

Brokering innovation to better leverage R&D investment

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Abstract

The aim of this research is to investigate the contributory role of innovation brokers in leveraging R&D investment to enhance industry-wide capabilities. The case of the Australian CRC for Construction Innovation is examined in the context of an organisation's ability to acquire, assimilate, transfer and exploit R&D outcomes to their advantage, and for broader industry and national benefit.

The research builds on an audit analysis of past R&D investment commissioned by the research team, which highlights an increase in business investment in the industry since 2001. This parallels the activities of the CRC for Construction Innovation. Researchers examine the relationship between the two in the context of the latter's contribution to growth in the absorptive capacity of the Australian construction industry as a whole. This paper thus highlights the tangible benefits to industry and researchers of collaborative research partnerships.

The researchers acknowledge this is one contribution to growth in construction industry R&D since 2001 and that further empirical investigation is required to fully understand conditions contributing to this increase.

Keywords: Construction industry, Australia, Innovation, Collaboration, R&D investment, CRC for Construction Innovation, Sustainable Built Environment National Research Centre

1. Introduction

Major challenges exist for the Australian construction industry (comprising the property, planning, design, construction and facility management supply chain) in effectively leveraging R&D investment due to: the disaggregated nature of this industry (DIISR, 1999); the predominance of small to medium sized enterprises (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 focussing on short-term business cycles (Newton, et al., 2009).

SBEncr and Barlow (2011) report a substantial increase in private sector R&D investment in Australia between 1990 and 2008, especially since 2001. He notes that by 2008 Australian businesses are recorded as spending eight times as much on construction-related R&D as public institutions (p.4) (based on Australian Bureau of Statistics data for the construction industry, which includes the: building construction; civil and heavy engineering construction; and construction services sectors).

Simultaneously, productivity in this sector continues to lag that of 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 research. Investigation is focussed on the maximising the benefit of R&D, with the intent of developing policy guidelines to assist both the private and public sectors to maximise this investment.

This paper addresses this issue in connection to 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

organisational capability in relation to the acquisition, assimilation, transformation and exploitation of external knowledge for enhanced competitive advantage (Zahra and George, 2002).

Firstly, this paper highlights the nature of R&D investment trends in the Australia construction industry (SBEnrc and Barlow, 2011). Secondly, the conceptual framework for this research is outlined, addressing the role of innovation brokers in building the absorptive capacity of the industry (Winch, (2005), Winch and Courtney, (2007), Schiele and Krummaker, (2011)). Finally, a key national innovation broker and its contribution to amplifying the impact of R&D investment on Australia's construction industry since 2001 are analysed. In conclusion, the paper highlights further areas for ongoing investigation to build the empirical basis for further understanding R&D investment in this industry.

2. Background

The Australian Department of Innovation, Industry, Science and Research (DIISR, 1999) illustrates the nature of this sector highlighting the large number of players (Figure 1).

Figure 1 here

The Australian Expert Group on Industry Studies (Manceau et al., 1999) recognised this industry as a 'product system' as opposed to a cluster, complex or sector (Figure 2). This definition reflects both: (i) its reach into both services and manufacturing; and (ii) the manner in which innovation in this system spans products, processes and services.

Figure 2 here

The Australian Royal Commission into the Building and Construction Industry report (Cole, 2003) highlights the complexity and inter-relatedness of those involved in the Australian construction industry listing over 80 major employer and industry associations, organisations 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).

Table 1 here

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 GDP (Furneaux, et al., 2010).

In their 2010 report productivity in the Australian construction industry (in the context of assessing the impacts of building information modelling) the Allen Consulting Group report 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 (manufacturing) sectors, Manley and Kajewski (2011, p.10) analysis of findings from a 2004 industry-wide survey reveal a focus on productivity improvement. These findings reveal just over one 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 for Construction Innovation identified and operationalised 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. Maximising 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 through investigating the role of innovation brokerage in maximising the outcomes of R&D investment.

2.1. Past R&D investment

An analysis of past R&D investment in Australia from 1990 to 2008 underpins this research. Hampson and Manley (2001) highlight a downward trend in public-sector investment in the construction industry from 1992 to 1997 (Table 2).

