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The Potential Contribution of Small Firms to Innovation in the Built Environment

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ABSTRACT

The methods by which small firms overcome the disadvantages of their size to implement innovation on construction projects are examined here through five case studies. It is found that such methods include working with advanced clients, prioritising relationship-building strategies and using patents to protect intellectual property. Key obstacles to innovation implementation by small firms on construction projects are found to be bias in the allocation of government business assistance and regulatory inefficiencies under federal systems of government. The study's findings derive from a theoretical framework which emphasises firm capabilities and environment, and innovation typologies. Further research is recommended into the impact of government assistance and regulation on small innovative construction firms.

Keywords: technology innovation, construction industry, small firms, open innovation, Australia

The innovation performance of the construction industry has been the subject of much criticism by academics, policy makers and practitioners, especially over the past 10 years. Such criticism and the subsequent search for solutions has been most obvious in the UK, with investigations such as the Egan Inquiry (1998) prompting a range of related studies in the UK and in other countries. Nevertheless, progress has been slow globally, such that the industry is still perceived to be underperforming. In recent academic comparisons of innovation activity across different sectors of the economy, construction underperforms significantly compared to manufacturing (Reichstein, Salter & Gann 2005). Although some authors rightly point out that such comparisons can be misleading (Winch 2003), the cited study made adjustments to the definition of the construction industry within the Standard Industrial Classifications to ensure a fair comparison.

Continued poor performance is also reflected in the fact that construction clients globally remain unsatisfied with typical project outcomes (Boyd & Chinyio 2006). The answer to the industry's continuing problems is said to lie in building a stronger innovation culture to improve the rate and quality of innovation across the construction system, particularly given increasing client demands for integrated services (Hartmann 2006). The industry appears to be moving in this direction; however it faces a number of significant challenges related to the production of assets that are complex, unique, long-lived, fixed, expensive, and risky (Nam & Tatum 1988).

It is against this backdrop that small construction firms operate. Not only do they face the difficulties summarised by Nam and Tatum (1988), they must also contend with higher levels of competition than larger firms, and with the resource disadvantages of their size.

This paper focuses on a group of small firms that were able to overcome the above challenges and introduce innovation on construction projects. Five Australian case studies are considered, all involving strategic technological product innovation that was successfully implemented on a construction project between 2000 and 2004. The research question driving the study is 'How do small firms overcome the resource disadvantages of their size and successfully implement innovation on construction projects?' Despite the challenges small firms face, it is shown that they can play an important role in driving project innovation.

CONCEPTUAL BACKGROUND

Firm-level innovation processes can be simplified to comprise two main innovation drivers – those internal to the firm and those external (Manley & McFallan 2006; Barrett & Sexton 2006; Hartmann 2006; Seaden, Guolla, Doutriaux & Nash 2003; Winch 1998). These drivers can usefully be seen to constitute the firm's capabilities (an expansion of the old technology-push innovation model), and the

firm's environment (an expansion of the old market-pull model). Firm capabilities comprise core competencies (Prahalad & Hamel 1990) and the methods the firm uses to build and exploit them. The firm's environment constitutes the macro context and the implementation context. These constructs are summarised in Table 1.

Table 1: Internal and External Construction Innovation Drivers

Internal Capabilities	
Core Competencies	Core competencies are valuable, rare, inimitable and non-substitutable (Barney, Wright & Ketchen Jr. 2001). Such competencies facilitate sustained competitive advantage for businesses (Barney et al. 2001; Drejer, 2002).
Business Strategies	Within the complex system of construction, two key strategies underpinning core competency and innovation activity by firms are knowledge-anchoring and relationship-building (Drejer & Vinding 2006). These are high level strategies that add crucial competitive value to three more basic strategies that underpin effective innovation, comprising those associated with employees, technology and marketing (Manley 2006; Seaden et al. 2003). The construction innovation literature thus highlights five key business strategy types, defined by management functions, that grow firm competency and support innovation on projects.

