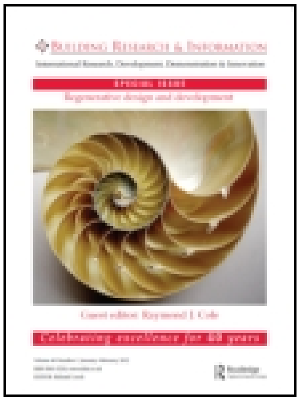

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Brokering innovation to better leverage R&D investment

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INFORMATION PAPER

Brokering innovation to better leverage R&D investment

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What is the contribution of innovation brokers in leveraging research and development (R&D) investment to enhance industry-wide capabilities? The case of the Australian Cooperative Research Centre for Construction Innovation (CRC CI) is considered in the context of motivating supply chain firms to improve their organizational capabilities in order to acquire, assimilate, transfer and exploit R&D outcomes to their advantage, and to create broader industry and national benefits. A previous audit and analysis has shown an increase in business R&D investment since 2001. The role of the CRC CI in contributing to growth in the absorptive capacity of the Australian construction industry as a whole is illustrated through two programmes: digital modelling/building information modelling (BIM) and construction site safety. Numerous positive outcomes in productivity, quality, improved safety and competitiveness were achieved between 2001 and 2009.

Keywords: construction industry, innovation, innovation brokers, research and development (R&D) investment, Australia

Quelle est la contribution des courtiers en innovation concernant l'exploitation des investissements en recherche et développement (R & D) pour renforcer les capacités dans l'ensemble du secteur ? Le cas du Centre de Recherche Coopérative Australienne pour l'Innovation dans le Bâtiment (CRC CI – Australian Cooperative Research Centre for Construction Innovation) est étudié dans le contexte de l'incitation des entreprises de la chaîne logistique à améliorer leurs capacités organisationnelles afin d'acquérir, assimiler, transférer et exploiter les résultats de la recherche et développement à leur avantage, et de créer des avantages plus larges au niveau de l'industrie et du pays. Une précédente analyse et audit a montré une augmentation des investissements de R & D des entreprises depuis 2001. Le rôle joué par le CRC CI dans l'augmentation de la capacité d'absorption de l'industrie australienne du bâtiment dans son ensemble est illustré par deux programmes : la modélisation numérique/modélisation des informations sur le bâtiment (BIM) et la sécurité sur les chantiers de construction. De nombreux résultats positifs en termes de productivité, de qualité, d'amélioration de la sécurité et de compétitivité ont été obtenus entre 2001 et 2009.

Mots clés: industrie du bâtiment, innovation, courtiers en innovation, investissements en recherche et développement (R & D), Australie

Introduction

Major challenges exist for the Australian construction industry (comprising the property, planning, design, construction and facility management supply chain) in effectively leveraging research and development (R&D) investment due to the disaggregated nature of this industry (Department of Industry, Innovation, Science and Research (DIISR), 1999); the predominance of small to medium-sized enterprises (SMEs) (the industry employs some 950 000 people through

250 000 firms); intense competition; a history of limited investment in R&D and new technologies; and a project-based culture focusing on short-term business cycles (Newton, Hampson, and Drogemuller, 2009).

There has been a substantial increase in private sector R&D investment in Australia between 1990 and 2008, especially since 2001. By 2008 Australian businesses were recorded as spending eight times as much on construction-related R&D as public institutions (Barlow, 2012, p. 4).[1]

Simultaneously, productivity in this sector continues to lag behind the rest of the economy (Allen Consulting Group, 2010). Understanding this shift in investment and mechanisms for translating this investment into enhanced performance is the subject of current paper. Investigation is focused on maximizing the benefit of R&D, with the intent of developing policy guidelines to assist both the private and the public sectors to maximize this investment.

This issue is addressed in connection with the contributory role of innovation brokers in motivating supply chain participants to better focus R&D investment and in turn boost the benefits of R&D to this industry. This is being considered in the context of the ability of an innovation broker to increase organizational capability in relation to the acquisition, assimilation, transformation and exploitation of external knowledge for enhanced competitive advantage (Zahra and George, 2002). The role of the Cooperative Research Centre for Construction Innovation (CRC CI) as a nationwide innovation broker in Australia is considered from 2001 to 2009 for maximizing outcomes of R&D expenditure. In 2009 the functions and activities of this organization transferred to the Australian Sustainable Built Environment National Research Centre (SBEnrc).

The paper is structured as follows. First, the nature of R&D investment trends in the Australia construction industry is highlighted. Second, the conceptual framework is outlined, addressing the role of innovation brokers in building the absorptive capacity of the industry. Third, the contribution of a key national innovation broker, the CRC CI, to amplify the impact of R&D investment on Australia's construction industry since 2001 is illustrated.

Background

DIISR (1999) illustrates the nature of this sector, highlighting the large number of players (Figure 1).