Table 2 here

Most recently SBEnc and Barlow (2011) 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 Australian businesses did. 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 1992-93 and 2008-09.

Table 3 here

Further to this R&D spend in the construction sector since 2001 has been outperforming that of business as a whole (Figure 3). Note that this diagram compares construction R&D expenditures (left axis) with total business R&D expenditures (right axis), with the right axis has been adjusted so that the growth-rates of both curves from 1992 are comparable.

Figure 3 here

Important in the context of this paper is that a greater percentage of construction research is now being undertaken within the construction sector itself. In 1992, 43% of this activity was performed outside the construction industry, while in 2008 this figure had dropped to 17% (Table 4).

Table 4 here

Figure 4 contrasts growth patterns in three sectors of the construction industry with that of three relevant manufacturing sectors. This figure highlights that the most rapid growth has occurred in the building construction and heavy and civil engineering construction sectors. This disparity in growth between these and the construction services sector also raises additional questions for future investigation.

Figure 4 here

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.

3. The 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: (i) 'roadmap research' (rather than 'the search for new technologies'); (ii) clients as the key stakeholders in the innovation process; (iii) 'the importance of working in networks' (as facilitated by innovation brokers in this industry); and (iv) the 'relative unimportance of universities as the sources of new ideas' (pp.85-86).

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).

This paper discusses how a key innovation broker, the Cooperative Research Centre for Construction Innovation (CRC CI) has filled this role and contributed to this increase in construction-based R&D investment since 2001 by providing an environment in which partner organisations (and consequently their suppliers) were able to leverage their R&D investment. CRC CI delivery

strategies closely aligned with the first three of the themes identified by Winch (2005).

Winch (2005) defines construction industry focussed innovation brokers as organisations 'acting as a member of a network of firms' focussed 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 organisation '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 through highlighting the distinction between potential capacity, that is, 'the firm's ability to acquire and assimilate knowledge (i.e. inbound absorptive capacity), and realised capacity defined as 'the ability to transform and exploit knowledge', the latter being especially important to the capacity to create competitive advantage.

Spithoven et al., 2010 explore the role of construction-related collective research centres in Belgium and their role in enhancing the absorptive capacity of small and medium enterprises (SMEs) in that country. They conclude that such intermediary organisations do make a contribution to the ability of organisations 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). Through 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 the importance of both knowledge and human resource strategies were of key importance to the industry. These

approaches suggest that the Australian industry has been actively growing organisational 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 SBEnrc and Barlow (2011) regarding the growth in business R&D in this sector in Australia.

It is in this context that this paper seeks to highlight tangible links between the contributory role of innovation brokers in building the absorptive capacity of an industry dominated by fragmentation. The authors examine the role of the CRC CI as a nation-wide innovation broker from 2001 to 2009 (when the functions and activities of this organisation transferred to the Australian Sustainable Built Environment National Research Centre (SBEnrc)). They also acknowledge that further empirical study is required to determine the extent of this contribution, 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 urbanisation, uptake of information and communications technologies (ICT) enabled design and delivery, 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, p.11).

4. Brokering innovation

Zahra and George's (2002) conception of the four capabilities (and associated components) of absorptive capacity, namely: acquisition, assimilation, transformation and exploitation, is being used in the present research. These authors highlight 'intensity, speed, and direction' (p.189) as influencing organisational abilities to acquire knowledge. In terms of assimilation, they

consider an organisation's routines and processes as important in allowing the organisation to benefit from external sources of knowledge (p.189). Transformation is discussed as an organisation'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: (i) '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 demonstrate how the innovation broker contributed to the acquisition, assimilation, transfer and exploitation of knowledge in organisations within the Australian construction industry.

4.1. The CRC for Construction Innovation as innovation broker

This collaboration brought together 28 industry, government and research partners from across Australia with an initial \$14M contribution from the Australian Government; \$10M in cash contributions from the participating organisations; and a further \$40M 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. This network included the Queensland University of Technology/CSIRO Construction Research Alliance, Construction Queensland, Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Construction Industry Institute of Australia (CIIA), Royal Melbourne Institute of Technology (RMIT), the Queensland Government, and Bovis Lend Lease. Additionally throughout the 1990's a series of national initiatives and investigations were focussing 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, Australia).

