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KEY INFLUENCES ON CONSTRUCTION INNOVATION

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ABSTRACT: The goal of this paper is to identify the main factors driving or hindering construction innovation. An analysis of the relevant literature indicates there are six primary influences: (i) clients and manufacturers; (ii) the structure of production; (iii) relationships between individuals and firms within the industry and between the industry and external parties; (iv) procurement systems; (v) regulations/standards; and (vi) the nature and quality of organisational resources. Attention to these factors by businesses and public-policy makers would be a key component of effective innovation strategy and policy. Further research is needed, however, to explore the relationships between innovation influences; and between innovation influences and other aspects of business strategy and environment, in the context of broader societal considerations. Further research should also identify quantitative estimates of the impact of innovation on the construction industry.

Keywords: Construction industry, construction innovation, innovation influences, innovation drivers, innovation obstacles.

INTRODUCTION

The goal of this paper is to identify the main factors driving or hindering construction innovation. The building and construction industry is one of the most important in modern economies. When related industries (such as manufacturers of building products and systems, designers, and property managers) are included, the industry accounts for about 15 per cent of the national product of most nations (Seaden and Manseau, 2001; Marceau *et al.*, 1999).

The higher the levels of innovation in the construction industry, the greater the likelihood that it will increase its contribution to economic growth. Unfortunately, in most countries, there is a perception that the industry is not generally innovative, and that there is much room for improvement. Government reports commissioned in recent years have identified such problems as poor rates of investment in research and development (R&D), fragmented supply chains, and lack of coordination between academia and industry in research activities (Dulaimi *et al.*, 2002). These are not simply issues of relevance to public policy makers; industry participants need to review their capacity to innovate. As Tatum (1991, 447) points out:

At the bottom line, engineering and construction firms need to innovate to win projects and to improve the financial results of these projects. They must innovate to compete. Development and effective use of new technology can provide important competitive advantages for engineering and construction firms. These advantages stem from distinctive technical capability, improvements in operations, and image as a technically progressive company.

Construction innovation as a field of study has generated a number of useful critiques of the industry's performance. This paper reviews recent (largely post-1997) literature primarily from the US, UK and Australia, with the objective of highlighting the primary influences on innovation in construction. The review covers a broad range literature, providing a brief and succinct overview of key innovation influences. Readers interested in

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further detail on any topic are encouraged to pursue the reference material.

This review identifies six main factors that influence innovation in construction – clients and manufacturers, the structure of production, relationships between individuals and firms within the industry and between the industry and external parties, procurement systems, regulations/standards, and the nature and quality of organisational resources.

These influences are the key factors driving or hindering business innovation. Attention to them by businesses and public policy makers would be a key component of effective innovation strategy and policy. Further research is needed however to explore the relationships between innovation influences; and between innovation influences and other aspects of business strategy and environment, in the context of broader societal considerations.

The next section explores the meaning of 'innovation' in the construction context.

INNOVATION AND THE CONSTRUCTION INDUSTRY

The concept of an 'innovation' is variously understood by stakeholders, and its definition if often vigorously debated. Nevertheless, within the construction industry, the definition provided by Slaughter (1998) is broadly accepted by participants and academics. She defines innovation as follows:

Innovation is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change.

Innovation in the construction industry can take many forms. Slaughter (1998) characterises such innovation according to whether it is 'incremental' (small, and based on existing experience and knowledge), 'radical' (a breakthrough in science or technology), 'modular' (a change in concept within a component only), 'architectural' (a change in links to other components or systems), or 'system' (multiple, integrated innovations).

At a broader level, the Organisation for Economic Cooperation and Development categorises innovation in the Oslo Manual on the basis of international research across a number of industries. The manual describes innovation as being either 'technical' or 'organisational'. Technical innovation involves either 'product' or 'process' innovation, whereas organisational innovation includes changes to organisational structure, introduction of advanced management techniques, and implementation of new corporate strategic orientations (Anderson and Manseau, 1999).

It is increasingly accepted that construction innovation encompasses a wide range of participants within a 'product system' (see, for example, Marceau *et al.*, 1999). This broad view incorporates the participants shown in Figure 1, including governments, building materials suppliers, designers, general contractors, specialist contractors, the labour workforce, owners, professional associations, private capital providers, end users of public infrastructure, vendors and distributors, testing services companies, educational institutions, certification bodies, and others.