The Australian Expert Group on Industry Studies (Marceau, Hampson, and Manley, 1999) recognized this industry as a 'product system' as opposed to a cluster, complex or sector (Figure 2). This definition reflects both: (1) its reach into both services and

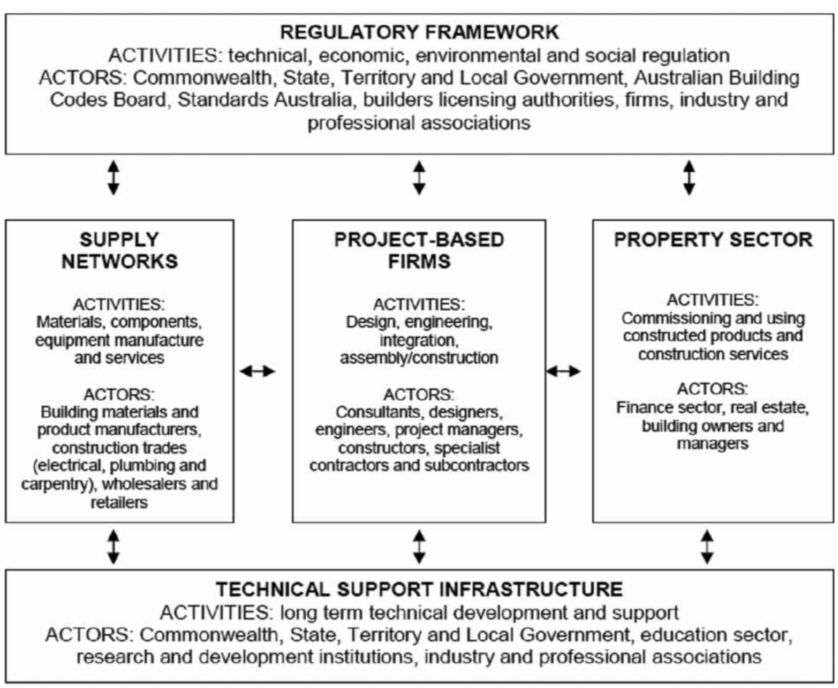

Figure 1 Building and construction industry cluster map. Source: Department of Industry, Innovation, Science and Research (DIISR) (1999), p. 10)

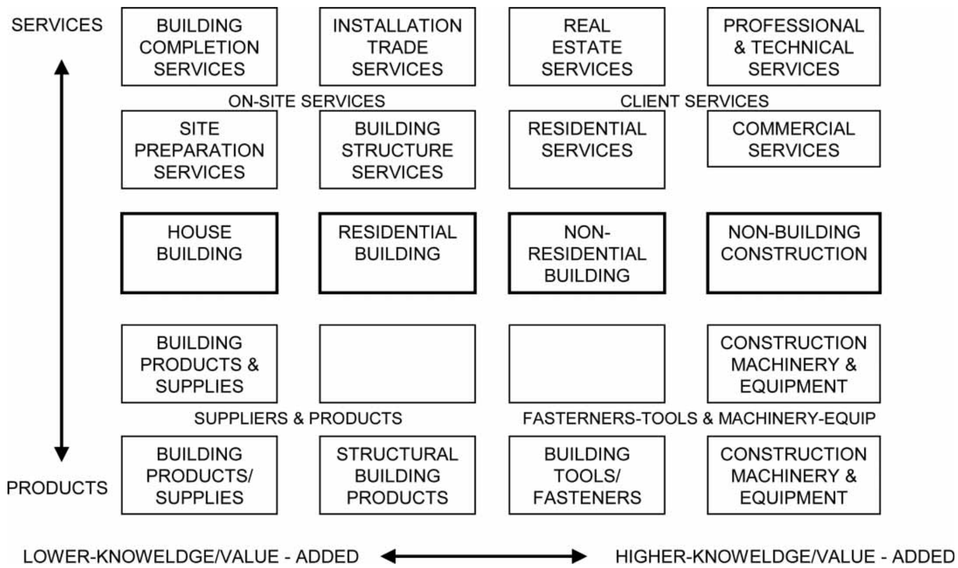

Figure 2 Map of the creation–production–distribution chain. Source: Marceau, Hampson, and Manley (1999), p. 37

manufacturing; and (2) the manner in which innovation in this system spans products, processes and services.

The Australian Royal Commission into the Building and Construction Industry report (Cole, 2003) highlights the complexity and interrelatedness of those involved in the Australian construction industry listing over 80 major employer and industry associations, organizations and unions. De Valence (2010) presents industry-related data demonstrating the need for an inclusive approach and identifies a number of distinct industry sectors within the product system (Table 1).

The cumulative value of this industry in Australia in 2008 was A$160 billion (Newton *et al.*, 2009), accounting for 14–20% of the national gross domestic product (GDP) (Furneaux, Hampson, Scuderi, and Kajewski, 2010).

