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Classification of innovation for strategic decision making in construction businesses

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Innovations in construction may be classified in several different ways. To encourage construction firms in Singapore to innovate, a practical approach is provided for the classification of innovations, in order to guide construction firms in their development of innovation strategies. A qualitative systems model, portraying the innovation behaviour of contractors, is developed and validated through Pearson correlation analysis and interviews. From interviews with 21 construction practitioners, the profit maximization goals of construction firms are shown to be a major driving force of innovation. Construction innovation should be classified in accordance with the types of benefits and returns that emerge from them, which makes the investment of money and effort in innovation worthwhile. Three classes of innovations were identified: innovations that consumers are willing to pay for; innovations that reduce contractors' construction costs; and innovations that encompass intangible benefits, thus providing contractors with competitive advantage.

Keywords: Willingness to pay, profit maximization, innovation, systems thinking.

Introduction

Bowley (1960) is the first author who noted that two types of innovations are evident in construction: those that change the product and those that affect processes. Since then, authors such as Nam and Tatum (1988, 1989), Groàk (1992) and Slaughter (2000) have provided a variety of definitions of construction innovation that acknowledge such classification. The importance of each type of innovation to the development of the construction industry has been widely debated. Winch (2003) notes that for over 20 years, innovation research has been dominated by Abernathy and Utterback's model (summarized and developed in Utterback, 1994) where product-enhancing innovation is the key. Nonetheless, Slaughter (2000) argues that in construction, the process of innovation is also important. This is because the introduction of innovation projects by one party requires the collaboration of others if it is to be successful.

This paper argues that although the classification of innovation in terms of product and process innovations provides contractors with a clear division of the source and type of resources required for their innovation strategy, they remain silent on the competitive advantage that such innovations may provide for the contractors. In turn, the impact of such advantages on the contractors' future business strategies is unclear. Dunning (1993) observes that many of the created assets in today's organizations are intangible and are 'firm' or 'ownership' specific. With the increasing international mobility of enterprises and technologies (Lundvall, 1992), the competition between construction firms of different origins will continue to intensify. Hence innovation, an important tool for companies in their development of competitive advantage, is indispensable. A new classification of innovation is proposed that guides contractors in making strategic decisions for their construction businesses.

Pedersen (1996, p. 184) defines construction innovation as 'the first use of a technology within a construction firm either in the process or in the product'. The Construction Research and Innovation Strategy Panel (1997, p. 5) defines construction innovation as, 'The successful exploitation of new ideas, where ideas are new to a particular enterprise, and are more than technology related—new ideas can relate to process, market or management'. The key notion of innovation is therefore

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'newness', notwithstanding the medium that carries this novelty. It rests on 'practices so new that the set pattern of accepted processes or products is developed or replaced' (Langford and Dimitrijevic, 2002, p. 17). Therefore, the definition of construction innovation adopted for this study is: 'the purposeful search for new knowledge and the application of this knowledge in production'. 'Newness' applied in most industrial contexts may encompass two notions: (1) differentiation; and (2) the creation of competitive advantage.

Betts and Ofori (1992) note that product differentiation from innovation would seem elusive to the contractors as construction contractors do not usually offer designs but are only involved in the construction of one-off projects in response to clients' demands. Nonetheless, Cannon and Hillebrandt (1990) offer four means of product differentiation in construction: by offering a range of project management methods; by extending their activities from construction into design; by extending activities into financial packaging; and by extending forward into commissioning and facilities management. Although these strategies may differentiate contractors from their competitors, they do not offer contractors a clear vision of the impact of such differentiation measures on their businesses. Without such vision, the competitive advantages that these innovations may provide cannot be specified. Hence, the desirability of such innovation strategies to the contractors is diminutive.

The foundation of the new classification of innovation proposed by this study should thus focus on the notion of competitive advantage, the element that counts to contractors in their strategic decision-making process. The time is thus right for the 'opening of the black box' for contractors. Contractors should strategize their innovations in a sustainable manner and move away from pursuing a shopping list approach of product and process innovation in their selection of innovation schemes.

Research aim and objectives

This study aims to investigate 'how innovation can be made part of the construction business strategy'. The scope of study is thus at the firms' level. Its objectives are to: (1) investigate the factors that influence contractors' decisions to innovate; (2) develop a systems model that provides an overview of the competitive impacts of innovations on contractors' businesses; and (3) recommend a classification of innovation that complements the systems model.

This paper first discusses factors that contractors would consider when strategizing innovation for their businesses. Next the research methods are introduced. These include Pearson correlation statistical analysis, interviews, and systems modelling. From the empirical results, a provisional systems model is developed. This model is further improved with qualitative results from the interviews to produce a final systems model. From the final systems model, a classification of innovation for strategic decision making in construction business is developed.