An important feature of the CRC CI was the appointment of both industry and research partners to lead each of the three research programs, 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 program outcomes (CRC CI, 2005, p.8). Manley & Thorburn (1997, p.10) discuss such research interactions and emphasise that 'innovation becomes a team effort' as all aspects of product generation,

production and marketing are tackled together (Rimens, 1996, p.24, in Manley and Thorburn, 1997, p.11). Schiele and Krummaker (2011) note the importance of: (i) opportunities for knowledge transfer through bringing academics and practitioners together as co-researchers; and (ii) 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 and at least two research partners to ensure: both academic rigor; practical application for the industry; and 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 organisational 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 organisations, and more broadly through active liaison with a range of industry associations including: 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).

The following illustrates how the CRC CI, as an innovation broker, contributed to this process through enhancing mechanisms for the acquisition, assimilation, transfer and exploitation of knowledge for partner organisations (and their suppliers). Examples have been drawn from two themes: (i) digital modelling and building information modelling (BIM); and (ii) construction site safety.

4.2. 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 modeling 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 as an innovation broker contributing to industry capabilities.

Table 5 here

To further illustrate this, 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 ICT and BIM. The acquisition and assimilation of knowledge occurred through 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 Modeling* (CRC CI, 2009a & b) 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: (i) *FM as a*

Business Enabler (CRC CI., 2007b) demonstrating innovative methods for improving FM performance, aligning services and performance objectives; and (ii) *Adopting BIM for Facilities Management: Solutions for Managing the Sydney Opera House* (CRC CI, 2007c) demonstrating the: application of ICT and BIM; benefits of digitising design documentation and operational and maintenance manuals; and including a strategy for the Sydney Opera House's future adoption of BIM. Findings were disseminated to 300 attendees of FM industry conferences (organised 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 their FM services portfolio could be enhanced (CRC CI, 2006a, p.13).

The impact of this research is evidenced through industry recognition winning 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.

4.3. Construction site safety

Workplace fatalities in Australia's construction industry cost the nation \$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 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.

Table 6 here

To demonstrate 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 being to reduce construction workplace accidents by creating a voluntary national practice guide (CRC CI, 2006a, p.19).

These projects have thus had a broad impact and been implemented in organisations 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 in its exploitation by partners in 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 Safety Excellence Program. Around 3,000 people have attended the Program, contributing to a decrease in Workers Compensation Claims from 20 claims per 1,000 workers in 2003 to less than 4 claims per 1,000 workers in 2009-10 (SBEnc, 2010).

Whilst the initial project partners were primarily large organisations, small-to-medium enterprises (SMEs) have clear benefits from this research due to the “ripple effect” that is apparent in the Australia’s construction industry. Training programs 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 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 (SBEnc, 2010, p.16). Through such mechanisms the capacity and safety performance of the industry as a whole is thus enhanced.

4.4. 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 organisation’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.

Figure 5 here

Through 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:

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

Tangible examples of the benefits of CRC CI's role as an innovation broker are detailed in the *CRC CI Exit Report* (2009c). Examples of benefits include: (i) attendance at four international conferences convened by the CRC CI by two thousand people; (ii) 40 industry publications providing benefit to the broader industry supply chain; and (iii) 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 for Construction Innovation.

5. Conclusions and further research

This paper highlights a significant shift in R&D investment in the Australian construction sector in the past decade. Given the fragmented nature of this industry coupled with low productivity, specific attention needs to be paid to how such investment can be better leveraged to maximise the outcomes and impacts of such investment.

The specific focus of this paper was the role of a national innovation broker, the CRC for Construction Innovation. The formation of CRC CI in 2001 paralleled this growth in construction industry based investment. The case for the activities of CRC CI contributing to this growth in investment has been examined in the context of growing industry-wide capabilities. A case has been presented that these activities built upon an existing network of R&D collaborations from the 1990's, creating a focussed 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 both project partners, and to the broader industry through establishment of a stronger innovation network, publications, seminars and changes in industry standards and associated training.