Table 1 Australian building and construction sectors

Engineering	Road and bridge construction; electrical generation and transmission; water and sewerage; processing plants; miscellaneous including rail, harbours, recreational and pipelines
Non-residential building – private	Commercial offices; hotels, factories; shops; other including warehouses, terminals, service stations, car parks, telephone exchanges, etc.
Non-residential building – public	Educational; health; recreational

Source: Compiled from De Valence (2010), pp. 54–55.

In its 2010 report on productivity in the Australian construction industry (in the context of assessing the impacts of building information modelling), the Allen Consulting Group (2010) reported that:

> labour productivity in the construction sector has been growing, albeit at a slower rate than the aggregate productivity in Australia. (p. 6)

Additionally they highlight that productivity in:

> the rental, hiring and real estate services and professional, scientific and technical services sectors … has actually declined since early 2000, while overall productivity in Australia is growing. (p. 6)

Whilst Winch (2003) challenges the comparisons of the construction industry with other (*e.g.* manufacturing) sectors, Manley and Kajewski's (2011, p. 10) analysis of findings from a 2004 industry-wide survey reveal a focus on productivity improvement. These findings show just over half of the respondents reported the desire for efficiency and productivity improvements as a key driver for their innovation efforts. To address this issue of lagging productivity (whether perceived or actual), the Australian Procurement and Construction Council (APCC) and the Australian Construction Industry Forum (ACIF), together with the CRC CI identified and operationalized a set of national Key Performance Indicators (KPIs) to track productivity performance across the industry in 2007. The KPIs relate to: safety; productivity and competitiveness; economic security; workplace capability; and environmental sustainability/eco-efficiency. Maximizing outcomes and impacts of R&D investment in this industry is therefore both an industry-wide priority and a challenge due to its expansive nature, and poor track record to date in improving productivity. This paper addresses this issue by investigating the role of innovation brokerage in maximizing the outcomes of R&D investment.

Past R&D investment

Hampson and Manley (2001) highlight a downward trend in public sector investment in the Australian construction industry from 1992 to 1997 (Table 2).

Most recently Barlow (2012) identified a substantial increase in private sector investment between 1992 and 2008 (in particular since 2001) whilst the public sector investment continued to decrease as a percentage of total spending. In the early 1990s, Australian public institutions were spending nearly three times more on construction-related R&D than did Australian businesses. Yet by 2008, Australian businesses were spending eight times as much on construction-related R&D as public research institutions (Table 3). This trend has continued with an increase in overall investment of approximately 3.8% between 1992–1993 and 2008–2009.

Since 2001, R&D spending in the construction sector has been outperforming that of business as a whole (Figure 3). Note that Figure 3 compares construction

Table 2 Public sector research and development (R&D) expenditures in construction as a percentage of total R&D

Year	%
1992–1993	74.7
1994–1995	62.5
1996–1997	59.8

Sources: Derived from Marceau, Hampson, and Manley (1999), p. 61; and Hampson and Manley (2001)

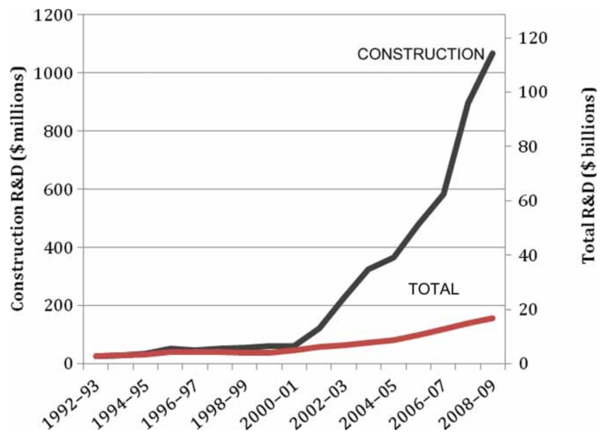

Figure 3 Growth in 'construction' research and development (R&D) relative to total business R&D. Source: Barlow (2012), p. 9. Note: (1) it is derived from ABS 8109; (2) it compares business R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total business R&D expenditures (right axis); and (3) the right axis has been adjusted so that the growth rates of both curves from 1992 are comparable

R&D expenditures (left axis) with total business R&D expenditures (right axis); the right axis has been adjusted so that the growth rates of both curves from 1992 are comparable.

It is important to note that a greater percentage of construction research is now being undertaken within the construction sector itself (as defined by ANZSIC 2006 classification scheme as used in ABS 8104). In 1992, 43% of this activity was performed outside the construction industry, while in 2008 this figure had dropped to 17% (Table 4).