External Environment	
Macro Context	The contributions of Winch (1998) and Gann and Salter (2000) provide important descriptions of the construction firm's environment. Key elements of this environment as described by these authors comprise clients, research centres, education providers, industry associations, supply chain partners, regulators and government assistance. As construction innovation is typically implemented on projects, the quality of the interaction environment surrounding a project, influenced by these features of the environment, is particularly important (Sexton & Barrett 2003).
Implementation Context	On a construction project, innovation implementation processes will be managed by a group of firms, reflecting the fact that "almost all innovations in construction have to be negotiated with one or more actors within [a] project coalition" (Winch 1998: 273). For project-based firms, an important part of their environment is therefore the temporary and unique micro-environment surrounding each project. This element of the firm's environment is strongly impacted by the client's procurement system, which significantly shapes the innovation capacity of the project team (de Valence 2007).

The drivers summarised in Table 1 combine with the characteristics of an innovation to influence networking opportunities and implementation success, in the context of increasingly open innovation systems (Chesbrough, Vanhaverveke & West 2006).

The literature reveals increasing sophistication in the characterisation of different types of innovation, from simple distinctions between product and process innovation to more detailed categories along an expanding set of dimensions. New typologies categorise innovations based on implementer's control, output class, degree of novelty, knowledge characteristics, system linkages, decision making, source of idea and process (Harty 2005; OECD 2005; Gopalakrishnan & Bierly 2001; Slaughter 2000; Mitropoulos & Tatum 1999; Winch 1998; Rothwell 1994; Powell 1991; Teece 1986). Understanding innovation characteristics along these dimensions assists the firm in the development of appropriate implementation strategies.

The small firm dynamics surrounding the three constructs described here – firm capabilities, firm environment and innovation characteristics – are explored in the interpretation of construction case studies later in this paper.

METHODS

In 2003, the Building Research, Innovation, Technology and Environment (BRITE) study was funded by the Australian Commonwealth Government, together with key state government client agencies. Between 2003 and 2005 the research team undertook 12 case studies of successful innovation on Australian construction projects in the non-residential building and road sectors.

The current paper draws on five of these 12 case studies, being projects where innovation was driven by a small firm. The unit of analysis here is the small firm that drove innovation adoption, as part of the coalition of organisations involved in its implementation on the project. This differs to the focus on a single firm often adopted in traditional manufacturing-based innovation studies (Gann 1997). A small firm is defined here according to Australian Bureau of Statistics (ABS) standards, as a firm employing less than 20 people (ABS 2002). Readers interested in more detail concerning methods are referred to Manley (2008).

OVERVIEW OF THE FIVE CASE STUDIES

All of the case studies provided evidence of significant cost savings arising from the innovation driven by the small firms. These savings are described in detail in Manley, Blayse and McFallan's study (2005). The direct beneficiary of the innovation was always the client, through improved project outcomes, although in some cases clients distributed a share of savings back to the innovating firm or project team. This was typically under contracts that involved some method of relationship enhancement. All of the small firms interviewed noted that their innovation had enhanced their reputations and increased the likelihood of future work opportunities, with the same and related clients.

Clients in all cases were focused on cost saving innovations, rather than quality improving innovations. Cost saving innovations can be easy for small firms to implement if they can demonstrate a low risk-profile. Similarly, the innovations that represented the adoption of well-trialled advances were easier to implement than more novel innovations. While the focus of all of the innovations was cost savings, there were many cases where associated time savings, safety improvements and quality improvements were also evident.

In all cases, the innovation champion within the small firm was the owner. This finding largely reflects the very small size of the firms in the sample, and is consistent with the findings in Barrett and Sexton (2006). Table 2 outlines the five case studies, each of which focused on technological-product innovation that was unbounded, interactive and strategic. Each innovation was introduced by a small firm to an Australian construction project between 2000 and 2004.

Table 2: Case Study Summaries

	Case A	Case B	Case C	Case D	Case E
Project description	Identification and repair of faults in 200 new concrete bridge beams	Stormwater management at a small community building	Two 3500 m ³ roofs over sports stadium ends	Up-grading the air-conditioning system at an art gallery	16 km pavement through saturated ground
Industry Sector	Road Sector	Building sector	Building sector	Building sector	Road Sector
Budget	AUS \$1m	AUS \$13,000	AUS \$10m	AUS \$100,000	AUS \$4m
Completed	2000	2002	2003	2004	2004
Innovation introduced	Ground penetrating radar to find defects in bridge beams	Managing stormwater with storage gutters and infiltration	Post-tensioned steel trusses to create long span roofs	Twin-coil air-conditioning to improve energy efficiency	A permeable road pavement meeting strict environmental requirements
Type of small firm driving the innovation	Consultant	Subcontractor	Consultant	Subcontractor	Subcontractor
Core competency of small firm driving the innovation	Development of high frequency GPR to improve the accuracy of defect identification	Firm holds patents for the collection and storage of water in a container at the drip line of roofs	Firm holds patents relating to post-tensioned steel roofs	Firm holds patents for twin-coil series pipe circuiting	Firm holds patents for tyre-reinforced permeable pavements
Type of innovation	Explicit Incremental New to industry	Explicit Architectural New to world	Tacit Architectural New to world	Explicit Modular New to world	Tacit Incremental New to world
Key relationships with...	Client	Client; Research centre; Education provider; Regulator	Client; Industry association	Client; Research centre; Industry association; Supply chain; Regulator	Client; Research centre; Supply chain; Regulator; Government agency
Firm size (no. of employees)	3	5	6	16	10
Firm age (years)	22	10	3	6	9