Review of literature

Financial aspects of construction innovation

Authors (such as OECD, 1997; Prahalad and Venkat, 2004) agree on one key principle: innovation is the primary source of wealth creation. A new technological device is a source of some advantage for the innovator where, depending on the elasticity of demand, a combination of lower price and higher mark-up than the competitors will allow the innovator to gain larger market share and seek greater returns (Shields, 2005). Therefore, authors (such as Linde and Porter, 1995; Slaughter 2000) observe that innovating firms are essentially seeking returns through either introducing a new product or applying a new production process. Hence, Harper (1963) notes that the root problem of poor growth in any industry may be due to the repeated failure to capitalize on the power of profit incentives to induce productive efforts, investments and innovations.

Although profit is a possible driver of innovation by contractors, there are 'costs' in realizing innovation. Hence, for business investments in innovation to increase, there must be adequate incentives to invest (Harper, 1963). The 'cost' of innovation is often regarded as high for business in general and construction in particular as it takes time to develop innovation and trial innovations may be expensive (Gerwick, 1989). In addition, in construction, potential technologies are often not widely diffused (Toole, 1998). Hence, contractors are typically missing a great amount of information. This increases their risks in investing in new technologies that may lead to adverse consequences such as project failure.

Bingham (2003) observes that firms can reap benefits from, and maximize the potential of, innovation only if their capabilities and ambitions match the companies' wants and needs: cost reduction; new product features and line extensions; new products to augment existing lines of business; and new products for new lines of business. In Bingham's (2003) list of companies' wants and needs, cost reduction is often the only selection criterion applied by construction clients. This is especially so for public clients which have a duty to account for the taxpayer's money (Latham, 2002). This results in low profit margins for contractors and hence, inadequate incentives for construction firms to innovate. Construction firms thus tend to differentiate themselves not in terms of technological capabilities, but in terms of cost. Since cost is the focus of competitive advantage in construction and innovation is an expense, innovation is not a feasible strategy for attaining the competitive advantage that construction firms are seeking. Therefore to provide a practical classification of innovation to suit the purposes of contractors, this study reviews the factors that influence contractors' decisions to innovate.

Construction quality and productivity

In construction, productivity is often determined by the complexity of the construction process in relation to the extent of use of capital equipment to supply buildings (Davis Langdon & Seah International, 2000). However, construction firms today still do not significantly invest in advanced technologies that improve the efficiency and quality of the construction process and product. Instead, they depend on basic resources such as labour and simple equipment.

For instance in Singapore, construction firms often prefer to use cheap and unskilled foreign workers rather than initiate or increase investments in advanced technologies. Hence, the construction industry is highly labour intensive and often faces labour shortages and poor workmanship. With the lack of creation of advanced factors, construction productivity has been declining and labour efficiency is often cited as poor (Horner and Talhouni, 1995; Radosavljevic and Horner, 2002). In Korea, Jin and Ryung-Goo (2003) observe that in the 1970s, the productivity of the construction industry was twice as high as that of manufacturing. This gap was maintained through the 1980s but narrowed until the middle of the 1990s owing to the lack of technological developments in the construction industry. Since then, while manufacturing productivity increased rapidly, construction productivity has stagnated, and the productivity gap was reversed in the second half of the 1990s. By 1999, the productivity of manufacturing was 40% higher than that of construction. This decline of construction productivity may be attributed to the inadequate funds for contractors to develop or maintain their competitive edge owing to the cost competition in the industry that has led to very low profit margins. The classification of innovation for strategic decision making in construction businesses thus not only has to consider the possible improvements in construction productivity and quality through innovations but also has to account for the cost of innovation and identify suitable stakeholders to undertake this financial burden.

Research capabilities

Learning to innovate is strongly related to the availability of capital investments for plant and equipment (Milford, 2000). Hence, it is important that contractors are determined to commit resources and establish supportive policies and priorities required for innovation (Tatum and Funke, 1988; Slaughter, 2000). Their commitment should be maintained beyond the initiation stage, and throughout the project until the innovation has been successfully implemented (Ling, 2003). However, Burrows and Seymour (1983) observe that operating cost is the overriding concern in both the day-to-day business of construction and the longer-term deliberations on the changing practices of the industry. Hence, with the costs of innovation increasing owing to higher personnel, equipment, regulations and testing costs (Shields and Young, 1994), firms face strong pressures to reduce such costs (Business Week, 1992, 1993a, 1993b; Corcoran, 1992). Nonetheless, Shields and Young (1994) indicate that it is not prudent to minimize financial costs because too much focus on them can reduce the quality of the innovation programme over the long run. Hence, for contractors to have long-term commitment to innovation, they require a large amount of excess funds to invest in creating and maintaining their competitive advantage through innovation.

Consumers' satisfaction

Ofori (1990) states that clients vary considerably in size, interest and motivation. He observes that four groups of clients are discernible: public sector clients, private occupiers, property companies and investors. However, not all four groups directly contract with the construction firm and hence, have a direct impact on the decisions of the construction company to innovate. Therefore, this study divides clients into two parties. First, the term 'client' designates the initiator of the construction process, the individual or group financing the project that has a direct impact on the construction company's decision to innovate. Second, the 'consumer' comprises the end users of the building product who are not the first initiator of the construction process but may indirectly affect the construction company's decision to innovate through their level and type of demand for building products.