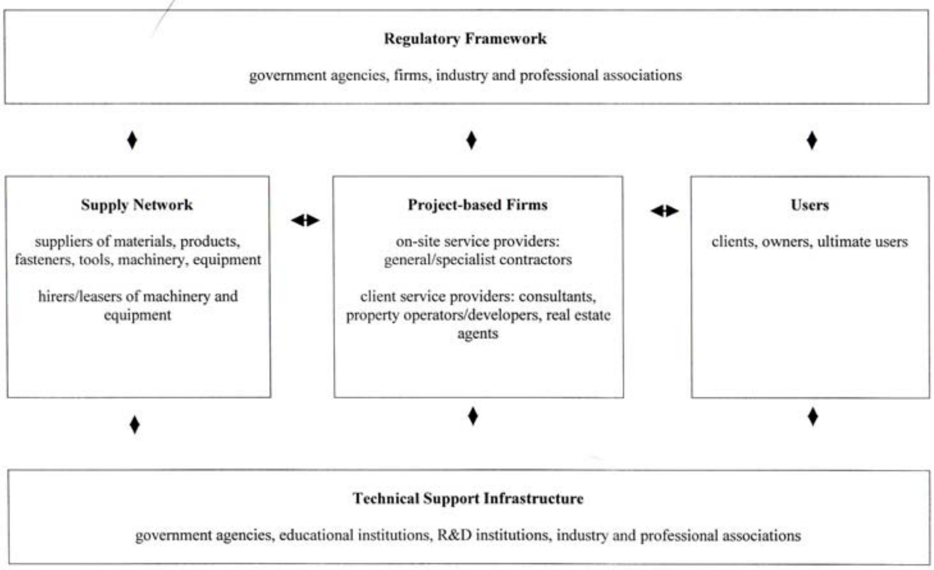

Figure 1: Participants in the building and construction project system (based on Gann and Salter, 1998)

Figure 1 is a diagrammatic representation of the broad range of key participants in the construction industry, and of the need for active networking between them. As Marceau *et al.* note (1999), in discussing the construction industry as a product system:

Conceived as a system, B[uilding] & C[onstruction] is partly manufacturing (supplies and materials, components, equipment) and partly services (engineering, design, surveying, consulting, even hire and lease and management). It is also much more than that since the essence of B&C is coordination of a very large number of different products and services and their transformation into a 'road', 'airport', 'office block' or 'hospital'. …This means that innovation occurs in a wide variety of economic and productive arenas.

The remainder of this paper examines the most notable of these arenas.

CLIENTS AND MANUFACTURING FIRMS

Clients and manufacturing firms are key industry participants in terms of driving innovation. Clients are commonly considered to have enormous capacity to exert influence on firms and individuals involved in construction in a way that fosters innovation (Seaden and Manseau, 2001; Barlow, 2000; Gann and Salter, 2000; Nam and Tatum, 1997; Kumaraswamy and Dulaimi, 2001).

Clients are able to enhance innovation in construction in a number of ways. They can identify specific novel requirements to be supplied by developers, building product suppliers, contractors, and operators (Seaden and Manseau, 2001); exert pressure on project participants to improve buildings' lifecycle performance, overall characteristics, and project flexibility to cope with unforeseen changes (Gann and Salter, 2000); and generally demand higher standards of work (Barlow, 2000).

The more 'demanding' and experienced the client, the more likely it is to stimulate innovation in projects it commissions (Barlow, 2000). The same goes for the 'technical competence' of the client – clients that (a) maintain internal construction management groups; (b) conduct internal R&D or design projects themselves; (c) seek to supplement their technical competence; (d) have a history of innovation; (e) are professional; and/or (f) maintain long-term relationships with the same designers/contractors are most likely to set the pre-conditions for innovative behaviour on a project (Nam and Tatum, 1997).

The key role of clients in promoting construction innovation is one of the most striking themes running through the literature. This theme is an echo of findings in many other industries (Winch, 1998). Indeed, the role to be played by clients in promoting innovation is so well accepted by academics and policy makers that 'current policy in the UK identifies the experienced client as the main institutional leader in stimulating construction innovation' (Winch, 1998). Similarly, key agencies in the Australian context recognise this dynamic and have policies in place to maximise the leverage that their roles as clients afford.

Manufacturing firms are also key sources for construction innovation, because they often provide innovative components and building products that are incorporated into buildings (Anderson and Manseau, 1999). Manufacturing firms tend to operate in more stable and standardised markets than do contractors and consultants, allowing them to maintain R&D programs. These programs are key drivers of innovation in the industry. Manufacturing firms are also better able to build up knowledge bases and engage in virtuous cycles of learning because their activities are not project based, allowing them to avoid learning discontinuities. The original innovations developed by manufacturers are adopted by construction clients, contractors and consultants, improving the performance of the industry (Anderson and Manseau, 1999).