The authors acknowledge that further empirical data gathering and analysis is required to better understand this trend and the implications for R&D investment in the construction industry. Several other issues (including changes to the R&D tax concessions, and/or demand-side drivers for investment) may

also have contributed to this change. To this end, further research is being undertaken which 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: (i) underlying conditions for this shift in investment; and (ii) impact of R&D investments since 2001.

6. References:

Allen Consulting Group (2010). *Productivity on the building network: Assessing the impacts of building information models*. Melbourne: Built Environment Industry Innovation Council.

Cohen, W.M., & Levinthal, D. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35 (1), 128-152.

Cole, T.R.H. (2003). *Australian Royal Commission into the building and construction industry*. Canberra: Australian Government.

Côté, M., & Miller R.E. (2012). *Stimulating Innovation: Is Canada Pursuing the Right Policies?* Available at SSRN: <http://ssrn.com/abstract=2057923> or <http://dx.doi.org/10.2139/ssrn.2057923>

CRC for Construction Innovation (CRC CI) (2005). *Annual report 2004-05*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2006a). *Annual report 2005-06*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2006b). *A construction safety competency framework*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2007a) *Annual Report 2006-07*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2007b). *FM as a Business Enabler*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2007c). *Adopting BIM for facilities management: Solutions for managing the Sydney Opera House*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2009a). *National guidelines for digital modelling*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2009b). *National guidelines for digital modelling: Case studies*. Brisbane: CRC for Construction Innovation.

CRC for Construction Innovation (CRC CI) (2009c). *Exit Report*. Brisbane: CRC for Construction Innovation.

De Valence, G. (2010). Defining an industry: What is the size and scope of the Australian building and construction industry?, *Australasian Journal of Construction Economics and Building*, 10 (1/2), 53-65.

Dewulf, G. (2011). *Managing public-private innovation programs: Lessons from the Netherlands, the United Kingdom and Australia*. Amsterdam: PSIBouw.

Department of Industry, Innovation, Science and Research (DIISR) (1999). *Building for growth: an analysis of the Australian building and construction industries*. Canberra: Commonwealth of Australia,.

Furneaux, C.W., Hampson, K.D., Scuderi, P., & Kajewski, S.L. (2010). Australian construction industry KPIs. In *CIB World Congress Proceedings – Building a Better World* (pp. 1-12). Salford Quays: CIB.

Hampson, K.D. & Brandon, P. (2004), *Construction 2020: A vision for Australia's property and construction industry*. Brisbane: CRC for Construction Innovation.

Hampson, K.D. & Manley, K. (2001). Construction Innovation and Public Policy in Australia. In G. S. Manseau, A. & Seadon, G.S. (Eds): *Innovation in*

Construction: An International Review of Public Policies (pp.31-59). Abington: Spon Press.

Hampson, K.D., Messer, D. & Manley, K. (2007). *Driving Collaboration and Innovation in Australian Property and Construction*. Unpublished manuscript.

John Holland & CRC for Construction Innovation (CRC CI) (2010). *Working towards a safer construction industry*. Brisbane: Sustainable Built Environment National Research Centre.

Manley, K. & Kajewski, S. (2011). Innovation in context: A case study of the Australian context. In De Valence, G. (Ed.), *Modern Construction Economics: Theory and Application* (pp. 135-153). Abington: Spon Press.

Manley, K. & Thorburn, L. (1997). *The Role of the Research System In 'Learning Economies'*. Canberra: Pro-Vice-Chancellor Research Subcommittee of the Australian Vice-Chancellors' Committee.

Marceau, J., Hampson, K.D. & Manley, K.(1999). *Mapping the building and construction product system in Australia*. Sydney: Australian Expert Group on Industry Studies (AEGIS).

Newton, P., Hampson, K.D. & Drogemuller, R. (2009). *Technology, Design and Process Innovation in the Built Environment*. Abingdon: Taylor and Francis.

Schiele, H. & Krummaker, S. (2011). Consortium benchmarking: Collaborative academic–practitioner case study research, *Journal of Business Research*, 64 (10), 1137-1145. doi:10.1016/j.jbusres.2010.11.007.

Spithoven, A., Clarysse, B., a&nd Knockaert, M. (2010). Building absorptive capacity to organize inbound open innovation in traditional industries. *Technovation*, 30(2), 130-141. doi:10.1016/j.technovation.2009.08.004.

