Construction Innovation: Fifth Generation Perspective

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Abstract: Despite what many researchers, governments, and commentators say, there is a considerable amount of innovation that occurs in the construction industry. Negative opinions of construction innovation are often misinformed by data and methodologies designed to measure innovation in other sectors and by a misunderstanding of the realities of innovation in the construction industry. A theoretical model of innovation in construction is developed on the basis of fifth-generation innovation research. Through interviews with 58 thought leaders from across the Australian and United Kingdom construction industries, this model is contrasted with what happens in practice to refine a model of innovation that can form the conceptual basis for future research. The findings support but also contrast many aspects of the mainstream innovation literature around fifth-generation innovation. In particular, ideas around systemizing innovation do not sit comfortably with the way that innovation happens in practice in the construction industry. The organization of innovation in construction is a dynamic process that needs to move in response to the different stages of the construction process, starting with an organic approach in early design and tender stages and moving to a more systematic approach during the delivery phase, in which tight budgets and programs demand great discipline. Innovation late on occurs in response to problems rather than in anticipation of opportunities early on and demands a different management approach. Findings also support the crucial role of clients in construction innovation but suggest that most clients care little about this and do not have the tools to assess innovation in bids. There is a fundamental contradiction here that undermines respondents' preferences for market-led rather than regulation-led innovation, which needs further exploration. **DOI: 10.1061/(ASCE)ME.1943-5479.0000368.**

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Introduction

The Organization for Economic Cooperation and Development (OECD) (2010) describes innovation as the creation of new products, services, or business processes that create wealth or social welfare. This definition is important because it departs from traditional models of innovation, which many researchers, governments, and commentators use to assess innovation activity in organizations. These models have their origins in the *Oslo Manual* (OECD 2005) and *Frascati Manual* (OECD 2002), which portray innovation as a highly linear, scientific, and research and development (R&D) driven process of the type commonly found in high-technology industries, such as manufacturing, electronics, and pharmaceuticals. For example, Constructionline's (2013) survey of 400 firms in the United Kingdom construction industry concluded, on the basis of R&D spending, that contractors are the least innovative in the construction industry, with an annual R&D investment per capita of £227 compared with £670 for architects and £1,087 by manufacturers. This supports other data on the basis of R&D statistics produced by the Australian Innovation System Report (DIISR 2010), which claimed that the construction sector has historically had low levels of innovation, with only 30.8% of businesses innovating (the lowest of any sector). As Gambatese and Hallowell (2011) have pointed out, the tendency to judge an industry's or firm's innovation record on the basis of R&D statistics has left many with the misleading impression that construction is rather backward and slow to adopt new ideas. It has also ensured that much of the innovation that occurs in the construction sector goes unnoticed and is invisible to traditional metrics and measurement frameworks used to rank firms and industries. This is because few firms in the construction sector generate radical new ideas in the laboratory. Instead, most firms innovate in response to the necessity to solve day-to-day problems and it can be argued that although these companies might not invest in speculative, experimental, and laboratory-based experimentation, they are actively innovating nonetheless. Cutler's (2008) review of Australia's national innovation system recognized this problem, noting that formal R&D accounts for only one-third of the total business expenditure on innovation, that innovation occurs in many different ways in business, and that this needs to be better recognized in national innovation statistics.

Barrett et al. (2008) list numerous important differences between construction and manufacturing, which might call into question any simplistic comparisons of innovation. For example, when one looks at the construction sector as a system of contributors over the whole lifecycle of a building, it is clear that a much larger constituency of stakeholders needs to play a role in the innovation process. As Widen et al. (2013) concluded in their examination of stakeholder engagement in construction innovation, a structured process of engagement has to be an integral part of the innovation process being underpinned by an explicit plan for communication and engagement with identified key stakeholders. Within this social context, there are also politics to be handled and vested interests to be considered. In contrast to manufacturing, innovations are rarely large scale and radical in construction but are small-scale incremental improvements in services or products. Innovation in construction also tends to be more ad hoc than in manufacturing firms on the basis of ideas from employees and managers developed incrementally along the way in response to

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challenges during the service delivery process. In contrast to manufacturing that is typically technology intensive, construction is a service-based industry that is inherently labor intensive. Although construction is becoming more technology driven, Sundbo (1996) argues that this ensures that innovation is more behavioral than R&D driven. As Gronroos (2000) shows, even when a service-based organization develops a systematic and planned innovation process, innovations themselves must be developed by the people working in that organization who often work closely in collaboration with customers as coproducers of knowledge. More recently, Ozorhon (2013) has supported this and argued that in the construction sector, innovation is cocreated in a multiparty environment in which collaborative working among team members and strong commitment are the primary enablers of innovation. Furthermore, given the strong behavioral dimension of innovation in construction, it is not surprising to find that Chan et al. (2013) have recently highlighted the importance of a strong innovation climate as a proxy of organizational innovation.