Innovation was driven by small firms that were either consultants or sub-contractors. Employment within the firms ranged from three to 16 people, and the firms were between 3 and 22 years old. Four of the five small firms used patents to protect their innovations. The project budgets ranged in size

from AUS\$100,000 to AUS\$10m. Three of the projects were in the non-residential building sector, with two in the road sector.

DISCUSSION

This section examines the ways in which the five small firms successfully implemented their innovations as part of the coalition of firms on the project team. It focuses on their networking behaviours, given the environment in which they were operating, including the implementation context; their capabilities and the characteristics of their innovations.

Firm Environment

The way that the small firms interacted with the environment in which they operated had a big impact on their success in introducing innovation on the projects studied. The central factor supporting the efforts of these firms was the quality of their relationships with key system participants. By far the most important participant was their clients. These small firms all worked with advanced clients. Such clients are likely to engage in 'judicious risk taking', which favours adoption of new technologies. The small firm interviewees noted that the advanced clients they worked for had: developed internal R&D programs; networked with specialist experts; set challenging project requirements; used value-driven tender selection; encouraged alternative tenders; designed of new forms of contract; used relationship management on projects; and participated in technology demonstration programs.

All of the case studies involved a project managed by an advanced client exhibiting most or all of the above behaviours. This meant that in all cases the implementation context was marked by procurement systems that were conducive to innovation.

In order to attract the interest of their clients, the small firms in this study needed a pre-existing set of relationships with other important system participants, to help them develop and protect their innovations. These comprised relationships with: research centres (B, D, E); education providers (B); industry associations (C, D); supply chain partners (D, E); regulators (B, D, E); government business assistance providers (E).

The more technical and unique the innovation was, the more likely the small firm was to have a relationship with a research centre. For two of the patented inventions, this relationship was particularly prominent – the airconditioning system (D) and the recycled-tyre pavement (E). For other innovations, relationships with educators were more important, as in Case B where tradespeople require new skills to fit the new water saving devices and the small firm innovator is providing new course content to training colleges.

In all cases, industry associations provided technical advice and access to global knowledge bases which supported the small firm innovators, while in Cases C and D such associations had organised awards that were won by the innovators. This latter activity is particularly helpful for small firms in building a reputation for innovation. Of course, such a reputation is not built in isolation and the small firm innovators were very reliant on their supply-chain partners, particularly given that their size implies resource shortages, for example in relation to finances, knowledge and relationships. In Cases D and E in particular, very close relationships with supply-chain partners provided complementary core competencies which were critical in meeting project requirements.

The small firms' relationships with regulators had proved far less satisfactory than those with the system participants described above. All the innovators in the sample felt that adoption rates for their technologies were being hampered by confusing, restrictive and inflexible regulations. This finding is supported by data from the UK Innovation Survey conducted in 2001 which shows that small firms are more likely to find regulations an obstacle to their innovation activity than large firms (Reichstein et al. 2005). Small firms have fewer resources than large firms to invest in overcoming regulatory barriers. In Australia, the adoption of performance-based standards by the Building Code in 1996

appears to have done little to alleviate regulatory barriers to innovation. The problem appears to be the level of prescription remaining in new performance-based standards.

Another problem is Australia's federal system of government, where each state has its own set of regulations and is likely to demand local trials to verify the compliance of new technologies, even if similar trials have been successfully conducted in other states. Such regulatory problems were much more significant for the small firms with radical technologies, and for the small firms seeking work in multiple states. The recycled tyre pavement in Case E met this description and thus the innovators were very involved in negotiations with regulators, with typically frustrating results. These considerations are taken up again in the Innovation Characteristics section to follow.