STRUCTURE OF PRODUCTION

A large body of literature points to the nature of production in the construction industry and its deleterious consequences for innovation, some of which appear to be unavoidable, while others arise because of custom.

One of the features of production said to be most difficult is the temporary or one-off nature of construction projects. This is associated with discontinuities in knowledge development and in transfer of knowledge within and between organisations, and restraints on the development of an 'organisational memory' (Dubois and Gadde, 2002). The one-off nature of most building projects limits the degree to which a given innovation will be applicable to other situations, reducing the benefits of innovation and therefore incentives to innovate. It also tends to have the effect that different solutions to similar or identical client requirements are developed time after time, meaning that organisational learning is hindered (Barlow, 2000).

The nature of the product itself also tends to be ill suited to creating the conditions necessary for innovation (Miozzo and Dewick, 2004); Pries and Janszen, 1995). Built structures are generally expected to be highly durable. This has two negative consequences for innovation. The first is that it creates a preference for tried and tested techniques. The other is that the longevity of buildings and infrastructure places pressure on suppliers to maintain stocks of spares far into the future, reducing the incentive for manufacturers to change product ranges. The large number of actors involved in any given project is also problematic (Barlow, 2000; Pries and Janszen, 1995). Typically, each firm or individual involved in a project controls only one element in the overall process. Large and complex projects involve significant challenges to effective communication and give rise to disparate and discordant effort that is unfavourable to innovation.

Traditional approaches to the management of construction projects have also been criticised as tending to dampen conditions for innovation. In a recent paper, Koskela and Vrijhoef (2001) call for a complete revision of the theory of construction management, which they see as currently deficient. A number of researchers have elaborated on the problems caused by traditional management approaches. For example, Winch (2000) has suggested that the allocation of hierarchical roles has important consequences for innovation. Comparing the nature of hierarchies in French and British construction firms (as evidenced by the firms involved in construction of the Channel Tunnel), Winch concludes that the French 'model' of management is conducive to a greater level of innovation than is the British model. This was because French construction managers were given greater autonomy and had wider, more flexible role definitions than their British counterparts.

More generally, Barlow (2000) explains that the construction process is usually managed by dividing work into discrete packages, which are purchased sequentially and then completed by specialists. This means that project workflows are susceptible to interruptions. The only feasible way to manage the risks associated with such interruptions is to institute cascading legal contracts that pass risk down the supply chain (for example, from contractor to sub-contractor). This creates more pressure for tried and tested approaches and severely curtails parties' ability and willingness to innovate.

Finally, the construction industry in most countries is dominated by a large number of very small participants, who have limited resources to undertake innovation (McFallan, 2002). This sort of industry structure requires the existence of strong industry relationships if innovation opportunities are to be maximised.

INDUSTRY RELATIONSHIPS

Industry relationships have an extremely significant influence on construction innovation (Anderson and Manseau, 1999; Miozzo and Dewick, 2002; Dubois and Gadde, 2002). The importance of relationships lies in their capacity to facilitate knowledge flows through interactions and transactions between individuals and firms. These interactions and transactions can include processes related to product integration (between manufacturers and assemblers and installers of construction products), processes related to project organisation and coordination, diffusion of technologies and practices, flow of labour, and information flow from various sources (Anderson and Manseau, 1999).

Dubois and Gadde (2002) describe the relationships endemic in construction as 'loose couplings'. This describes the temporary coalitions of firms and individuals that come together to complete a project, and then disband. These arrangements can both inhibit and encourage innovation. They encourage innovation to the extent that each construction project is an 'experimental workshop', in which innovations can develop in response to the idiosyncratic features of the site, the people involved, and the unique demands of the project. However, learnings are often not 'codified' and hence are lost to future projects. Further, firms and individuals' learning environments are constantly changing, inhibiting their ability to form 'cognitive structures' favourable to learning. On balance, tighter 'couplings' among firms and individuals involved in construction projects are likely to be more supportive of innovation. Miozzo and Dewick (2004) reach similar conclusions, calling for stronger inter-organisational cooperation as a way of enhancing construction innovation:

In a complex systems industry such as construction, firms must rely on the capabilities of other firms to produce innovations and this is facilitated by some degree of continuing cooperation between those concerned with the development of products, processes and designs.