Questioning the value of mainstream innovation literature to construction, Barrett et al. (2008) note that the vast majority of innovation theory derived from R&D studies of manufacturing firms has been focused on large enterprises and has neglected to sufficiently consider the special innovation challenges faced by the many small to medium sized enterprises (SMEs) that dominate the construction industry. Sexton et al. (2008) found that SMEs are motivated to innovate by different factors to large firms, i.e., survival rather than growth and by the need to solve immediate project-related problems. The SMEs are also more open and responsive to their market environment than large firms and rely more on personal client relationships and the tacit knowledge and experience of their employees. Typically, they are also less technology intensive, lack the slack resources to innovate, and are more highly geared than large firms.

So it would seem that construction might not be as backward as Woudhuysen and Abbey (2004) claimed and that any debate over the relative performance of the sector is more complex than that informed by R&D statistics alone. Indeed, Winch (2008, p. 23) questioned the continued "holding-up" of manufacturing as best practice, pointing out that the automobile sector also "has its incompetent back-street garages and dodgy car salesmen." Winch argues that the construction sector at its best displays highly sophisticated skills in addressing highly complex and difficult production problems in a way that draws considerable respect from other industry sectors. Other research has begun to question this simplistic perspective, revealing that a considerable amount of innovation does occur in the construction industry, even though it is often hidden from view [Abbot et al. 2007; National Endowment for Science, Technology, and the Arts (NESTA) 2007].

Understanding of the preceding issues and what they mean for modeling innovation in the construction sector is only starting to emerge. But it is known that to rely on traditional measures of R&D investment to compare the construction industry's innovation performance with other industries is potentially deceiving and that alternative models are needed to conceptualize the way that innovation actually occurs in construction. For the preceding reasons, the aim of this paper is to deepen understanding of how innovation happens in reality in construction. More specifically, by building a model of innovation from the innovation literature and contrasting this with data from interviews with 58 senior thought leaders in the United Kingdom and Australian construction industries, it aims to refine a conceptual picture to guide future research in this area and make more informed judgments about levels of innovation other than those based purely on R&D.

Fifth-Generation Innovation

Since Schumpeter's (1947) early economic theories of innovation, Tidd (2006) has identified five generations of models in the innovation literature. First-generation models were highly linear and structured and emerged after the Second World War out of the many large-scale scientific R&D projects in hi-tech industries like nuclear engineering, space exploration, and medicine. They saw innovation as a supply-push process, in which innovation was driven by technical capabilities to create new products rather than by the need for them in the market place. During the 1970s, as the effect of formal R&D on industrial innovation started to diminish and baby boomers prospered, second-generation models reconceptualized innovation as a demand-pull process driven by consumer thirst for new products and services. In the 1980s, inspired by lessons from the Japanese industry, third-generation coupling models emerged to challenge the linearity of earlier models, focusing on the need for integration and teamwork among research, production, engineering, and marketing functions, which is facilitated through techniques, such as total quality management, just-in-time, and lean production. As computer technologies emerged during the 1990s, fourth-generation parallel line models emerged, emphasizing the need for integration of information flows in supply and demand chains, working with customers and business partners, and the importance of linkages and alliances. Most recently, in response to an increasingly networked society, fifth-generation systems integration models emphasize the role of systems integration, social capital, and business networks in facilitating the cocreation of knowledge across different knowledge domains. It is argued that innovation arises not so much from the ownership of assets or from one individual firm working in isolation, but from dynamic capabilities in manipulating resources and working in integrated global networks of specialized firms to cocreate new knowledge.

Fifth-Generation Innovation in Practice

In imagining what a fifth-generation organization would look like in practice, the work of Eisenstat et al. (2001) and Samson (2011) is useful. Their analysis of innovative companies shows that they encourage people in the lower reaches of their organizations to show initiative and contribute to future strategy. Rather than viewing their businesses as a portfolio of business units, these companies view themselves as a flexible portfolio of resources, which they can bring to bear on promising opportunities. In these decentralized opportunity-based firms, a corporate center connects the quasi-autonomous business units. Resources from multiple business units are not held in silos but are organized around emerging opportunities in different parts of the organization. Through strong innovation-focused strategy and leadership, opportunity owners are authorized through central screening to mobilize whatever resources they need. Samson (2011) also showed that innovative firms are differentiated by a robust and systematic innovation capability. According to Samson, the secret to systemizing innovation lie in securing six main principles of organization: customer focus; collectively challenging orthodoxies; dedicated resources; measuring innovation return on investment; recognizing and rewarding innovation; and accountability for innovation.

Although over 50 years old, Burns and Stalker's (1961) work also remains very relevant to fifth-generation innovation principles. They showed that firms with an organic organizational structure were most effective in quickly responding to unexpected opportunities. Organic organizations have a network structure with a central hub, little hierarchy, few rigid rules and procedures, and which places a high value on external knowledge and is driven by the

power of relationships. Organic structures place people at the heart of business success and emphasize the importance of freedom of choice, empowerment, collaboration, and integration. As Muller and Becker (2012) show, it is this approach that lies behind the success of what are widely seen as some of the world's most well-known and successful companies. These companies design their business around people and collaboration to maximize the likelihood of chance collisions between people and knowledge, which are normally separated by traditional business practices and knowledge silos. These organizations actively set up opportunities for serendipity, they put themselves in front of new experiences, and have the vision and adaptive capacity to see and seize opportunities that unexpectedly arise. Reflecting this theme, numerous authors have highlighted the importance of collaboration in the innovation process in construction, including Gann (2000), Leiringer (2006), Walker and Rowlinson (2008), and Ozorhon (2013). They have pointed to the potential of collaborative procurement models, such as alliances and public private partnership (PPP), to stimulate innovation by building trust and teamwork between project members.