Another relationship that was less than satisfactory for the small firm innovators was that with government providers of business assistance schemes. Government assistance is currently focused on small firm innovators in the manufacturing industry. Such assistance is not tailored to the needs of construction businesses, nor is it actively promoted to the construction industry (Manley 2004). The experiences of small firms in the sample mostly confirmed this experience, although the innovator in Case E was aware of the Commonwealth Government's R&D tax concession and was also undertaking R&D on a scale large enough to make application to the scheme worthwhile.

Overall, it has been shown that relationships between the small firm innovators and advanced clients, research centres, education providers, industry associations and supply chain partners, greatly assisted the innovators in successfully implementing their technologies. Within the firm's environment, the roles played by regulations and government assistance schemes were less positive.

Firm Capabilities

All the small firm innovators possessed core competency related to their innovations that was unique and valuable. The small firms sought to maximise the return to their core competencies by employing a range of business strategies. The case studies revealed that *formal* business strategies relating to relationships, technology and marketing were important in supporting innovation implementation, while *informal* knowledge and employee strategies were also important.

The implementation success of the small firm innovators revolved around their relationship management skills. Indeed, the firms relied more on their relationship strategies than any other strategy type. This may be because relationship skills underpin success across all strategy types. Relationship skills were critical in networking with other members of the supply chain and in convincing the small firms' clients of the merits of their technologies. Relationship skills were also used to generate and exploit marketing contacts and to optimise the input of employees.

It is also unsurprising that technology strategies were important to the success of the small firms in implementing their technologies. Four of the five cases (B-E) involved original technology that has been patented by the innovators. This patenting strategy certainly has the potential to safeguard intellectual property and provide an income stream. However, as small firms, the ability to protect patents is limited. Hence, the innovators in Cases D and E were actively seeking relationships with established firms that could provide access to assets such as reputation, supply-chain access and financial strength. In the meantime, the owners of the small firms played the role of technology champions, requiring patience in the face of myriad regulations, and careful site-based quality control to avoid product failure which would be damaging at this stage in the firms' development. In Case E, the owner was also focused on monitoring the activities of imitators. This was not so much to sue for breach of patent, as this was beyond the reach of the firm's resources, but to make sure there were not any spectacular failures that could affect the reputation of the original innovator.

Typical marketing strategies used by the small firms to increase the rate of diffusion of their technologies included applying to award schemes run by industry associations (C, D) and obtaining external verification of the claims associated with the technology (B, D, E). The compliance cost for award schemes is often quite low, and competition within particular sub-categories is not always

strong, making application a worthwhile investment. External validation is a more customised process, requiring heavier investments and greater reliance on relationship and knowledge skills.

The last two strategy types considered here, knowledge strategies and employee strategies, were actively employed by the small firms, but informally rather than formally. It may be that because the small firms studied have only recently entered the commercialisation phase of their activities, the importance of formal knowledge and employee management is yet to peak. In the meantime, the firms appear to manage both areas satisfactorily using more informal means. For example, in terms of knowledge management, the firms were very focused on translating learnings between projects. This represents best practice in an industry that is known to suffer significantly from loss of knowledge between projects (e.g., Drejer & Vinding 2006; Gann & Salter, 2000). Yet it is clear that their success in this regard is very much related to the small scale of their activities. The relative ease with which small firms can integrate project learnings into continuous business processes is one of the advantages they have over their larger competitors.

The informal approach of the small firms to management of their employees is understandable given the small numbers of workers involved. The case studies were marked by very close and long-term relationships between employees and owners which appeared to provide a highly motivating business culture, supportive of creativity and innovation, without the need for formal structure. This is a very positive feature of small firms, providing another advantage over larger firms. The advantages of being a small firm in relation to knowledge and employee management to some extent offset resource disadvantages.

Innovation Characteristics

Project-based innovation is highly interactive and unbounded, thus the small firms' control over implementation of their technologies was shared amongst the construction team. Indeed, the case studies were marked by intensive negotiations between stakeholders surrounding the adoption of the innovations onto the projects. During this implementation phase, the small firms needed a good understanding of power relations on the project and beyond, and how these related to the characteristics of their innovations.

