB	Case 3 – CADD to IPD
Majority	Working environment Level of interest of project team members Formation of task groups	Working environment	
Several	Capabilities of the people involved in the innovation	Capabilities of the people involved in the innovation Level of interest of project team members Formation of task groups	Capabilities of the people involved in the innovation Level of interest of project team members Working environment
Some			Formation of task groups

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 20 - Construction innovation drivers - environmental pressure

	Case 1 - RWS	Case 2 – GB	Case 3 – CADD to IPD
Majority	Market pull industry wide		
Several	Governmental clients with innovative demands	Governmental clients with innovative demands Innovation stimulating regulations	Governmental clients with innovative demands Market pull industry wide
Some	Innovation stimulating regulations	Market pull industry wide Government guarantee for markets for innovative firms Subsidies for innovative applications and materials	Innovation stimulating regulations
None	Government guarantee for markets for innovative firms Subsidies for innovative applications and materials		Government guarantee for markets for innovative firms Subsidies for innovative applications and materials

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 21 - Construction innovation drivers - technological capability

	Case 1 - RWS	Case 2 – GB	Case 3 – CADD to IPD
Majority			Tech. leadership strategy
Several	Programs promoting access to technology Tech. push		Finance the pilot projects
Some	Tech. leadership strategy Finance the pilot projects Technology fusion	Product evaluating institutions Finance the pilot projects	Tech. push
Minority		Programs promoting access to technology Tech. leadership strategy	Programs promoting access to technology Technology fusion
None	Product evaluating institutions	Technology fusion Technology push	Product evaluating institutions

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 22 - Construction innovation drivers - knowledge exchange

	Case 1 - RWS	Case 2 – GB	Case 3 – CADD to IPD
Majority	Training of workers on the site Stimulation of research Broad view of risk	Integrated & informal R & D function	Lateral communication structures Training of workers on the site
Several	Lateral communication structures	Lateral communication structures Stimulation of research Training of workers on the site Creation of knowledge networks Programs promoting collaboration	Integrated and informal R & D function Stimulation of research
Some	Effective information gathering Programs promoting collaboration Creation of knowledge networks	Effective information gathering	Effective information gathering Creation of knowledge networks
Minority		Broad view of risk	Programs promoting collaboration Broad view of risk
None	Integrated & informal R & D function		

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 23 - Construction innovation drivers - boundary spanning

	Case 1 – RWS	Case 2 - GB	Case 3 – CADD to IPD
Majority	Involvement of the client Strategic alliances in long-term relationships		Empowerment of innovation leaders Integration of design and build Innovations from suppliers
Several	Mechanisms sharing financial risks and benefits Explicit coordination of the innovation process Innovations from suppliers	Coordination of participating groups Explicit coordination of the innovation process Empowerment of innovation champions Empowerment of innovation leaders	Strategic alliances in long-term relationships Explicit coordination of the innovation process Empowerment of innovation champions
Some	Coordination of participating groups Integration of design and build	Strategic alliances in long-term relationships Integration of design and build Involvement of the client Innovations from suppliers	Coordination of participating groups Mechanisms sharing financial risks and benefits Involvement of the client – within organisation
Minority	Empowerment of innovation leaders Empowerment of innovation champions	Mechanisms sharing financial risks and benefits	

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20

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