More recent research has taken ideas around flexibility further by showing that innovative firms have both formal and emergent elements in their business strategies. According to both Minztberg (1984) and Hubbard et al. (2002), successful firms recognize that the future cannot be planned with complete certainty and that they need agility to respond quickly to new business opportunities. Both Hillebrandt and Cannon (1994) and Green et al. (2008) argue that in construction firms, strategy is largely emergent than preplanned and shaped by unexpected opportunities and individuals and often maverick behavior. However, rather than being driven by the need to innovate, this would appear to be a function of the industry's need to organize within an uncertain project-based structure.

In organic structures, numerous researchers within and outside construction have noted the importance of developing an innovation culture to guide behavior (Robbins et al. 2003; Brandon and Lu 2008; Chan et al. 2013). According to Sutton (2001), the following common attributes tend to characterize the cultures of innovative firms: meaning; activism; listening; customer focus; experimentation and risk taking; trust; structured thinking; cellular structures; fluidity; divergent thinking and geekiness; creative conflict; collaboration and integration; challenging; fun; open-mindedness; empowerment; and broad unconventional metrics for judging success.

There is also an important and contentious external dimension to innovation research revolving around the role of governments and customers in the innovation process. Given that many private firms are not prepared to take the risk involved in blue-sky academic research, the role of the government has been found to be critical in fostering innovation (Hilmer and Field 2011). Indeed, many of the problems the world faces today, such as climate change, are so complex that they can only be solved at an intergovernmental level. A government's role in driving domestic innovation requires them to do 10 main things: step in to fund the basic research that private firms are not likely to invest in; assist entrepreneurs to commercialize research by ensuring that sufficient mentoring, support, and venture capital is available to fund start-up companies; reduce the risk of innovation by providing a stable and conducive economic, legal, and regulatory environment for it to occur and cultivate confidence in capital markets; provide leadership by insisting on innovation through their purchasing power and procurement arrangements as a major client; stimulate innovation through incentives, competition, and innovation policies; build up a country's human capital through their education systems and immigration policies, which provide a talented pool of human resources to provide innovative ideas; and create a positive regulatory environment within which innovation can occur (Fairclough 2002). Although there is a whole debate about the role of governments in innovation from interventionist to laissez-faire, there is a view that in industries like construction, regulation has an especially important role in driving reform. In their interviews with over 30 thought leaders in the United Kingdom construction sector, Loosemore and Holliday (2012) argued that although there is evidence that too much regulation can stifle innovation through red and green tape, there is also little history of voluntary change within the industry. So many parts of the industry need to be encouraged to innovate through regulatory reform.

When it comes to the role of clients in the innovation process, Culter (2008) makes the point that although there are many similarities and differences between innovation in manufacturing and service-based industries, what crucially distinguishes service-based innovation is the central important role of customers in the innovation process. This view is supported by Gambatese and Hallowell (2011) whose research into the factors that influence innovation in the construction sector pointed to the importance of client support in valuing and driving innovation. Similarly, Egbu (2008) and Barrett (2008) argue that clients can come together, and through their combined purchasing power, help the industry create a consensus around a meaningful shared vision and a way to implement it. Clients have a major role to play in the way that the construction market operates, and they should aspire to be better clients by demanding innovation, avoiding cutthroat competition, and creating a trusting and stable environment for innovation to occur through equitable risk distribution and a longer-term value-driven view of their building investment over its entire lifecycle rather than seeing it as a short-term construction cost.

Although many point to the crucial role of clients in promoting more innovation in the construction sector, Loosemore and Phua's (2011) analysis of corporate social responsibility in construction showed that many clients are simply not prepared to pay for innovation. Also, Brandon and Lu (2008) argue that relying on clients as drivers of innovation is a cop out by the industry. Relying on clients to drive innovation, they argue, discourages firms from investing in their own new ideas and recognizing and acting out their shared responsibility for the advancement of the industry. Hobson and Treadaway (2008) support this position. However, as Manley et al. (2006) points out, the construction sector serves a wide variety of clients with an equally wide variety of needs and not all clients are equally mature in terms of their approach to the innovation process. Lim and Ofori (2007) also recognized that not all construction clients will pay for innovation, and Sexton et al. (2008) argue that a client's role in the innovation process varies from passive to balanced to dominant, depending on the attributes of the client involved. Like Manley et al. (2006), they found that dominant clients actively engage with driving innovation in the industry and tend to be those that repeatedly use the industry to procure assets critical to its core business. These types of clients therefore have a central interest in directing the way those assets are built. In contrast, the passive client is normally a small, inexperienced, speculative, or one-off user of the industry that tends to consume off-the-shelf products. Between these two extremes is the type of client that works in partnership with the industry to develop innovative solutions for their needs. These clients tend to be large, intelligent, and informed businesses that have a clear vision for what they want. They need not be repeat users of the industry but they know about managing projects successfully. Sexton et al. (2008) argue that this type of client has been the underlying assumption for most models of innovation in the construction management literature.