Figure 4 contrasts growth patterns in three sectors of the construction industry with those of three relevant manufacturing sectors. It highlights the fact that the most rapid growth has occurred in the building construction and heavy and civil engineering construction

Table 3 National research and development (R&D) trends in construction

	Business R&D		Public R&D	
	A$	As a percentage of Australian business total	A$	As a percentage of the Australian public total
1992–1993	27 million	0.9	78 million	2.2
2008–2009	1.12 billion	6.5	136 million	1.2
2009–2010	1.13 billion	6.8	Not yet available	

Note: (1) Values are derived from ABS 8112 and ABS 8104; (2) the table shows R&D expenditures by sector focused on the socio-economic objective (SOE) 'construction'; (3) 'Public R&D' counts R&D from the university sector and from state and federal government agencies; and (4) dollar values are shown in current terms, *i.e.* without the use of multipliers to account for inflation.
Source: Barlow (2012), p. 4.

Table 4 Business research and development (R&D) trends in construction

	Socio-economic objective: construction		Industrial sector: construction industry	
	Current A$	As a percentage of the Australian business total	Current A$	As a percentage of the Australian business total
1992	27 million	0.9	15 million	0.5
2008	1.13 billion	6.8	977 million	5.9

Note: (1) Values are derived from ABS 8104; and (2) the table shows Australian business R&D expenditures focused on the socio-economic objective 'construction' and reported by the construction industry.
Source: Barlow (2012), p. 10.

sectors. This disparity in growth between these and the construction services sector also raises additional questions for future investigation.

This shift in R&D investment from government funding to private sector funding in the past decade may reflect an underlying growing self-awareness and research confidence within the construction industry. An improved understanding of the conditions generating these changes and any associated underlying structural adjustments is important to inform future R&D investment and its management and dissemination to ensure maximum impact.

Conceptual framework

Winch (2005) discusses the construction industry as a player in a 'low-velocity innovation game'. Four emerging themes identified by Winch include the relative importance of: (1) 'roadmap research' (rather than 'the search for new technologies'); (2) clients as the key stakeholders in the innovation process; (3) 'the importance of working in networks' (as facilitated by innovation brokers in this industry); and (4) the 'relative unimportance of universities as the sources of new ideas' (pp. 85–86).

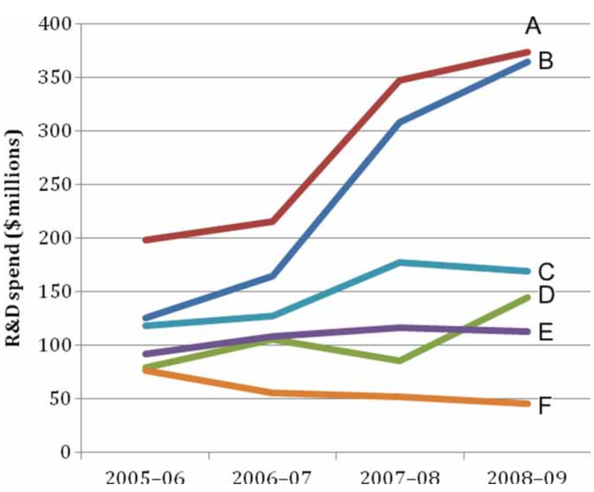

Figure 4 Research and development (R&D) growth trends by industry sector. Source: Barlow (2012), p. 25. Note: (1) it is also derived from ABS 8104: A = heavy and civil engineering construction; B = building construction; C = fabricated metal product manufacturing; D = construction services; E = non-metallic mineral product manufacturing; and F = wood product manufacturing

Côté and Miller (2012) contribute to a further clarification of the relevant nature of innovation, being incremental and that which is undertaken in a mature market where sustaining competitive advantage is a driver. The authors propose that in this environment:

> customers call upon 'experts' to help them develop innovative projects that redefine the state of the art. (p. 9)

CRC CI aimed to provide an environment in which partner organizations (and consequently their suppliers) were able to leverage their R&D investment. CRC CI delivery strategies were closely aligned with the first three of the themes identified by Winch (2005).

Winch (2005) defines construction industry-focused innovation brokers as organizations 'acting as a member of a network of firms' focused on 'enabling other organisations to innovate' (p. 91). Winch and Courtney (2007) further state that brokers play a key role 'facilitating diffusion' (p. 747). From the point of view of the absorptive capacity, the role played by an innovation broker may be examined in terms of the improvement of those capabilities which enable an organization:

> to recognise the value of new, external information, assimilate it, and apply it to commercial ends. (p. 128)

Zahra and George (2002) further extend this idea by highlighting the distinction between potential capacity (*i.e.* the firm's ability to acquire and assimilate knowledge – inbound absorptive capacity), and realized capacity defined as 'the ability to transform and exploit knowledge'. The latter is especially important to the capacity to create competitive advantage.

Spithoven, Clarysse, and Knockaert (2010) explore the role of construction-related collective research centres in Belgium and their role in enhancing the absorptive capacity of SMEs in that country. They conclude that such intermediary organizations do make a contribution to the ability of organizations to benefit from new knowledge through undertaking functions such as knowledge intelligence, agency and repository (through activities such as gatekeeping, roadmapping, establishing technical libraries and the like). By fulfilling these functions, 'the collective research centres absorb knowledge from the external environment' and adapt it to members' needs (p. 139).