All of the innovations implemented by the small firms were strategic, technological and product-based. They were also 'unbounded' (Harty 2005) in the sense that the small firms implementing the innovations shared control within the project team. The innovations involved technical changes to physical output which had been planned over the long term and introduced in a project environment. Four of the five innovations were previously unseen 'world-firsts' protected by patents (B, C, D, E). The value of these innovations was recognised by the project clients, who were willing to pay intellectual property fees for their use.

Three of the innovations (A, B, D) were classified by the authors as explicit, because they can be adopted by users relatively easily. In Case B (storage gutters) it was also easy to observe how the innovation worked, while in Cases A (GPR) and D (twin-coil airconditioning) the operation of the innovations was not easy to observe, although codifiability and teachability were high. The innovations in Case C (post-tensioned steel roofs) and E (tyre pavement) were defined as tacit because users cannot easily adopt the technologies without the assistance of experts. In Cases C and E, representatives of the innovating firms were engaged on-site to ensure appropriate quality control and maximise the effectiveness of the technology. Hence, tacitness can be an advantage because it may create revenue opportunities for innovators. However, this same dependency of the user can work the other way if users perceive a lack of flexibility on the part of the innovator and therefore choose not to adopt the technology. This latter dynamic occurred for the technology in Case D, until codification was increased to reduce reliance on experts within the innovating firm.

Four of the five cases (A, B, C, E) involved small changes in knowledge, while the airconditioning innovation in Case D represents a significant departure from existing methods. Three of the cases (A, D, E) involved a small change in the technical and supply-chain systems to which they were

introduced, while two cases (B, C) involved significant changes to the systems to which they were introduced. The cases do not reveal a positive correlation between large changes in knowledge and large system impacts, which is consistent with Slaughter's (2000) classification system.

It might be expected that innovations that require significant changes in related components would be more challenging for small firms to implement. Indeed, this is reflected in the experience of the innovating firms on Cases B and E, where building codes and educational practices required changing to optimise diffusion of their technologies. However, the components that needed changing in Case C were directly within the control of the client and would better meet their needs, so they were easily changed. The key variable differentiating these two sets of examples is the extent to which project team members support the system changes required and have the power to enforce them. If an innovation impacts distant systems, over which team members have little control, then implementation can be more difficult for the small firm to influence, even if required changes are relatively minor (in Cases B and E, slowing diffusion despite success on the case study project).

The cases suggest that the most difficult types of technologies for small firms to implement on construction projects are those with distant system ramifications and those with low codifiability. The former suggests the need small firms have for a supportive implementation context, one in which key participants have far reaching power to affect change. The latter, low codifiability, might support revenue streams for established firms (by tying users to the firm's experts), however many small technology firms are still struggling with market acceptance of their products. At this stage in their development, without a reputation to support them, low codifiability can restrict market penetration.

The case studies also indicate a growing acceptance within the construction industry of the value of intellectual property and a willingness to pay for it. Patenting, which is associated with long-term proactive innovation, thus emerges as a valuable innovation characteristic, if the small firm can devise an appropriate strategy/partnership to defend such an asset against copying. The entrepreneurial spirit that can successfully support a small firm against the resource disadvantages of its size, and help it to innovate, involves a long-term growth perspective, such as that associated with patenting activity. It may be that small construction firms will be more successful if they can pursue such long-term proactive innovation, rather than reactive attention to site-based problems as they arise.

CONCLUSIONS

The findings suggest that the following factors are central to successful implementation of project-based innovation by small firms: close and on-going work with advanced clients; emphasis on relationship strategies; and ownership of intellectual property. It is this last factor that can attract the attention of advanced clients, particularly if the small firm has undertaken demonstration trials and had the results externally validated by an independent research centre. Once armed with an evidence portfolio, the small firm's marketing strategy ideally involves prioritising relationship-management along the supply chain and with clients. Further, small firms have an advantage over larger firms in the relative ease with which they are able to manage internal knowledge flows and employees.

The innovation success of each of the small firms also relied on a narrowly defined core competency that could not be replicated easily, which enabled them to meet the needs of a niche market. This competency gave them access to advanced clients, that is, those clients who have a higher propensity to adopt innovations, compared to other clients. Further, although all innovative firms require strong inter-organisation networks, particularly in construction where production is undertaken in teams, small innovative firms may have a greater reliance on the quality and breadth of their external relationships. Such relationships are required to compensate for the riskiness of innovation activity *and* the riskiness of being small.

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