Conceptualizing a Fifth-Generation Innovation Model for Construction

Synthesizing the preceding research, it is possible to build a conceptual model of the construction innovation process using the fifth-generation principles. This is illustrated in Fig. 1 and explained subsequently.

Stage One: Encourage It

During this phase, managers create the enabling conditions that allow innovation to occur. A business culture is created in which people feel they can innovate and instinctively do so without consciously thinking about it. There is a demand and supply side to this process. The supply side is the responsibility of business, and the demand side is the responsibility of the clients and governments. On the supply side, firms should link innovation to strategic corporate objectives. This innovation strategy should be democratically conceived and adaptable, presenting a set of flexible strategic choices rather than a rigid set of goals. Leadership is also crucial in creating a vision that attracts new ideas. Leaders should build a culture of tolerance, transparency, trust, and openness that enables people to put forward ideas in confidence and take calculated risks without fear of blame or failure. Clients should also use their purchasing power to demand and expect innovation and set goals that stretch firms to think in new ways. They should also create a competitive environment that recognizes and rewards innovation and develop systems to value it. Governments also play a role in reducing the risk of innovation by providing a stable and conducive economic, legal, and regulatory environment for innovation to occur.

Stage Two: Allow It

Having created an environment in which people feel comfortable to innovate and feel a duty to do so, the allow it phase is where new ideas are developed. The quality and quantity of ideas produced and the speed at which they develop depends on managers developing a peripheral vision that recognizes the value of information from diverse sources. They should encourage curiosity and a thirst for knowledge and invest in R&D to explore new ideas and generate new knowledge to identify unmet market needs. Firms should also seek to collaborate by building social capital and developing unique interfirm networks with other innovators. Sharing risk and reward through integrated supply chains, they should seek to build