'Innovation brokers' can assist in orchestrating cooperation and knowledge growth to achieve innovation outcomes. This class of industry participants includes professional institutions, universities and other tertiary institutions, construction research bodies, and individual academics and researchers. The unifying attribute is that they act as producers and/or repositories of knowledge (Gann, 2001; Winch, 1998) and actively disseminate this knowledge (Manseau, 2003). In some cases, they may act as a 'space' for the evaluation of the merits of competing technologies (Winch, 1998).

Innovation brokers can act as information intermediaries between construction firms and others, helping firms become aware of technologies and competencies that may not otherwise come to their attention (Manseau, 2003).

The construction industry, according to Davidson (2001), is one that can benefit greatly from the services of innovation brokers. This is because the practice of 'technology watch' within the industry is either impractical or simply non-existent by reason of the following factors: (a) very little research is actually carried out by entities that design or build themselves; (b) the industry is rarely 'high tech' and innovation is constrained by the project nature of production and by prescriptive contract documents and customary competition on price only; and (c) the industry is comprised mainly of very small firms with small margins that leave little left over after hedging for risk. Manseau (2003) notes especially the potential for innovation brokers to enhance the innovative capacity of small to medium enterprises.

The structure of production in the construction industry involves challenges that can be met through the existence of robust industry relationships that can enhance knowledge flows. Innovation brokers, especially those with a multi-industry focus, can assist in maximising knowledge flows, helping to overcome the limitations of 'technology watch' in the industry.

PROCUREMENT SYSTEMS

Procurement systems that tend to discourage construction firms from risking the adoption of non-traditional processes and products are most injurious to innovation. These systems include those that place a premium on speed and urgency or on competition on the basis of price alone, establish rigid role responsibilities, or promote adversarial and self-protective behaviour (Kumaraswamy and Dulaimi, 2001).

A number of procurement systems are available to construction clients, including traditional lump-sum (fixed price), design-build, novation, construction management, project management, on-call multi-task contracting, guaranteed maximum price, full cost reimbursable, and BOOT (build, own, operate, transfer). The traditional lump-sum contract is the most conservative, and the most detrimental to innovation, drawing the most criticism in the literature (Walker and Hampson, 2003). It involves the highest cost risk for contractors, the highest incidence of adversarial relationships, the lowest level of integration across the supply chain, and the poorest innovation outcomes (Kumaraswamy and Dulaimi, 2001).

Higher levels of innovation arise when a more innovative procurement method is chosen. From an innovation perspective, it is the presence of a well-integrated team that is of most importance, as this aspect of a procurement system is key in driving innovation (Walker *et al.*, 2003). This might involve partnering alongside fixed cost contracts to improve communication, learning, and innovation outcomes on straightforward projects. For more complex projects, a design-build, construction management, project management, or BOOT style arrangement can have good innovation outcomes. These approaches integrate design and construction functions (and sometimes financing and operation), leading to improved design constructability and economy, through innovation. Communication, learning, and innovation are also improved across the supply chain through management by a single entity. Further, incentives for innovation are enhanced as there is greater scope for capturing benefits (Walker *et al.*, 2003; Kumaraswamy and Dulaimi, 2001).

Procurement methods that encourage construction team integration improve innovation outcomes. Importantly, the performance of any of the above contract types can be enhanced through the application of relationship management techniques, particularly the adoption of partnering or alliancing on projects. Indeed, even the performance of lump sum contracts can be improved through the application of a partnering approach (Winch, 1998, 274):

The shift from competitive tendering to partnering [and alliancing] provides one of the most important opportunities for moving towards [a gain/risk sharing] approach. Those in a position to innovate need to be rewarded for taking such risks. If they are so rewarded, they will have incentives both to adopt new ideas from outside the firm, and to capture the learning from problem solving to propose better ways of doing things to the client

Partnering is typically defined in the literature as a commitment between the client and the contractor(s) to actively cooperate in order to meet separate but complementary objectives. It is a structured management approach, which encourages teamwork across contractual boundaries (CIB, 1997). Partnering is associated with the use of a range of tools, including charters, workshops, team-building exercises, dispute resolution mechanisms, benchmarking, total quality management, and business process mapping (Bresnen and Marshall, 2000, 232). Partnering is typically offered as an option to contractors and is a management structure rather than a legal scheme.

The innovation benefits of partnering are well established in the literature. Bresnen and Marshall (2000, 231) note the following advantages over traditional approaches: increased productivity, reduced costs, reduced project times, improved quality, and improved client satisfaction.