Manley and Kajewski (2011) report findings from a 2004 Australian industry-wide survey which demonstrates both knowledge and human resource strategies were of key importance to the industry. These approaches suggest that the Australian industry has been actively growing organizational capacity in relation to the acquisition and exploitation of knowledge throughout the past decade (in order to build their competitive advantage). This aligns with previously highlighted evidence from Barlow (2012) regarding the growth in business R&D in this sector in Australia.

Brokering innovation

The present paper adopts Zahra and George's (2002) conception of the four capabilities (and associated components) of absorptive capacity: acquisition, assimilation, transformation and exploitation. Key influences on organizational ability to acquire knowledge are 'intensity, speed, and direction' (p. 189). In terms of assimilation, an organization's routines and processes are vital if an organization is to benefit from external sources of knowledge (p. 189). Transformation is an organization's:

> capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge. (p. 190)

And finally, exploitation is examined as a capability based on the routines that allow firms to refine, extend and leverage existing competencies or to create new ones by incorporating 'newly acquired and transformed knowledge' into its operations (p. 190).

Further to this, Winch (2005) highlights some of the important characteristics of innovation brokers which contribute to their effectiveness in the low-velocity innovation environment of the construction industry. These include: 'the ability to integrate across networks' (p. 86); 'providing a neutral space' (p. 87); being an intermediary between the source of innovation (*e.g.* the research partner) and the implementers (*e.g.* the industry partner) (p. 91); providing objective validation (p. 91); and assisting in the diffusion of research findings and outcomes (p. 91).

Based on this conception, the following narrative provides a series of examples from projects delivered through the CRC CI between 2001 and 2009 to illustrate how the innovation broker contributed to the acquisition, assimilation, transfer and exploitation of knowledge in organizations within the Australian construction industry.

CRC CI as innovation broker

This collaboration brought together 28 industry, government and research partners from across Australia with an initial A$14 million contribution from the Australian government; A$10 million in cash contributions from the participating organizations; and a further A$40 million in in-kind support (as reported in annual reports) from over 400 individuals (Hampson, Messer, and Manley, 2007). Prior to its formal establishment in 2001, a nascent and active set of relationships existed between researchers and industry across Australia.[2] Additionally throughout the 1990s a series of national initiatives and investigations were focusing on the performance of the building and construction industry. Impetus for the CRC CI joint venture came from two key sources. The first was from the Australian government's 'Building for Growth' Action Agenda, which aimed to enhance the long-term competitive advantage of Australian businesses. The second was from the momentum and experience gained through a research collaboration undertaken on the design and construction of the National Museum of Australia on the Acton Peninsular (Canberra, ACT, Australia).

An important feature of the CRC CI was the appointment of both industry and research partners to lead each of the three research programmes to ensure:

> that national collaboration and industry focus was encouraged and maintained throughout the research and implementation phases. (Hampson *et al.*, 2007, p. 3)

These Research Program Directors and Deputy Directors, along with the Chair of the Research Committee, formed the Research Leadership Team which in conjunction with the Research Committee reported to the CRC CI Board on research policy, strategy and planning, as well as undertaking reviews and evaluations of the project and programme outcomes (CRC CI, 2005, p. 8). Manley and Thorburn (1997, p. 10) discuss such research interactions and emphasize that 'innovation becomes a team effort' as all aspects of product generation, production and marketing are tackled together (Rimens, 1996, p. 24, cited in Manley and Thorburn, 1997, p. 11). Schiele and Krummaker (2011) note the importance of: (1) opportunities for knowledge transfer by bringing academics and practitioners together as co-researchers; and (2) that such collaboration provides the opportunity for meta-discourse to arise between both parties, thus enhancing the richness of the experience. CRC CI projects were required to have the active engagement of at least two industry partners and at least two research partners to ensure academic rigor and practical application for the industry as well as to encourage collaboration.

Winch (2005) draws further attention to the importance of translating knowledge acquired through such networks as best-practice exemplars into business-as-usual practice. He notes the role of organizational absorptive capacity in achieving this, as a result of 'their greater ability to learn and implement new ideas' (p. 95). This capacity was developed both within partner organizations, and more broadly through active liaison with a range of industry associations.[3]

The following two examples illustrate how the CRC CI acted as an innovation broker. Its contribution was through enhancing partner organizations' (and their suppliers') mechanisms for the acquisition, assimilation, transfer and exploitation of knowledge. Examples have been drawn from two themes: (1) digital modelling and building information modelling (BIM); and (2) construction site safety.