Studies of innovation in manufacturing have long stressed the positive influence of the consumer and the client on innovation (Rothwell *et al.*, 1974; Cooper and Kleinschmidt, 1987; Von-Hippel, 1988; Lundvall, 1992). In studies of the capital goods sector, the literature places clients and consumers at centre-stage in the innovation process (Gardiner and Rothwell, 1985; Miller *et al.*, 1995; Nam and Tatum, 1997; Gann, 2000). Miller *et al.* (1995) show that the consumers of complex bespoke products tend to be key sources of knowledge on innovation, and key drivers of it. Gardiner and Rothwell (1985) suggest that clients should be full 'partners' in the innovation process. Nam and Tatum (1997) note that in 70% of the construction projects they researched, clients and consumers made important technical decisions and often shared a high proportion of the risks associated with innovation.

However, Ball (1988) observes that many construction companies have not attempted to introduce novel processes, owing to conservative consumers and clients who make it difficult for them to be innovative. Ivory (2005) examines three construction case studies and observed that clients, in the present economic, regulatory and cultural climate, are not always supporters or sponsors of innovation. The client's involvement in the innovation process depends on the degree to which the client perceives there to be direct benefits to it (Von-Hippel, 1988). Clients concerned with budgets and completion times are likely to shrink from innovation. Hence, clients should not be routinely expected to take on the risks and costs associated with innovation (Ivory, 2005).

Nonetheless, the National Customer Satisfaction Survey (Housing Forum, 2001) in the UK indicates that while consumers' satisfaction does not have positive impacts on construction businesses, a low satisfaction score indicates that consumers are likely to make negative comments on the firm and switch the provider. Hence, a good understanding of user needs is a key to innovation success (Herstatt and Von-Hippel, 1992). Innovation can only enable contractors to gain, or prevent the loss of, a strategic market position and possibly improve profitability when consumers feel satisfied with the companies' innovative services and products.

Research method

Model development method

This study employed systems modelling which involves the modelling of intertwined causal loops. Table 1 presents the typical denotations used in preparing causal loop diagrams. At the foundation of the systems approach are positive and negative feedbacks. Positive feedback is represented by a reinforcing loop that is structured by none or an even number of negative links while negative feedback is represented by a balancing loop that is structured by an odd number of negative links. Positive feedback creates reinforcing behaviour and negative feedback moderates a system towards an equilibrium position.

To validate the relationships within a systems model, each key variable has to be significantly correlated to all other key variables considered. Pearson correlation was utilized by this study to investigate the positive and negative correlation values that determine the direction and degree of association between the key variables considered in this study. Statistical software Statistical Package for the Social Sciences (SPSS) version 11.5 was used to calculate the bivariate correlations.

To understand the relationships between innovation costs and benefits, four variables are statistically considered: contractors' level of investment in innovation; construction labour productivity; contractors' research capabilities; and contractors' turnover. These factors are operationalized with measurable indicators in Table 2. For the indicator of the level of innovation performed by contractors, this study adopts the proxy of business enterprise intramural expenditure on R&D (BERD) as defined by the OECD (OECD, 2002). Extramural expenditure is not utilized in this study as it involves R&D performed by other sectors of the economy such as governments and non-profit organizations. Hence this study takes BERD under the classification of construction industry in the international standard industrial classifications (ISIC) Rev. 3 as the total volume of construction firms' investment in innovation within a nation for a particular period. Details of the selection of ISIC Rev. 3 will be discussed later. The rest of the proxies in this study follow this classification for the statistics on local contractors.

Data collection

The OECD produces internationally agreed instruments, decisions and recommendations in areas where multilateral agreement is necessary for individual

Table 1 Denotations for causal loop diagramming (Sterman, 2000)

Types of causal links	Denotations
$A \xrightarrow{+} B$	All else remaining equal, an increase (decrease) in the variable 'A' increases (decreases) the variable 'B' above (below) what it would otherwise have been
$A \xrightarrow{-} B$	All else remaining equal, an increase (decrease) in the variable 'A' decreases (increases) the variable 'B' below (above) what it would otherwise have been

Table 2 Variables measurement framework

Variables/factors	Measurement framework
Local contractors' investment in innovation	Annual R&D expenditure of local contractors
Construction labour productivity	Percentage change in construction value add per person employed
Research capability of local contractors	FTE[a] value of R&D personnel in construction
Turnover of local contractors	Annual turnover of local contractors

Note: [a]FTE: full time equivalent. Methodology based on *Frascati Manual* (OECD, 2002).

countries to make progress in a globalized economy (OECD, 2006). The OECD is also well known for its publications, country surveys and statistics covering economic and social issues from macroeconomics, to trade, education, development and science and innovation. Hence, it is useful for this study to utilize the definitions provided by the OECD as the basis for further investigating and defining the variables in this study. This study also follows the classification undertaken by the *Frascati Manual* (OECD, 2002) that utilizes the ISIC Rev. 3 for the purposes of R&D statistics (Section 2.5). This study's focus is on the ISIC classification of 'construction', which includes 'general construction and special trade construction for buildings and civil engineering, building installation and building completion. It includes new work, repair, additions and alterations, the erection of prefabricated buildings or structures on the site and also construction of temporary nature' (United Nations, 2002, p. 129).