These benefits also apply to alliances, perhaps with greater surety given the existence of commercial drivers to ensure cooperative behaviour under alliances. Project alliancing can be considered a highly evolved form of partnering that is enshrined in a contract. Alliances are costly to set up and so tend to be reserved for very large and/or complex projects (say over $US40 million) with high risk profiles (Manley, 2000).

The main difference between partnering and alliancing is that the latter employs contractually established commercial drivers to provide financial incentives for good project performance, while partnering has been characterised as being based on 'soft-issues'. Partnering relies on trust and integrity rather than the letter of the law.

The innovation benefits of relationship management on construction projects, in the form of partnering or alliancing, derive from stronger flows of knowledge between organisations and less reluctance by firms and individuals to propose and adopt non-standard solutions (Barlow, 2000; Kumaraswamy and Dulaimi, 2001).

REGULATIONS/STANDARDS

Gann and Salter (2000) argue that government regulatory policies exert a strong influence on demand and play an important part in shaping the direction of technological change. According to Dubois and Gadde (2002), this has generally been a negative influence internationally, with many government regulations and industry standards hampering innovation.

Recently however, a growing body of literature points the virtues of *performance-based* regulations over the industry's historical reliance on *prescriptive* regulations. While the prescriptive approach specifies all of the 'materials, configurations and processes required to achieve a desired regulatory goal…[the] performance approach leaves many of these factors open, specifying only the final regulatory goal…stop[ping] short of specifying how it should be met' (Gann *et al.*, 1998, 281).

Although performance approaches are often seen to promote innovation more vigorously than prescriptive approaches, the ultimate impact of any regulation or industry standard depends on the capabilities of the regulators (Gann *et al.*, 1998, 281):

The process of developing regulations is complex, relying upon the knowledge of key players. The extent to which technical change is encouraged … depends on the availability of new knowledge, together with the development of appropriate mechanisms.

Regulators need sector-specific knowledge relating to market conditions, advanced practices and technologies, organisational competencies, industry structure, competition, and technical infrastructure. Care is required in the design and implementation of performance approaches; they will not necessarily promote innovation. Lack of knowledge on the part of regulators can result in fossilisation of practices by setting requirements based on existing technologies (Gann *et al.*, 1998).

If the design of regulations and standards is approached strategically, positive innovation outcomes may be expected through the codification of existing technology and the creation of demand for new practices and technologies (Gann *et al.*, 1998, 286):

By imposing requirements which are too strict for current technology [regulators] force the industry to develop new technology in order to comply. High standards may therefore induce demand for improved technologies which otherwise would be commercially unsuccessful.

Enforcement methods also have an impact on innovation. Gann *et al.* note that a complex enforcement regime is unlikely to encourage innovation and that 'clarity and simplicity is needed in the regulatory process to enable the up-take of good practice and encourage innovation' (1998, 291).

ORGANISATIONAL RESOURCES

Even assuming the presence of external conditions favourable to innovation, it is important for firms and individuals involved in construction to have in place attitudes and processes conducive to innovation. These fall under the broad heading of 'organisational resources', and include the 'culture' of innovation within the firm, the skills to successfully adopt innovations developed elsewhere, the presence of key individuals who 'champion' innovation, processes that facilitate the codification/retention of acquired knowledge, and an innovation strategy.

Culture of innovation

Intangible organisational attributes that are likely to be conducive to innovation include (a) not penalising new ways of working if they do not succeed; (b) a 'culture of collaboration', in which people are able to question ways of working without fear of penalty if they are unsuccessful; and (c) a shared perception that participants are all striving to achieve a greater understanding of each other's goals (Barlow, 2000). More generally, there needs to be explicit recognition that learning requires openness to new ideas and ongoing dialogue (Love *et al.*, 2002).

Absorptive capacity

Some in-house technical competence is required for firms to benefit from research and absorb results of research conducted elsewhere. For construction organisations to take full advantage of knowledge transfer necessary for innovation, they need to have sufficient 'absorptive capacity'. Gann (2001) considers that absorptive capacity is a function of prior knowledge and on-going technical capability. In this respect, the extent to which firms employ a 'critical mass' of professionally qualified employees able to interpret and act on research results is important.