Digital modelling and BIM

In line with a central vision to increase industry productivity, several projects addressed the issue of improving productivity through the use of digital modelling and BIM. Table 5 presents activities aligned with Zahra and George's (2002) capabilities and components by way of demonstrating the CRC CI's role

Table 5 Digital modelling and building information modelling (BIM)

Capability	Component	Example
Acquisition	Intensity, speed and direction	Demonstrated through several projects, including: • Benchmarking Information and Communication Technology Uptake & Integration (2002) • Life Cycle Modelling and Design Knowledge Development in Virtual Environments (2001–2004) • Sydney Opera House – FM Exemplar Project (2005–2006) • Off-Site Manufacture in Australia (2006–2007) • Business Drivers for BIM (2006–2007) • National BIM Guidelines & Case Studies (2007–2008)
Assimilation	Routines and processes enabling organizations to analyse, process, interpret and understand information	Engagement with partners for alpha and beta testing products; development of business processes alongside software, including: • LCADesign^{TM} (Life Cycle Analysis of Design) – a tool to enable informed decision-making on the environmental impact of buildings from three-dimensional (3D) computer-aided design (CAD) drawings • DesignCheck – a tool to allow quick and easy compliance assessment against building codes through interrogating 3D CAD drawings
Transformation	Develop and refine routines to combine existing and new knowledge	Application of pilot projects with partner organizations and case studies, including: • National Guidelines for Digital Modelling (Cooperative Research Centre for Construction Innovation (CRC CI), 2009a) – an overview of the effect of BIM on current working practices; what is needed to move to a model-based environment; and recommendations and guidelines for model creation
Exploitation	Routines enabling firm to refine, extend and leverage existing capabilities	Examples of integration into partner work practices, *e.g.* CRC CI (2009b): • North Lakes Police Station (2008) – Queensland Department of Public Works used BIM for multidisciplinary sharing of information internally, and with a steel fabricator • 1 Bligh Street (completed 2011) – a major commercial project to implement multidisciplinary BIM and the first BIM project for ARUPs services engineer's team following early advice from the CRC CI

as an innovation broker contributing to industry capabilities.

To illustrate this further, the CRC CI's Sydney Opera House FM Exemplar project, led by Rider Hunt and the Facility Management Association of Australia (FMA), provides a key example. Its intent was to deliver an integrated solution for Australia's facilities management (FM) sector across strategic, management and operational levels. Project activity occurred in the context of a suite of projects related to information and communication technology (ICT) and BIM. The acquisition and assimilation of knowledge occurred though the active engagement of industry partners and research partners. Knowledge transfer was achieved through the Australian government's Facilities Management Action Agenda; FMA, and CRC CI publications and workshops. Exploitation of this knowledge is demonstrated in the *National Guidelines for Digital Modelling* (CRC CI, 2009a, 2009b) which includes six case studies projects from across Australia.

Key recommendations from this project included: the ratification of draft BIM standards; liaison with government agencies and industry management and collaboration processes required for BIM-related FM implementation; and working with suppliers and contractors to develop more appropriate procurement systems (CRC CI, 2007a, p. 18). Outcomes included the publication of: (1) *FM as a Business Enabler* (CRC CI, 2007b) demonstrating innovative methods for improving FM performance, aligning services and performance objectives; and (2) *Adopting BIM for Facilities Management: Solutions for Managing the Sydney Opera House* (CRC CI, 2007c) demonstrating the application of ICT and BIM; the benefits of digitizing design documentation and operational and maintenance manuals. The latter document also included a strategy for the Sydney Opera House's future adoption of BIM. Findings were disseminated to 300 attendees of FM industry conferences (organized by the CRC CI) in November 2006, and to many thousands more since through conferences, and industry and academic publications. Knowledge processes and tools developed in the course of this project have been used by the Sydney Opera House to demonstrate to its stakeholders that effectiveness in its FM services portfolio could be enhanced (CRC CI, 2006a, p. 13).

The impact of this research can be evidenced through industry recognition. One example is winning awards including the 2007 FMA Rider Hunt – Terotech Industry Achievement Award for advancing facility management strategy and practice. The BIM component of the project also featured in two international awards: the Jury's Choice Category of the American Institute of Architects, Technology in Architectural Practice 2007 awards; and the Bentley Awards for Excellence 2007 Award for BIM in Multiple Disciplines. This research is acknowledged globally as a milestone project in demonstrating the value of BIM to an existing (and highly complex) building.

Construction site safety

Workplace fatalities in Australia's construction industry cost the nation A\$3.6 billion each year. Research also shows that 20–24 year olds in the building and construction industry are four times more likely to have a fatal accident than those in other industries (John Holland and Cooperative Research Centre for Construction Innovation (CRC CI), 2010, p. 2). Between 2004 and 2009, the CRC CI led health and safety-based research projects in an effort to address this critical national issue.

Table 6 provides examples of activities of this innovation broker in line with Zahra and George's (2002) capabilities and components of absorptive capacity.