The OECD member countries that follow the statistical methodology for their national data were selected for this study's empirical analysis. This ensures that international data that are comparable from the statistical methodology point of view were utilized. Furthermore, most OECD member countries have the knowledge base and technological capability needed to sustain a high standard of living (OECD, 1999). Thus the OECD countries possess the opportunities and demands for effective and novel products to be implemented.

The OECD countries in this study are based on the list of member countries from the year that provides the highest number of OECD countries with sustainable data. Most of the OECD member countries' data are consistent from 1992. In 1992, 17 out of a total of 24 OECD member countries (OECD, 2005) provided the complete set of data required by this study. Hence, the final sampling frame consists of 17 OECD member countries, and Singapore where the interviews for this study were conducted, providing a total of 18 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Singapore, Sweden, Spain, United Kingdom and United States.

However, as Singapore is not a member of the OECD, the OECD would not have adequate comprehensive data for Singapore. Hence, for Singapore, the annual R&D expenditure of local contractors is obtained from the *National Survey of R&D in Singapore*, which is based on the guidelines of the OECD's *Frascati Manual* (OECD, 1993). The rest of Singapore's secondary data are collected from various national publications, such as the *Yearbook of Statistics*, *Economic Survey* and *National Survey of R&D in Singapore*, which also follow the OECD's international statistical guidelines.

The data collection was undertaken in February and March 2005. In that period, these 18 countries only provided adequate data for all proxies in this study up to 2002. Hence, the period of analysis was the 11 years from 1992 to 2002, a total of 198 data points.

Statistical limitations

There are various statistical limitations in this paper. First, the variable 'contractor's level of investment in innovation' operationalized by the proxy, R&D expenditure, may only provide a partial representation of contractors' level of innovation. The level of innovation is an aggregation of many factors such as 'learning-by-doing' in project-based environments and innovative collaborative relationships between firms and their clients and suppliers.

An alternative to using R&D expenditure as a proxy for the contractors' level of innovation is to conduct surveys on Singapore contractors. However, this would only provide a partial figure, subject to the hazards of the response rate and the accuracy of responses. Moreover, this would be inappropriate in the present study because, first, the study is undertaken at the macro, national level. Hence, such partial data could not be sufficient for comparison with the other national level variables such as construction turnover. Second, this study involves the investigation of 18 countries. Hence, comparable data based on international methodology is important. The secondary data had to be in accordance with international standards of data collection methodologies. The R&D expenditure data approach adopted in this paper follows the guidelines set in the OECD's *Frascati Manual* that is applied in the leading countries where R&D expenditure is used as a proxy for measuring innovation. In the OECD's *Frascati Manual*, the expenditure flows of R&D are based on the replies from performers of R&D and not on replies from the sources of funds. This suggests that investments in any technology, personnel training or any innovation expenditures that the contractors deem to be part of their companies' innovation strategy would be reflected in the data they report on their 'R&D expenditure'

Second, the level of R&D expenditure studied in this paper is limited to that of the contractors. Various parties in the construction process, such as contractors, consultants and suppliers can also contribute to the level of innovation in the construction industry. This study has adopted such limitations to maintain the scope of the study within reasonable limits. In addition, in the ISIC for 'construction' (ISIC code 45), applied by international statistical organizations such as the OECD and World Bank, 'construction' is only classified under the sectors of: site preparation; building of complete constructions or parts thereof; civil engineering; building installation; building completion; and renting of construction or demolition equipment with operator. The sectors that consist of architectural and engineering consulting firms are excluded from ISIC code 45. To overcome such limitations in investigating innovation in the construction industry, Reichstein *et al.*'s (2005) study of the innovative behaviour of construction firms grouped architecture, engineering consultancy and associated services into the broad definition of the 'construction industry'.

This study has refrained from doing likewise. This is because first, to obtain data for the 'design and consultancy sector' of the construction industry, Reichstein *et al.* (2005) drew data from the UK innovation survey which involved a total of over 19 600 business units. However, this study's research method involves the collection of national data across 18 countries. Therefore, a research method similar to Reichstein *et al.*'s (2005) will be too wide for the scope and time frame of this study. Second, while Reichstein *et al.*'s (2005) objective is to enable a close comparison between the construction industry and other sectors of the economy, one of the aims of this study is to investigate and highlight contractors' level of innovation. By aggregating the roles of designers, consultants and contractors into a single measurement of innovation, the said objective of this study cannot be accomplished.