Sustainable Built Environment National Research Centre (SBEnrc) (2010). *Working towards a safer construction industry*. Brisbane: SBEnrc.

Sustainable Built Environment National Research Centre (SBEnc) and Barlow, T. (2011). *The built environment sector in Australia R&D investment study: 1992-2008*. Brisbane: SBEnc.

Winch, G. (2003). How innovative is construction? Comparing aggregated data on construction innovation and other sectors – a case of apples and pears. *Construction Management and Economics*, 21(6), 651 - 654. doi: 10.1080/0144619032000113708.

Winch, G. (2005). Managing complex connective processes: innovation broking. In Manseau, A. & Shields, R. (Eds): *Building Tomorrow: Innovation in Construction and Engineering* (pp. 81-100). London: Ashgate Publishing Limited.

Winch, G.M. & Courtney, R. (2007). The organization of innovation brokers: An international review. *Technology Analysis & Strategic Management*, 19 (6), 747-763. doi: 10.1080/09537320701711223.

Zahra, S.A. & George, G. (2002). Absorptive capacity: A review, reconceptualisation and extension. *Academy of Management Review*, 27 (2), 185-203. doi:10.5465/AMR.2002.6587995.

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Figure 1 - Building and construction industry cluster map (DIISR, 1999, p.10)

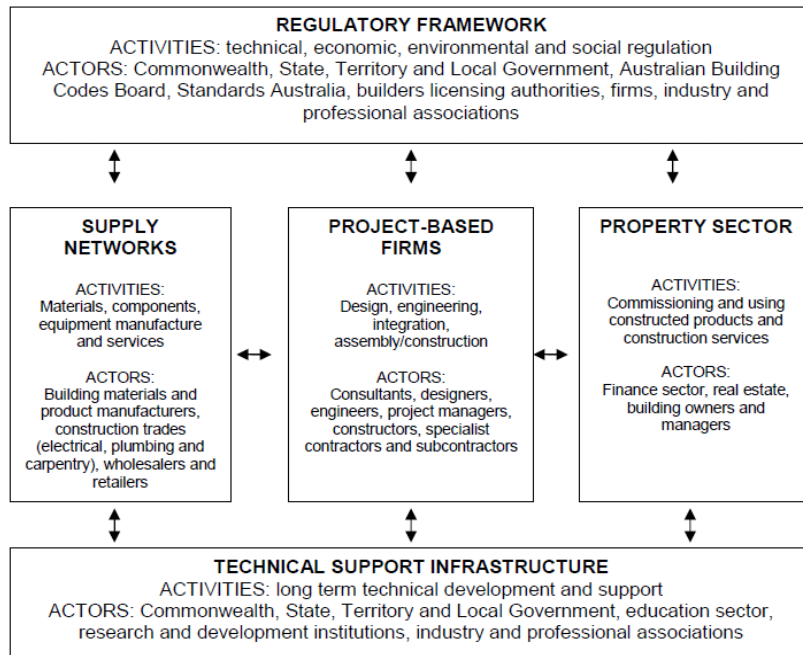


Figure 2 - Map of the creation-production-distribution chain (Marceau et al., 1999, p.37)