To illustrate the reach of the brokerage activities, the Construction Safety Competency Framework project had significant involvement (via focus groups, interviews and surveys) with 14 contractors; the Australian Constructors Association (ACA); the Australian Council of Trade Unions (ACTU); the Construction, Forestry, Mining and Energy Union (CFMEU); and State and Territory safety regulators. This framework identifies the critical safety management tasks required to improve site safety. Implementation is occurring nationally, in collaboration with industry and with the Office of the Federal Safety Commissioner through the development of toolkits and safety effectiveness indicators.

This project supported a second, Safer Construction, delivered in collaboration with the Engineers Australia-convened Safer Construction Taskforce and peak national associations for clients, designers and constructors, resulting in the publication of an industry-wide best-practice guide. The aim of this taskforce was the reduction of construction workplace accidents through the creation of a voluntary national practice guide (CRC CI, 2006a, p. 19).

These projects have thus had a broad impact and been implemented in organizations including John Holland, Queensland Transport and Main Roads (QTMR), Bovis Lend Lease, Joss Group, and Laing O'Rourke with approximately 14 000 construction workers undertaking safety training based on the CRC CI framework. Exploitation of this newly created knowledge is evidenced by partners developing and enhancing their own unique safety frameworks. John Holland, for example, has used the outcomes of the Construction Site Safety Project to enhance its Passport to

Table 6 Construction site safety

Capability	Component	Example
Acquisition	Intensity, speed and direction	Demonstrated through several projects, including: • Construction Site Safety Culture (2004–2006) • Guide to Best Practice for Safer Construction (2006–2007) • Safety Effectiveness Indicators (2007–2009)
Assimilation	Routines and processes enabling an organization to analyse, process, interpret and understand information	Development in conjunction with industry and researchers of the: • Construction Site Safety Competency Framework (CRC CI, 2006b) • Guide to Best Practice for Safer Construction (2007)
Transformation	Develop and refine routines to combine existing and new knowledge	For example, the development of: • A Practical Guide to Safety Leadership (2008) – a tool to help safety professionals apply the principles of safety culture within their organizations. It examines safety-critical positions and management tasks; combines practical examples and case studies to help identify behaviours and attitudes which need improvement
Exploitation	Routines enabling a firm to refine, extend and leverage existing capabilities	Integration into partner work practices, *e.g.*: • John Holland in the Passport to Safety Excellence Program and the Certificate IV in Safety Leadership (OHS) – Construction • QTMR in its Zero Harm Safety Program

Safety Excellence Program. Around 3000 people have attended the programme, contributing to a decrease in workers' compensation claims from 20 claims per 1000 workers in 2003 to fewer than four claims per 1000 workers in 2009–2010 for that organization (SBEnrc, 2010).

Whilst the initial project partners were primarily large organizations, SMEs have clear benefits from this research due to the 'ripple effect' that is apparent in the Australia's construction industry. Training programmes implemented by many large construction companies have also been rolled out to subcontractors. For example, John Holland requires many of its subcontractors to undertake its Passport to Safety Excellence Program based on the Construction Safety Competency Framework; and the NSW [New South Wales] Road and Transport Authority, Melbourne Airport, and Brisbane City Council all specified in their tender documents that training on the Construction Safety Competency Framework is required (SBEnrc, 2010, p. 16). Through such mechanisms the capacity and safety performance of the industry as a whole is thus enhanced.

Contributory role in enhancing R&D performance

Zahra and George (2002) provide a model which connects 'antecedents, moderators and outcomes' of construction to underline both external sources of knowledge and experiences that impact an organization's capabilities and that act as triggers for improvement. This model is adapted here, and overlaid with Schiele and Krummaker's (2011) concept of consortium research, illustrating the opportunity for meta-discourse (p. 1143) (Figure 5). Interaction between industry and researchers was a key aim of the CRC CI (Dewulf and Noorderhaven, 2011) facilitated through the active role of both realms in both governance and project decision-making.

By building on a rich pre-existing network of interactions, CRC CI was able to respond to key issues affecting R&D performance and productivity growth in the Australian construction industry. This contribution was done through:

- establishing a cohesive network of partners
- aligning private industry, public sector and research partners to develop research projects, manage and deliver research outcomes
- establishing an industry-supported roadmap for R&D investment, *i.e.* Construction 2020 (Hampson and Brandon 2004)
- establishing an intensive program of R&D projects in line with this roadmap
- developing tools aligned with business processes
- demonstrating links between existing and best-practice tools, methods and processes
- demonstrating how today's best-practice can become tomorrow's business as usual