Third, the paper does not account for different R&D structures in different countries. However, the level and direction of R&D investments would largely be determined by the structure of the countries' economies. The structures of the 18 countries' economies analysed according to the percentage of total employment and GDP and further analysed in terms of the three main economic activities of agriculture, industry and services are presented in Table 3. Table 3 shows that in most countries the services sector on average contributes about 65% of the total employment and GDP. This is followed by the industrial

Table 3 Countries' structure of economy (base year 2004) (World Bank, 2004)

	Percentage of total employment			Percentage of GDP		
	Agriculture	*Industry*	*Service*	*Agriculture*	*Industry*	*Service*
Australia	5.00	21.50	73.50	3.51	26.19	70.29
Austria	6.20	30.60	63.10	2.44	32.86	64.70
Belgium	2.20	24.70	68.20	1.38	27.85	70.78
Canada	3.60	22.40	74.00	2.52	31.77	65.72
Denmark	3.30	26.70	69.80	2.63	26.22	71.15
Finland	6.20	27.80	65.60	3.63	33.63	62.75
France	1.60	24.40	74.10	2.67	24.89	72.43
Germany	2.80	33.70	63.30	1.21	30.98	67.80
Italy	5.50	32.90	61.40	3.08	29.31	67.61
Japan	5.20	31.70	62.50	1.49	32.3	66.21
Netherlands	3.10	21.40	72.60	2.89	26.31	70.80
Norway	4.70	22.80	72.40	2.47	35.71	61.82
Portugal	12.80	35.40	51.70	3.86	30.42	65.72
Singapore	0.30	28.50	71.10	0.15	35.48	64.37
Spain	7.20	31.10	61.70	3.90	29.99	66.11
Sweden	2.50	25.10	72.30	2.14	29.56	68.31
United Kingdom	1.60	26.00	72.10	1.19	28.54	70.27
United States	2.60	23.10	74.40	1.62	24.73	73.65

sector (about 30%) and the agriculture sector (about 5%). Hence, these 18 countries' structures are aligned with Kamerschen *et al.*'s (1989) observation that in the highly developed countries, employment in the services industries actually exceeds employment in manufacturing. Although this paper limits the extent of investigating the compatibility of the R&D structure of each country, the economic structures of these 18 countries are reasonably similar and their composition is suitable for the investigation of the level of innovation within a single industry of construction in each country.

Interviews

The system model encompassed some non-measurable variables that could not be statistically validated. This study has adopted an interview approach to support the established logics. The objectives of the interviews are thus to provide further support to the logics of the causal loops, and to gather additional information regarding the feedbacks within the systems model. Semi-structured interviews with an interview guide were conducted. This enabled the responses to be guided, yet flexible. In addition, comparable information that focuses on the issues covered could be gathered from all interviewees.

Three main groups of actors were interviewed: national institutions, main contractors and clients. Contractors were further divided into four strata based on firm size and geographical origin to identify any characteristic differences in their perception of construction innovation (Table 4). Interviewees were selected through convenience sampling as the nature of the questions required the interviewee to be a top management person who understood the firm's business strategies and vision. Hence personal contacts were utilized.

Daymon and Holloway (2002) observe that the appropriate number of interviewees chosen for research will depend on the type of research question, the type of qualitative approach used in the study, material and time resources as well as the number of researchers involved in the study. Therefore, samples may be small as long as 'saturation' occurs: this is when no new information emerges that is important for the study (Daymon and Holloway, 2002). As data saturation was reached within the sample size of three for each stratum of interviewees, no more interviews were conducted. The profiles of the interviewees are presented in Table 4. A total of 21 construction practitioners were interviewed.

Table 4 Minimum number of interviewees for each selected NSI actors

Group	Stratum	Abbreviation	Designation	Minimum number of interviewees	
Local contractors	Small	SC 1	Owner	Total number of interviewees for 'local contractors'	9
		SC 2	Owner		
		SC 3	Marketing executive		
	Medium	MC 1	Construction manager		
		MC 2	Construction manager		
		MC 3	Contracts manager		
	Large	LC 1	Senior project coordinator		
		LC 2	Business process manager		
		LC 3	Project engineer		
Foreign contractors		FC 1	Contracts manager	Total number of interviewees for 'foreign contractors'	3
		FC 2	Project director		
		FC 3	Deputy managing director		
Clients	Public	PuC 1	Deputy director	Total number of interviewees for 'clients'	6
		PuC 2	Project manager		
		PuC 3	Program manager		
	Private	PrC 1	General manager		
		PrC 2	Managing director		
		PrC 3	Project manager		
National institutions		NI 1	Executive director	Total number of interviewees for 'national institutions'	3
		NI 2	Senior development officer		
		NI 3	Deputy director		
Grand total of minimum number of interviewees					21

Table 5 Pearson correlations results

		Contractors' investment in innovation	Construction labour productivity	Contractors' research capabilities	Contractors' turnover
Contractors' investment in innovation	Pearson correlation	1			
	Sig. (2-tailed)				
	N	198			
Construction labour productivity	Pearson correlation	0.223(**)	1		
	Sig. (2-tailed)	0.002			
	N	198	198		
Contractors' research capabilities	Pearson correlation	0.942(**)	0.180(*)	1	
	Sig. (2-tailed)	0.000	0.011		
	N	198	198	198	
Contractors' turnover	Pearson correlation	0.231(**)	0.142(*)	0.081	1
	Sig. (2-tailed)	0.001	0.046	0.257	
	N	198	198	198	198

Notes: **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Empirical results and analysis

Empirical results

From the Pearson correlation results presented in Table 5, all variables tested are significantly related to one another except for the relationship between two variables: 'contractors' research capabilities'; and 'contractors' turnover'. Hence, the following systems model would not portray any direct relationship between these two factors.