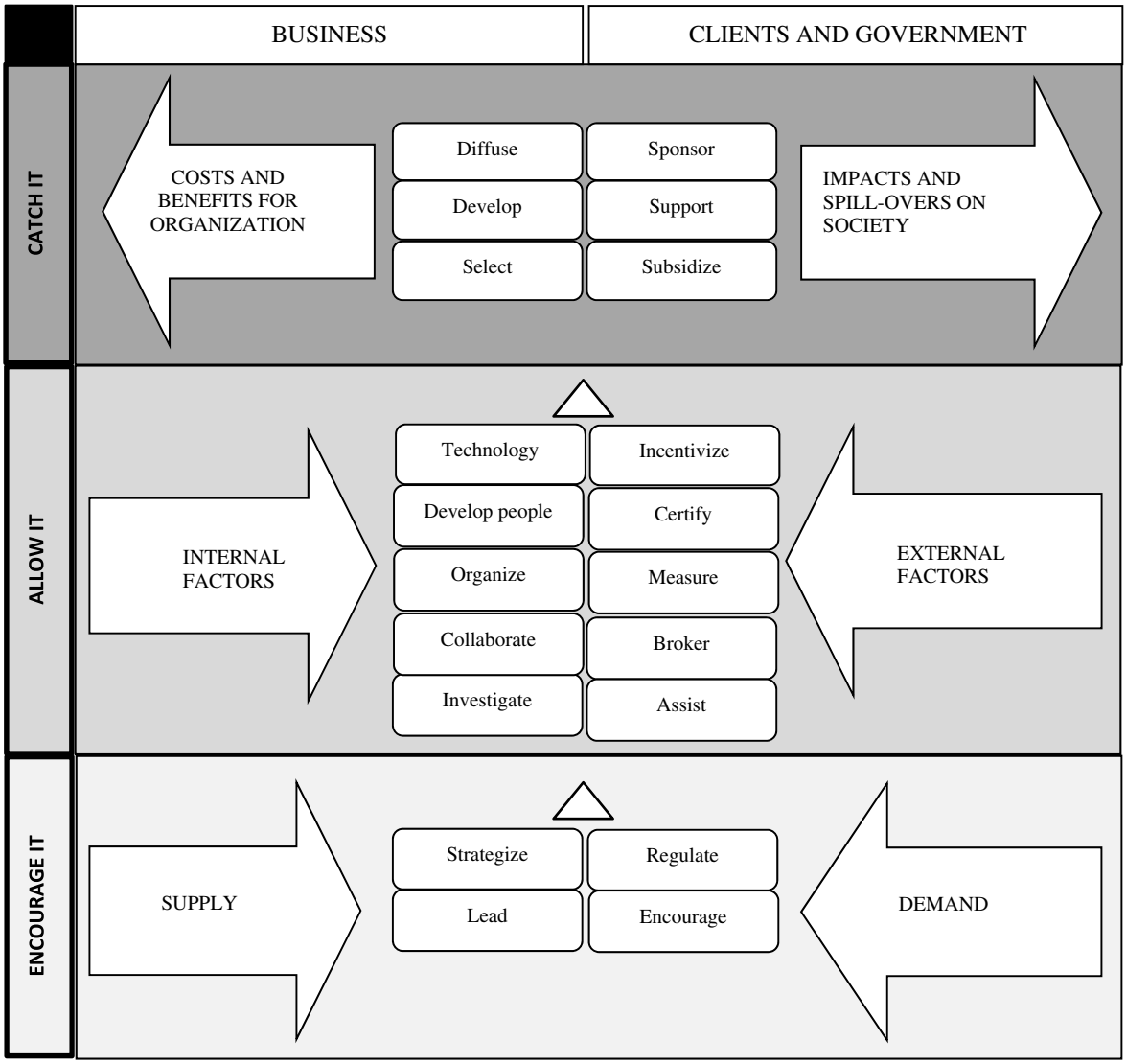

Fig. 1. Fifth-generation innovation model for construction

connections across traditional silos and knowledge domains. Organizationally, they should construct loosely coupled, decentralized organizational structures that avoid rigid organizational silos. Managers should develop their employees by giving them the skills and knowledge to innovate and empowering, incentivizing, and rewarding innovative people. By building engagement, managers should build employees' sense of identity with an organization and a positive emotional attachment to their job and colleagues. Technology should also be explored and integrated into organizational processes as a means to innovation but not an end in itself. Externally, governments and clients should incentivize firms to innovate, set clear and ambitious targets to encourage innovation, and establish common metrics to allow firms to measure innovation performance. Governments in particular should help firms build up their social capital by setting up interfirm knowledge sharing networks, connecting innovators with venture capitalists and customers, and organizing trade missions. Finally, they should help to stimulate innovation by seeking to reduce red tape by funding research that firms will not invest in and providing incentives to encourage firms to innovate.

Stage Three: Catch It

Having created the environment for innovation to thrive and having generated many new ideas, the catch it phase involves spotting a potentially marketable idea, developing it into a business opportunity, and implementing it effectively into the market to produce the returns anticipated. This stage is about timing and understanding when ideas match market needs. This does not happen in a linear predictable way. Ideas can get stuck in the allow it phase for many years without becoming a business opportunity. Indeed, some ideas may never be implemented, and, internally, the effectiveness of this process depends on effective selection through understanding market needs informed by market intelligence on good customer relations and feedback and the development of ideas into buyable products and services that match market needs through financing, design, adaptation, prototyping, testing, and refinement. Finally, those ideas need to be diffused into the market. Externally, clients and governments can sponsor innovation by acting as a champion, providing patronage, underwriting, seed funding, acting as the guarantor, and providing support for innovators.

Method

Understanding that any theoretical model is an approximation to reality, the practicalities of implementing these ideas in practice were tested against the views of leading innovators in the industry and government. To this end, 58 thought leaders were presented with the model and interviewed for their views on its relevance in practice (Table 1 for sample structure). These people were selected through snowball sampling from a core group of people who had been recognized by the Australian Government as leading innovators in their field through a ministerial invitation to sit on its Built Environment Industry Innovation Council (BEIIC) (http://www.innovation.gov.au/industry/buildingandconstruction/BEIIC/Pages/default.aspx). The BEIIC was established to advise the Australian Minister for Innovation, Industry, Science, and Research on innovation policy relating to industry competitiveness, sustainability, regulatory reform, procurement workforce capability, and new technologies. The interviews, which often ran to 2 h, were semistructured. Although they were guided by the model, a pilot study showed that it was also important to allow such experienced and prominent respondents to respond flexibly by relaying the many anecdotes and stories throughout their professional lives. This resulted in extremely rich data for analysis that is reported subsequently in a narrative that relates to each stage of the model. In presenting the results, narratives are used for two main reasons. First, the aim was not to test the relationship between any independent and dependent variables. Instead, the intention was to ask the respondents to talk about their experiences of working in the industry and how the model reflected this. So a quantitative approach and statistical analysis was not appropriate. Second, the results were intended to retain the full richness of insight contained in the narratives collected from these highly respected and experienced respondents. Meisel and Karlawish (2011, p. 2023) note that the power of narrative is in translating respondent accounts into data that people can comprehend. As Flyvbjerg (2011, p. 310) argues, "the force of example" is underestimated in scientific research and when done well, contains no greater bias toward verification of the researcher's preconceived notions than other methods of inquiry. The stories of experienced people are of enormous value and contain numerous insights that a quantitative approach relying on codified answers to predetermined questions and variables could not provide. Clearly, from over 100 hours of interview data, it is not possible to recount everything that was said in this paper. So what is presented subsequently are the main points that were issues of agreement across all the interviews. Although it is acknowledged that there were also some disagreements among respondents, these were relatively rare and there was a surprising level of consistency in the views presented.