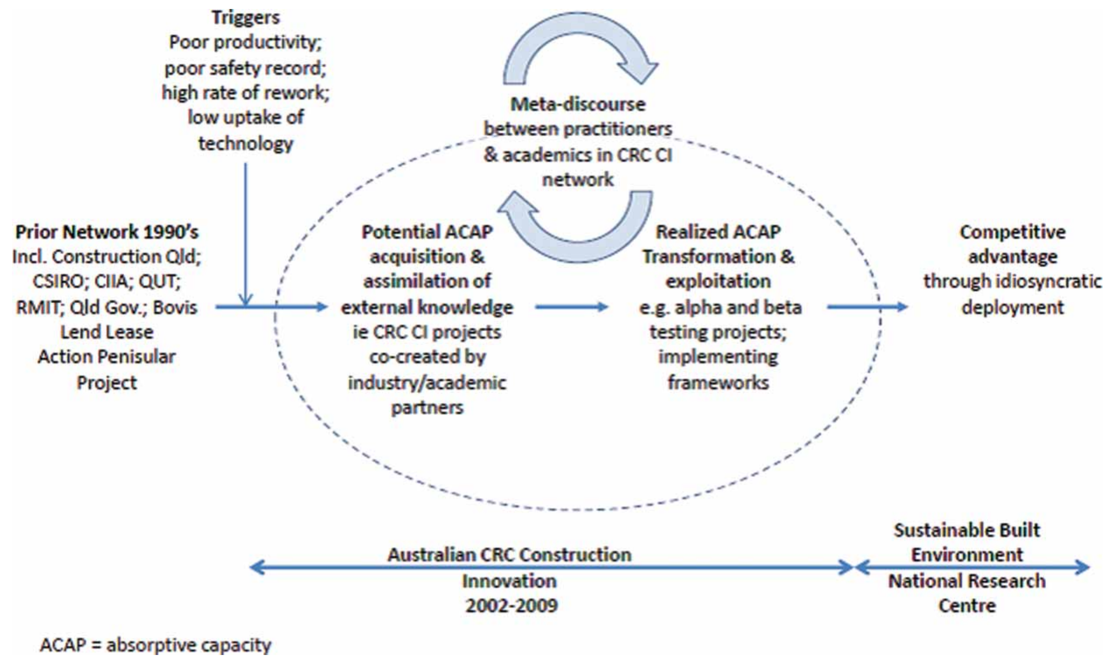

Figure 5 Contributory role in enhancing research and development (R&D) performance. Source: adapted from Zahra and George (2002)

Tangible examples of the benefits of CRC CI's role as an innovation broker are detailed in CRC CI (2009c). Some examples of benefits include: (1) the attendance of 2000 people at four international conferences convened by the CRC CI; (2) 40 industry publications providing benefit to the broader industry supply chain; and (3) project outcomes (such as Safer Construction and National BIM Guidelines) providing direct benefit through practical guidelines for clients throughout the procurement process. The intangible benefits of developing a supply chain innovation network across Australia and internationally has also been anecdotally confirmed as one of the positive and lasting outcomes of the CRC CI.

Conclusions

A significant shift in R&D investment has occurred in the Australian construction sector in the past decade. The specific focus was the role of a national innovation broker, the CRC CI. The formation of the CRC CI in 2001 paralleled this growth in construction industry-based investment. The case for the activities of the CRC CI contributing to this growth in investment has been illustrated by the growth in the context of growing industry-wide capabilities. These activities built upon an existing network of R&D collaborations from the 1990s, creating a focused environment in which practitioner and researcher could contribute to targeted outcomes of benefit to the industry. This in turn has facilitated increased involvement in the process of R&D and enhanced the uptake of research outcomes through the formal dissemination of research outcomes to project partners and to broader industry through the establishment of a stronger innovation network, publications, seminars, and changes in industry standards and associated training.

Further empirical study is required to determine the extent of the contribution by the innovation broker, alongside other possible contributory factors including: regulatory changes in R&D tax concessions in Australia since 2001 (Manley and Kajewski, 2011, p. 6); an increase in demand relating to the resources boom, increasing urbanization, uptake of ICTs, and growth in 'green' construction; and possible market failure around the ability of traditional public research mechanisms to deliver value to the private sector (Manley and Kajewski, 2011). Further research is being undertaken that will look more explicitly at investment in this industry, based on case studies of past investments and a national survey of industry participants to build understanding of the: (1) underlying conditions for this shift in investment; and (2) the impact of R&D investments since 2001.

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Endnotes

[1]Figures are based on Australian Bureau of Statistics data for the construction industry, which include the: building construction; civil and heavy engineering construction; and construction services sectors.

[2]This network included the Queensland University of Technology/Commonwealth Scientific and Industrial Research Organisation (CSIRO) Construction Research Alliance; Construction Queensland; CSIRO; the Construction Industry Institute of Australia (CIIA); the Royal Melbourne Institute of Technology (RMIT); the Queensland government; and Bovis Lend Lease.

[3]These include: the Australian Sustainable Built Environment Council (ASBEC); the Australian Construction Industry Forum (ACIF); the Australian Contractors Association (ACA); Engineers Australia; the Royal Australian Institute of Architects; the Facility Management Institute of Australia; and the International Association for Interoperability (IAI now buildingSMART) (CRC CI, 2005, p. 15).