Development and analysis of systems model

Based on the literature review and Pearson Correlation results, a provisional systems model of the impacts of innovation on construction businesses was developed; this is presented in Figure 1.

The Pearson correlation results can be analysed at two levels. First, the significance and direction of relationship between two key variables, such as the positive relationship between the 'contractors' investment in innovation' (A) and 'contractors' research capabilities' (B), is statistically validated to be significant (Table 5).

Second, as suggested by Park *et al.* (2004), some relationships between key variables in the systems models are not represented directly by the statistical results. They observe that this is due to the presence of 'soft variables' which can be viewed as a mediator. For instance, the indirect relationship between X and Z (through Y) can be presented in the diagram as

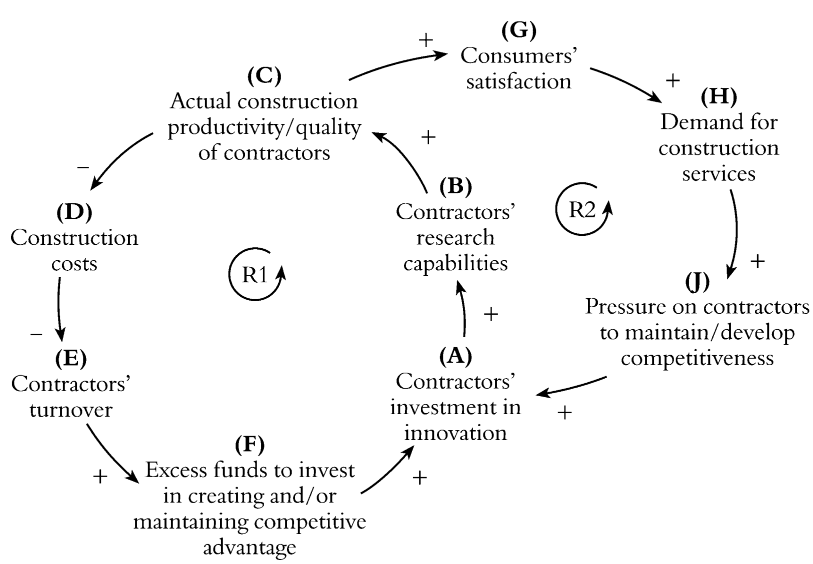


Figure 1 Provisional systems model

X→Y→Z where Y is known as the mediator. For example as shown in Figure 1, causal loop R1, the relationship of 'contractors' turnover' (E) and 'contractors' investment in innovation' (A) is through the mediator of 'Excess funds to invest in creating and/or maintaining competitive advantage' (F).

Park *et al.* (2004) offer two interpretations of such a relationship. First, Y may be viewed as a mediator of the X–Z relationship such that the effects of X on Z are completely mediated by Y. For example, an increase in 'contractors' turnover' (E) may drive an increase in 'excess funds to invest in creating and/or maintaining competitive advantage' (F). This would cause an increase in 'contractors' investment in innovation' (A). Second, X affects Y and Z directly. For instance, 'contractors' turnover' (E) causes an increase in both 'excess funds to invest in creating and/or maintaining competitive advantage' (F) and 'contractors' investment in innovation' (A). Kelloway (1998) observes that one of the conditions for mediator test is that X and Z are significantly related.

Owing to the presence of 'soft variables', the systems model must be validated by interviews. The next sections present the interview results, their applications, and further developments of the final systems model.

Results of interviews

Profit maximization—a driver of construction innovation

All 21 interviewees agreed that profit is the basic motivational force for innovation. This is similar to Linde and Porter's (1995) and Schumpeter's (1934) observations that firms are essentially seeking returns. LC 1 observed that 'Survival comes before R&D. There must be available profit to fund R&D'. This opinion generally reflected the viewpoints of all the 12 contractors interviewed. FC 1 noted that,

> The ability to set aside certain margins and being prepared to do so is important. Money in excess is very important. A company not making money will of course cut down on R&D and transfer its money to essential survival.

FC 1 continued: 'You need money to spin more money.' FC 2 also explained,

> Financial capacity directs how far you can go [in innovation]. Japanese contractors or any large foreign contractor usually have over 100 years of history. For us, we are a contractor and also a developer. We have our own investments in properties, and many other assets. Therefore, when we seek loans from banks, they are willing to provide the necessary loans because we are able to provide the required collaterals. How many contractors in Singapore are also developers?

LC 2 provided the viewpoint of a local contractor, observing,

> Foreign companies such as those in Japan have 500 years of history. How many firms in Singapore have even 50 years? Foreign companies such as Dragages and Shimizu have the essential backing from their banks. If local contractors obtain loans from local banks, these banks would sue once a single payment is defaulted. Local banks do not support the local construction industry. Without money, how can you compete?