Table 1. Sample Structure

Respondent	Number
Politicians	2
Senior policy advisers and public servants	8
Senior academics (professors)	2
Professional associations/advisory/lobbying bodies	3
Designers/architects/engineers	12
Contractors	12
Subcontractors	4
Manufacturers	5
Other, e.g., project managers, planners, quantity surveyor, unions, property developers, and facility managers	10
Total	58

Discussion of Results

Stage One: Encourage It

Respondents universally agreed with Samson's (2011) assertion that an organization has to be systematically set up for innovation, but there were divergent opinions of how this is best done. However, although there was a sense that strategy was important, there was also a feeling that innovation is often portrayed too "romantically" (RESP #3 POL) and through "rose painted glasses" (RESP #7 POL). There was agreement with Hubbard et al. (2002) that when it comes to innovation strategy, many felt that much of the literature in innovation is postrationalized and that most innovation occurred in response to a problem rather than in any preplanned way. As one respondent said, "Everyone needs to take an honestly pill" (RESP #7 POL). Most agreed that although many managers will say in retrospect that they had an innovation strategy that systematically led the business to innovate, in reality, much innovation starts with discomfort and a need to respond to an imminent problem. Having said this, there was also widespread agreement that innovation needs to be defined, the reasons need to be identified, and benefits need to be spelt out for employees, and that having a formal innovation strategy was key to giving people "permission to innovate" and "communicating that innovation

matters" (RESP #43 OTHER). Thus, the primary role of strategy was seen as creating a "predisposition to innovation" (RESP #46 OTHER) to formalize the process in some way, place it at the center of business priorities, and resource it properly. But at the same time, there was also agreement that although strategy must start at the top, innovation did not have its own separate strategy to provide employees in the lower reaches with a high degree of flexibility to move within the wider goals set by leaders: "You say what you want to be and what you want to achieve and then let people figure out how to get there"; "You can't innovate by going on course innovation 101 . . . it's all about people seeing and acting on opportunities" (RESP #9 Policy); and "Entrepreneurs don't run a process . . . they just do it. They do what needs to be done" (RESP #19 CON). This supports the finding of Green et al. (2008) that rather than being highly preplanned, construction firm strategies tend to emerge from the bottom up as a collective but contested endeavour of many people (often unsanctioned) from across different parts of a construction firm. Although broad strategies are often developed at the board level, they merely represent guidelines for action rather than strictly implemented action plans. The preceding was qualified further by numerous references to the importance of leadership in the innovation process, which for many was much more important than having a formal strategy: "People need to see the organization does new things—visibility is critical . . . .you can't tell people . . . you need to show them" (RESP #37 SUB). Without leadership, "innovation doesn't get an agenda or quantum" and "is directionless" (RESP #52 OTHER).

In a refinement to the literature on the drivers of innovation in construction, respondents indicated that innovations in construction were generated from two main sources: upfront competition to win jobs and the downstream need to deal with a problem on a project and deliver it safely, on time, and within budget. As one respondent said, "Upfront innovation is about winning the job and is driven by the need to beat the competition. But once you have the job it switches to how to deliver the project faster and more efficiently" (RESP #17 CON). As one respondent said, "Innovation at a project level must be practical . . . You can't have too much creativity on-site since the concrete has to be poured. There are basic things that need to be done and time is so tight that there is little time for creativity in doing things differently . . . where the innovation happens on-site is in dealing with problems to keep the program and budget on target. This is a different type of innovation—it is reactive not proactive" (RESP #19 CON).

In support of Egbu (2008), Barrett (2008), and Gambatese and Hallowell (2011), clients were seen to play a critical role in the innovation process. However, it was widely felt that most construction clients are not open to innovation or prepared to pay for it: "Most clients are completely irrelevant to innovation. They have no interest in it whatsoever. Unless of course it can reduce costs . . . then they have a great desire for innovation" (RESP #57 OTHER). These findings do not indicate that it is a cop out for the industry to look toward clients to show leadership in innovation. Purchasing a building is not the same as purchasing a widget. It is infinitely more complex and involved, as is the client's role in that process. The challenge it would seem is the education of clients and the development of tools to allow them to see the value of innovation to their core business. Clients are critical because if there is no one to sell to, then most people will not innovate. As one respondent said, "If clients do not want energy efficient buildings, then the industry won't build them. Similarly, if a firm isn't focused on innovation and setup to innovate, then incentives will have little impact in encouraging them to do so" (RESP #22 SUB).

Having emphasized the role of the market in driving innovation, good government innovation policy was widely seen as critical to stimulating a national conversation around the subject and "setting the enabling environment in which innovation can occur" (RESP #7 Policy). However, in discussing the role of governments in driving innovation, there was universal agreement that the primary reward for innovation must come from the market and not from the government. Finally, it was also generally agreed that governments should play an important role in stimulating innovation as major construction clients in their own right. Respondents did not see regulation and government incentives as important drivers of innovation. The main role of the government was to reduce red and green tape and provide a stable environment to invest in. If the market rewarded and demanded innovation, then they would innovate, a finding that questions Loosemore and Holliday's (2012) assertion that regulation is important to innovation in construction. However, these findings do not question that regulation is unimportant when the demand from clients is not there to create a market for innovation.