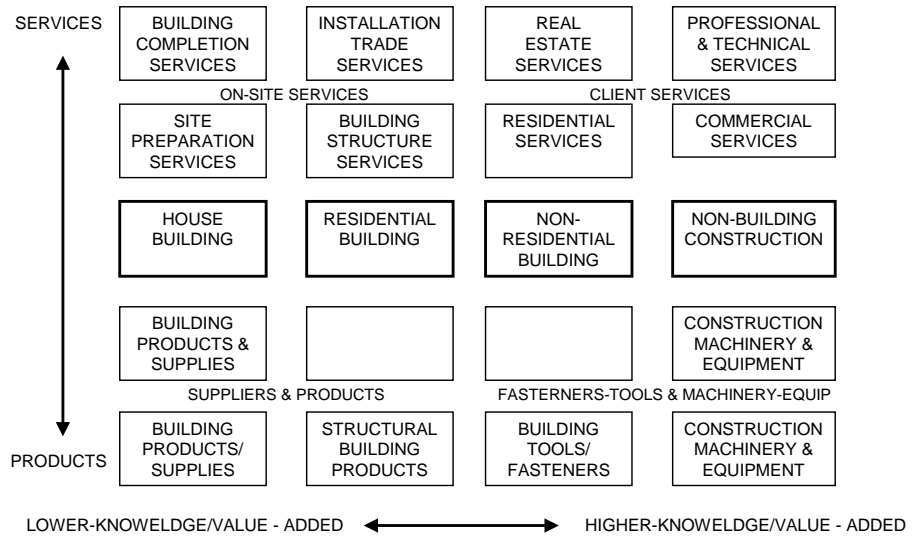


Table 1 - Australian building and construction sectors (Compiled from de Valence, 2010, pp. 54-55)

Engineering	Road and bridge construction; electrical generation and transmission; water and sewerage; processing plants; miscellaneous including rail, harbours, recreational & 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

Table 2 - Public sector R&D expenditures in construction as % of total R&D
(Hampson & Manley, 2001)

Year	%
1992-93	74.7
1994-95	62.5
1996-97	59.8

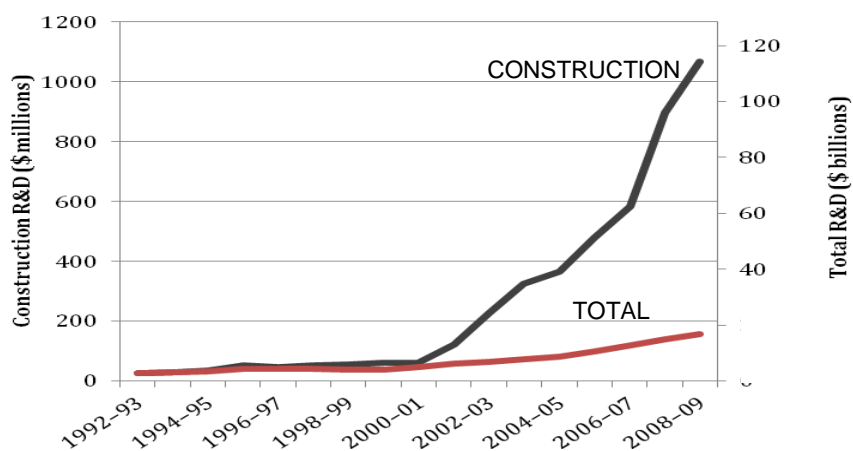
Note: derived from Marceau et al. 1999:61

Table 3 - National R&D trends in construction (SBEnrc and Barlow, 2011, p. 4)

	Business R&D		Public R&D	
	\$	% of total	Aus. business	As % of total
1992-93	27 million	0.9%		2.2%
2008-09	1.07 billion	6.3%		1.2%

Note: (i) Derived from ABS 8112. (ii) Shows R&D expenditures by sector focused on the socio-economic objective (SOE) 'construction'. (iii) 'Public R&D' counts R&D from the university sector and from state and federal government agencies. (iv) Dollar values are shown in current terms – i.e. without the use of multipliers to account for inflation.

Figure 3 - Growth in 'construction' R&D relative to total business R&D (SBEnrc and Barlow, 2011, p. 9)



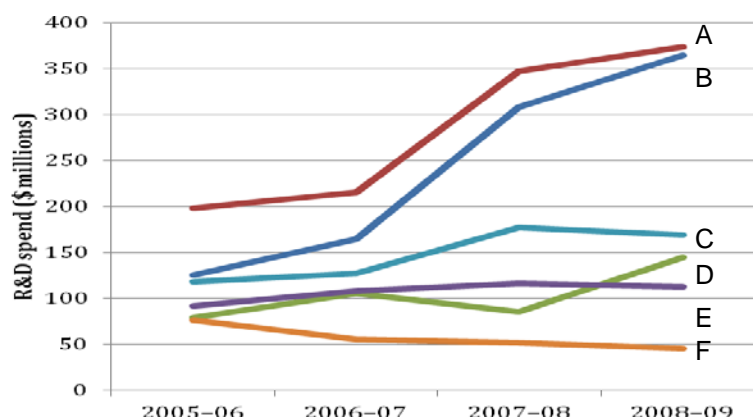
Note: (i) Derived from ABS 8109. (ii) Compares business R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total business R&D expenditures (right axis). (iii) The right axis has been adjusted so that the growth-rates of both curves from 1992 are comparable.