All nine local contractors interviewed noted that monetary risk is the most significant risk factor to consider in R&D. They noted specifically that the setting up and testing of prototypes requires large volumes of funds and hence involves high financial risks. Other risks cited included time, inadequate expertise, and fast-changing technology and imitation by competitors that shortens the life cycle of inventions. LC 3 observed that 'Contractors have to make their decisions on innovation based on quantified risks'. LC 2 also noted that,

> R&D can end up as wasteful efforts and resources. Bearing in mind that when you tender for projects, no one will ask you if you are engaging in R&D. The cost and risk are purely on your shoulders.

The clients interviewed also noted the importance of profit as a driver of innovation. PrC 1 observed, 'Where can local contractors get the money from [to innovate]? Without money there is nothing much more to say.' These responses from the interviewees are in line with the observation by Seaden *et al.* (2003) that there is a significant relationship between profitability and business innovation. Similarly, in Figure 1, R1 shows that 'Excess funds to invest in creating and/or maintaining competitive advantage' (F) drives the level of 'contractors' investment in innovation' (A).

Construction innovation—a contribution to contractors' competitive advantage?

Contrary to the point made by the OECD (1997), the contractors interviewed did not perceive innovation as being able to provide a competitive edge of a combination of lower price and a higher mark-up than competitors. They believed that innovation offers non-monetary benefits. This concept is presented in Figure 1, causal loop R2, where a positive consumers' reaction on a product or process improvement may lead to a continuous investment in innovation by contractors. SC 1 noted that,

> There must be substantial reasons to engage in R&D. For us, innovation is our strategy to establish rapport with our clients, which may in turn provide future benefits such as clients' willingness to award more projects to us.

To the large contractors, innovation provides non-monetary returns, such as recognition and prestige, which differentiate them from the rest. FC 2 observed that,

> Innovation allows my company to stay at the forefront of the industry. It also allows us to catch a market trend due to our increased know-how and experience. This usually enables us to satisfy our customers' demands and build their confidence in our service.

FC 2 further explained,

> I believe in any business, branding is important. You want people to know you are the only company that is able to provide a particular product or service. That is what makes you different and the core reason for people to search for you.

However, the view expressed by FC 2 may be based on the sophisticated demands of clients in his home market in Japan, where demands of consumers may be more advanced in terms of the required technology and quality. The clients interviewed observed that consumers play an important role in encouraging contractors to innovate. PrC 1 noted,

> Why should contractors innovate when there is no demand for it? As the ultimate recipient of the products, the consumers have to demand it and be willing to pay extra for it.

Likewise, PrC 2 asked the question,

> Who does not want to produce quality products that meet their consumers' level of satisfaction? But are consumers willing to pay for it? Furthermore, there has to be adequate demand for construction work to sustain the survival of contractors before you can talk about improving contractors' technologies.

Consumers' willingness to pay for construction innovation

The contractors interviewed agreed that when their productivity and quality improve, the demand for their companies' services would rise. The results of the interviews showed that the impact of productivity and quality on construction costs, and hence profit, differs. All the interviewees except one agreed that the effort to enhance quality increases costs, whereas productivity should reduce it. One private client, PrC 2, argued that although productivity should reduce construction costs, improved quality does not necessarily increase costs. He believed that contractors would provide the best quality within their budgets.

Construction innovation is able to produce improvements in productivity and quality. However, owing to their differing impacts on costs, the transferability of their development costs to clients differs. For example, to clients, higher productivity through the application of new equipment or management techniques is just a differentiation tool with which they can sieve the better contractors from the others. As long as contractors are able to finish the projects within the contract time, productivity is not a specific requirement but a bonus. The contractors with higher productivity would have a competitive edge over their counterparts in the tendering process. Productivity is not a tangible product that clients can sell to their end users. Hence, they do not usually pay for it. Interviewee PuC 1, stated,

> If contractors are more productive, why should I pay them? Higher productivity means they are able to do the same work with fewer workers. They should be giving me a discount!

However, Interviewee PuC 1 provided a different response for quality products.

> Yes. I will pay for quality. But I will justify it through the CONQUAS[1] score say in a performance contract. You have to hit the stated score or I will not pay the price premium. Instead, you will face a penalty.

FC 3 provided the example of Far East Organization which was able to sell its developments at higher prices by proclaiming that its CONQUAS scores are high. From this, it appears that quality could be sold for a premium to consumers but not productivity. On the other hand, productivity is a hidden benefit whose transferability to consumers is dependent on clients' business strategies. Clients mainly reap the benefits gained from productivity through earlier sale or rental revenues. Nonetheless, not many clients would be willing to pay an upfront premium for productivity either in terms of accepting higher tender prices or by discounting the consumers' product price, when there are no guarantees of such returns. Hence, PrC 2 suggested that,

> It does not matter if you are a contractor, architect or engineer. At the end of the day you have to look at who is the recipient of your product. You want to be a better contractor to whom? Who is the recipient? You have to drive innovation and deliver it in the way that counts. This is consumer profiling, the identification of your target market segment.