Innovation Champions

The presence of 'champions' within firms is commonly cited as a necessary ingredient for innovation (Barlow, 2000; Winch, 1998; Nam and Tatum, 1997). As Winch (1998, 274-5) notes:

Innovations need champions. Ideas are carried by people, and ideas are the rallying point around which collective action mobilizes. Unless the 'systems integrator' is convinced of the merits of the new idea, and has the skills to incorporate it into the system as a whole, change is likely to be slow.

The attributes of champions need to include possession, at the very least, of power and technical competence. This is because high levels of technical competence enable champions to overcome the uncertainty of construction innovation, and their authority enables them to challenge resistance to innovation (Nam and Tatum, 1997).

Knowledge codification

Gann (2001) suggests that project-based construction firms often struggle to learn between projects, and often have weak internal business processes. In this respect, it is important that firms involved in construction attempt to codify knowledge acquired on projects so it can more easily flow between projects. According to Gann and Salter (2000), in construction firms, knowledge associated with 'know-what' and 'know-why' generally tends to be codified, whereas knowledge linked to 'know-who' and 'know-how' is more likely to be tacit. The latter, however, may be tremendously important. For this reason, it is important that firms integrate project experiences into continuous business processes to ensure coherent organisation.

Innovation Strategy

Few firms in the construction industry have the resources or incentives to maintain a formal research and development program. This indicates the importance of effective implementation processes to enable firms to successfully adopt innovation developed elsewhere. It has been shown that this involves, in part, absorptive capacity, champions, culture, knowledge codification, innovation brokers, and relationships with manufacturers. Effective innovation performance at firm level requires combining elements such as these into a formal innovation strategy. The final form of the strategy will be a function of the quantity and quality of organisational capabilities (Walker *et al.*, 2003).

CONCLUSION

This review has shown that construction innovation is most usefully considered within a broad 'product system' perspective. This perspective encompasses the construction industry as usually understood, involving contractors and consultants, together with a range of other players that are considered important to construction innovation, but do not form part of conventional analysis of the industry. These players include clients, manufacturers, regulators, and technical support providers.

Within this context, a number of key influences on construction innovation were noted: clients and manufacturing firms, structure of production, industry relationships, procurement systems, regulations/standards, and organisational resources. Although presenting many challenges, these influences can be strategically managed to maximise innovation outcomes.

It is difficult to make comprehensive recommendations for improved business performance based on this review given that the important work of modeling relationships between key variables is yet to be undertaken. Nevertheless, it is useful to identify innovation strategies that are widely acknowledged as important to innovation outcomes; these include:

(i) enhancing client leadership, through high levels of technical competence, advanced demand patterns, and prudent risk-taking;
(ii) building robust relationships with manufacturers supplying the industry, in view of their involvement in R&D programs;
(iii) mobilising integrated approaches to construction projects, in response to the fragmentation of the industry arising from the one-off nature of most projects and the proliferation of small players;
(iv) improving knowledge flows, by developing more intensive industry relationships to offset the disadvantages of production based on temporary coalitions of firms;

(v) integration of project experiences into continuous business processes to limit the loss of tacit knowledge between projects;

(vi) active use of innovation brokers to facilitate efficient access to technical support providers, and other external players with complementary knowledge bases;

(vii) promoting innovative procurement systems, including partnering or alliancing, to enhance cooperative problem solving, the adoption of non-standard solutions, and equitable allocation of risk;

(viii) strengthening of performance-based regulations and standards, through the enhancement of technical knowledge held by regulators and other key players, and through the formulation of simple enforcement strategies; and

(ix) building up organisational resources, including developing a culture supportive of innovation, enhancing in-house technical competence, supporting innovation champions, and developing an effective innovation strategy.

While these are the most well supported recommendations arising from the review, the most novel findings relate to the role of:

(i) partnering and alliancing approaches to project delivery in creating a shared project vision and developing complementary objectives between project participants;

(ii) innovation brokers in adding value to knowledge bases and enhancing knowledge flows in support of innovation; and

(iii) performance-based regulation in generating alternative building and construction proposals.

Further research needs to be undertaken to explore the nature of relationships between innovation influences, which may not always be positive. There is also a need for research examining the interaction of innovation influences and other aspects of business strategy and environment. Although initial modelling work has already been undertaken in Manley (2001), this needs to be extended based on findings arising from the review presented here. Empirical estimates of how innovation (and other aspects of business strategy and environment) impacts on the building and construction industry were beyond the scope of this paper, but are clearly another area for further research.

Finally, the impact of broader societal considerations on the scope for business innovation in construction needs to be explored. This is particularly so given that the built environment impacts significantly on social conditions, while it is simultaneously impacted extensively by them.

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