Stage Two: Allow It

There was agreement that innovation primarily revolves around people of many types and at different stages of a construction project: "There is a need for people who can think outside the square and people who think inside the square" (RESP #$# MAN). Many respondents cited an example of new business units to emerge out of the personal interests and passions of individuals: "You find out what people are interested in and help them explore those ideas" (RESP #16 DES). For example, in one firm, the passion of one staff member for horses led to a successful business unit that specialized in equestrian stadia. In another firm, a new digital innovation business unit was born out of a Ph.D. completed by one member of staff. In a third firm, a sustainability group arose out of the long-term determination of an employee to drive this through the business. These examples mirror Muller and Becker's (2012) description of leading firms in other industries that design their business around people. However, respondents also pointed to a "forgotten layer of people in the industry" (RESP #19 CON), i.e., construction workers who undertake the work on-site. There was broad consensus that a drive for greater flexibility in the industry over many years has resulted in them being forced into casualized labor, reducing their ability to participate in workplace issues. As one respondent said, "The structure of employment in the construction industry is all about lowering costs and providing flexibility rather than being about innovation. Contrast this with the manufacturing sector, where in a factory of 100 workers, there are all sorts of opportunities for them to contribute ideas and to talk to managers" (RESP #8 POL) and "it's a race to the bottom" (RESP #56 OTHER). Many respondents pointed out that one of the major negative consequences of this employment structure is that the subcontractors who are expected by the large builders to innovate are largely separated from the benefits of doing so by repeated subcontracting and a widespread risk transfer mentality that ensures that those who need to innovate are often unable to benefit from the process. These comments highlight a largely unexplored element of construction innovation research relating to the role of subcontractors and their construction workers in this process. Although Barrett et al. (2008) and Sexton et al. (2008) have identified the dominance of the subcontracting business model as a major difference between construction and other industries, the role that tradesmen play in the process has been largely overlooked. Many also pointed to the lack of investment training in the industry, which has resulted in a stagnation of ideas. Firms who provide apprenticeships and develop their staff are in the minority and can place themselves at a major cost disadvantage to those that do not. This has

effectively frozen the intellectual development of the industry. As one respondent said, "The basic skills levels of workers in other industries are far higher generally than they are in construction. The knowledge base of workers in construction has hardly developed in the last 20 years because of the subcontracting revolution" (RESP #21 CON). These findings indicate that there seems to be a major disconnect between the ambitious and imaginative ideas that are concocted by large contractors and consultants and the ability of subcontractors to deliver them.

Although the concept of collaboration was widely considered as critical for innovation, many agreed that this was often unachievable in practice: "Collaboration is just a word . . . there is nothing new in this" (RESP #7 POL) and "collaboration in construction is a huge challenge. There is always a sense that one is giving away something. The industry is so competitive that collaboration between the few big firms is almost impossible" (RESP #32 SUB). For true collaboration to happen in construction, most argued that it was important to be involved early in the design process where solutions can be jointly developed. Most of the respondents talked about "going on a journey" with one another (RESP #57 OTHER) and that "early on, the door is fully open to innovation . . . but this is a highly protected place to be and most people are faced with a firmly closed door" (RESP #35 SUB). These findings support the views of Leiringer (2006) and Walker and Rowlinson (2008), which show that procurement reform is crucial to the innovation process. However, despite the rhetoric of collaboration, it also shows that in many projects, there are numerous organizational and cultural barriers to prevent this from happening.

Organic organizational structures are often posited as a solution to this problem in the innovation literature. However, although the idea of organic structures was recognizable to most of those interviewed, there was also widespread agreement that there was "a danger of being too utopian in creating a world where business are too frightened to innovate" (RESP #5 POL). As one respondent argued, "At the end of the day, delivering projects is a highly pragmatic endeavor which requires detailed planning and strong accountability, discipline, and reporting lines" (RESP #30 SUB).

Finally, although technology (business information modelling was repeatedly identified) most saw many challenges in introducing such technologies into the construction sector. In particular, there are the long-established ways of working, which have become institutionalized into the industry to change and then there are major problems in upskilling the supply chain in using this technology. As one respondent noted, "Construction is still fundamentally an industry based on relationships and people working together closely in a highly problem solving environment. So it is important to see technology not as a standalone piece but as part of a much larger organizational ecosystem and it generally won't work if it is treated in isolation from the rest of the business" (RESP #56 OTHER).

Stage Three: Catch It

Many respondents, apart from those with a manufacturing background, did not recognize the catch it phase of the model. The idea of systematically taking an idea from selection, although responding to market needs, to development, i.e., developing business models and undertaking market analysis, and to diffusion, i.e., marketing, selling, delivery, servicing, and feedback, did not reflect the way that ideas become accepted into the construction industry. As one respondent said, "A lot of innovation doesn't happen like this. Sometimes it's just solving a problem and you have a client. The catch it analogy sounds too linear. It is really for the inventor who is running around with an idea looking for a buyer" (RESP #12 DES). Although this may be true and many innovations in construction arise in response to problems, there was also the view that the construction sector focuses too much on incremental operational improvements in neglect of the large strategic game changers that can change the industry or provide them with a competitive advantage. There was also the view that clients are generally reluctant to invest in innovations like this. So being able to sell an idea is important if the industry was to make a step change: "Companies must better learn which client buttons to press" (RESP #43 OTHER).