Table 4 - Business R&D trends in construction (SBEnc and Barlow, 2011, p. 10)

	Socio-economic objective: construction		Industrial sector: Construction industry	
	Current \$	As % of Aus. business total	Current \$	As % of Aus. business total
1992	\$27 million	0.9%	\$15 million	0.5%
2008	\$1.07 billion	6.3%	\$882 million	5.2%

Note: (i) Derived from ABS 8104. (ii) Shows Australian business R&D expenditures focused on the socio-economic objective 'construction' and reported by the construction industry.

Figure 4 – R&D growth trends by industry sector (SBEnc and Barlow, 2011, p.25)



Note: (i) Derived from ABS 8104 and SBEnc & Barlow, 2011.

- A – Heavy and civil engineering construction
- B - Building construction
- C – Fabricated metal product manufacturing
- D – Construction services
- E – Non-metallic mineral product manufacturing
- F – wood product manufacturing

Table 5 – Digital modelling and BIM

Capability	Component	Example
Acquisition	Intensity, speed, and direction	Demonstrated through several projects including: <ul style="list-style-type: none"> – <i>Benchmarking Information and Communication Technology Uptake & Integration</i> (2002) – <i>Life Cycle Modelling and Design Knowledge Development in Virtual Environments</i> (2001-2004) – <i>Sydney Opera House - FM Exemplar Project</i> (2005-06) – <i>Off-Site Manufacture in Australia</i> (2006-07) – <i>Business Drivers for BIM</i> (2006-07) – <i>National BIM Guidelines & Case Studies</i> (2007-08)
Assimilation	Routines & processes enabling organisations to analyse, process, interpret & understand information	Engagement with partners for alpha & beta testing products; development of business processes along-side software including: <ul style="list-style-type: none"> – <i>LCADesign™ (Life Cycle Analysis of Design)</i> – a tool to enable informed decision-making on the environmental impact of buildings from 3D CAD drawings. – <i>DesignCheck</i> - 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 & new knowledge	Application on pilot projects with partner organisations and case studies including: <ul style="list-style-type: none"> – <i>National Guidelines for Digital Modelling (CRC CI 2009a)</i> – 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 & leverage existing capabilities	Examples of integration into partner work practices for example (CRC CI 2009b): <ul style="list-style-type: none"> – <i>North Lakes Police Station (2008)</i> – Queensland Department of Public Works used BIM for multi-disciplinary sharing of information internally, and with steel fabricator. – <i>1 Bligh Street (completed 2011)</i> – major commercial project to implement multi-disciplinary BIM and first BIM project for ARUPs services engineer's team following early advice from CRC CI.

Table 6 – Construction site safety

Capability	Component	Example
Acquisition	Intensity, speed, and direction	Demonstrated through several projects including: <ul style="list-style-type: none"> – <i>Construction Site Safety Culture</i> (2004-06) – <i>Guide to Best Practice for Safer Construction</i> (2006-07) – <i>Safety Effectiveness Indicators</i> (2007-09)
Assimilation	Routines and processes enabling organisation to analyse, process, interpret & understand information	Development in conjunction with industry and researchers of the: <ul style="list-style-type: none"> – <i>Construction Site Safety Competency Framework</i> (2006) – <i>Guide to Best Practice for Safer Construction</i> (2007)
Transformation	Develop and refine routines to combine existing & new knowledge	For example the development of: <ul style="list-style-type: none"> – <i>A Practical Guide to Safety Leadership</i> (2008) – a tool to help safety professionals apply the principles of safety culture within their organisations. 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 firm to refine, extend & leverage existing capabilities	Integration into partner work practices, for example: <ul style="list-style-type: none"> – John Holland in the <i>Passport to Safety Excellence Program</i> and the <i>Certificate IV in Safety Leadership (OHS) – Construction</i> – QTMR in their <i>Zero Harm Safety Program</i>

Figure 5 – Contributory role in enhancing R&D performance (adapted from Zahra and George 2002)