Many respondents also felt that this is the most critical and yet most difficult phase of the whole process, in which many firms seem to struggle. Some thought that very few firms have a strategic view of marketing their innovations. Furthermore, most companies do not have systems to systematically spot, assess, and develop good ideas. So it often comes down to the determination and passion of individuals to push their ideas through to reality. This ensures that many good ideas and people are lost from the industry:" Our sustainability strategy started with one person pushing it and never giving up. He was often knocked back but had a passion for it and eventually convinced everyone it was important" (RESP #42 CON).

Timing was also seen as critical to this phase of the innovation process. As one respondent said, "Unless there is a need at project level to either to win a bid or resolve a problem then it won't happen" (RESP #31 SUB). However, most acknowledged that there were very few willing clients who were prepared to test and prototype a new idea on their project. Clients did not appear to have clear methodologies for valuing innovation. Submitting a con-conforming bid was therefore a major risk. As one respondent said, "There is always resistance because new ideas involve change and the undoing of old systems and ways of doing things. Few people want to take the risk of trying something new and failing. There is no shortage of ideas in the industry but it is the opportunity for application which is often missing. It takes a courageous person to bring a new idea to fruition" (RESP #46 OTHER).

Conclusion

The aim of this paper was to deepen understanding of how innovation happens in construction firms. By building a model of innovation using fifth-generation models and contrasting this with data from interviews with 58 senior thought leaders, a new conceptual picture was developed and refined to guide government policy development, management strategy, and future research in this important area. For managers, the model simplifies the innovation process into three new phases on the basis of the way that industry leaders say it happens in practice. It also highlights the main internal and external drivers of innovation that firms should seek to manage if they are to develop an effective innovation strategy. For researchers in the field of construction innovation, the findings support but also contrast many aspects of the mainstream innovation literature, highlighting new questions and qualifications for construction academics around existing knowledge in this area. Much of the contemporary theory around fifth-generation innovation seems idealistic when compared with the realities of working in the construction industry, suggesting that much contemporary innovation research is of limited value to understanding the construction innovation process. This is to be expected because much of it has emerged from research undertaken in different non–project-based industry sectors that differ markedly to construction. In particular, the findings show that the idea of systemizing innovation does not sit comfortably with the way that innovation happens. Yet paradoxically, it was found that the idea of an organic organization was something that many felt uncomfortable with.

In reconciling what appears to be conflicting findings, this research has highlighted something that has not yet been explored in the construction literature. It appears that the organization of innovation in construction is a dynamic process of adjustment from an organic approach early on, i.e., when designing, planning, and tendering, to a more systematic approach during the delivery phase, in which tight budgets and programs demand great discipline. Innovation late on occurs in response to problems rather than anticipation of opportunities early on and demand a different management approach. So the idea of a single all-encompassing model of construction innovation would seem inappropriate and it is now clear that upfront innovation is the type of innovation that has been most discussed in the construction innovation literature and there is a need to further explore how innovation happens when work starts on-site. This is an important new avenue for innovation research in the future. The findings also support the crucial role of clients and customer orientation in the innovation process. It does not appear that firms rely on clients for innovation, but they are depending on clients to create a market for innovation that will enable them to unleash their creative abilities. These are very different dependencies. The findings also indicate that few clients are prepared to pay for innovation, yet respondents all agreed that innovation must be market led to have any sustainability. There is a fundamental contradiction here that perhaps explains why the industry is seen as relatively slow to adopt new ideas. Firms will not innovate if their ideas are not valued in the market and if the costs of development cannot be amortized across multiple projects. This is where the role of government policymakers and clients, so resisted by respondents, would appear to be crucial in driving innovation. Without a market for innovation, regulation is the only catalyst for change. These findings have indicated that there is still much to understand in untangling these contradictions. The structural and organizational barriers to innovation are well understood. Future research should focus on how they can be undone. This research shows that clients lie at the heart of this problem as does the subcontracting model of organizing construction work. Also, these findings reveal that there is much more to learn about the catch it phase of the innovation process, a process that once again is inextricably tied up with construction clients. Compared with other industries, this was broadly seen as a weakness in construction and more research needs to be done in this area. In conclusion, the construction sector is no less able to generate ideas than any other sector.

The limitation of this research was that it was on the basis of only 58 interviews. Although these interviews were with nationally recognized industry innovators and leaders with a vast amount of experience, the present model can only be considered preliminary until it is further refined and tested by more research. In particular, it would be useful for research to focus on each of the three stages to deepen understanding of them, their boundaries, and their relationships. There is also the vertical interface in the model to be explored between the government and private sectors. In other words, how does government regulation and policy influence levels of innovation in the industry and how does the relationship work the other way.

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