In Figure 1, productivity and quality improvements are seen to reduce costs. Although this is aligned with the statistical results, the interviews identified that the impacts of productivity and quality improvements on construction costs differ. This may be due to the limitation of this study where the statistical analysis only accounts for the relationship between productivity and turnover owing to the difficulty in providing an adequate national measure of construction quality. Nonetheless, the verification of the soft variable of quality through interviews shows that it may increase construction costs. Hence, this phenomenon is presented in the final systems model of this study.

Aligning interview results, literature and systems model

Table 6 provides a summary of the results. Both interviewees and authors (such as Gann, 2000 and Seaden *et al.*, 2003) suggest that clients and consumers are assuming a more dominant role in dictating the pace of change in large projects, and are playing a vital role in stimulating contractors to search for new ideas. Nonetheless in construction, consumers are often not able to translate clearly and completely their specifications for product, price and delivery, let alone the more subtle issues of personal needs or organizational priorities key in optimizing consumers' satisfaction (Lyons and Alexander, 1991). Dillion *et al.* (2005) observe that the creation of exceptional value for both the clients and the consumers is an important consideration of contractors strategizing to innovate. This study thus suggests that consumers should be aided in translating their demands and preferences through established national standards. For instance, in Singapore, the Building and Construction Authority (BCA) awards the 'Quality Mark for Good Workmanship' to developers who achieve the stipulated quality workmanship standard to enable consumers to explicitly state and evaluate the quality, service and product that they receive. This scheme is a strategy not only to encourage contractors to adhere to the quality demands of consumers but also to provide a communication tool between the clients and the contractors to a common standard of quality that both parties could understand.

Of course the involvement of clients in the innovation process may also in part depend on the degree to which the clients perceive direct benefits to them from the innovation (Ivory, 2005). Similar to the points raised in the interviews, Ivory's (2005) demotivators of clients' participation in innovation include: costs; restricted completion time; and unreliability of innovation success. Hence, construction clients should not be expected to be habitual risk takers regarding innovations. Aligning responses from the interviews with the literature review, this study concludes that contractors bear the large part of responsibility for financing innovation. This suggests two further considerations that are now discussed.

First, since the funding of innovations is largely based on the financial capacity of contractors, their perception of innovation risks plays a fundamental role in their decisions to innovate. Nevertheless, innovations provide potential profit and intangible returns, such as recognition in the industry as a provider of advanced constructed products, which make such risks practicable. From this, it can be inferred that, as established by the interview results of this study and of authors such as Linde and Porter (1995), Slaughter (2000) and Prahalad and Venkat (2004), profit is the basic motivational force of innovation in the construction industry.

Second, since consumers' willingness to pay for an innovation may reduce the financial burden of innovating contractors, the categorization of innovations, in accordance with consumers' willingness to pay for them, would play a fundamental role in contractors' decision-making strategies, and possibly be the key in overcoming contractors' financial limitations in innovations.

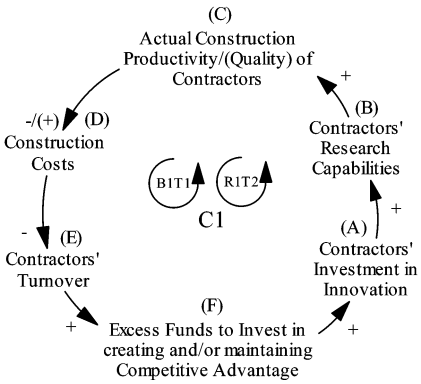
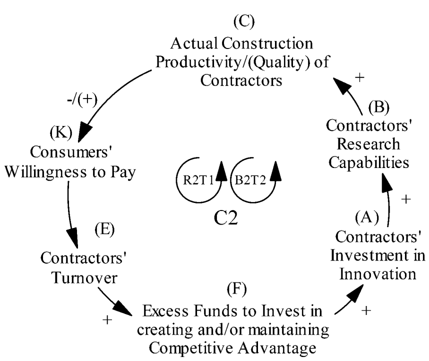
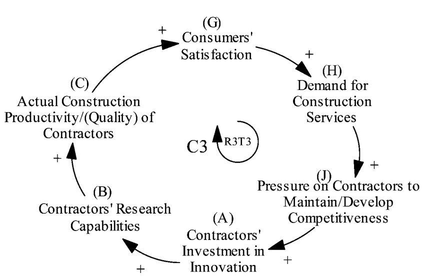
Recommended classification and final systems model

The results from the interviews indicate that not all innovation costs can be transferred to clients. Thus, two questions arise. First, why are contractors unable to transfer the cost of innovation to clients? Generally, manufacturers such as those of automobiles and mobile telephones can derive returns from innovations through price premiums on their products. Second, does this in turn imply that innovation is not useful in deriving competitive advantage in construction? From the results of the interviews, innovation in construction may be classified into three main categories:

(1) Type 1 innovations: innovations that consumers are willing to pay for.
(2) Type 2 innovations: innovations that reduce contractors' construction costs.
(3) Type 3 innovations: innovations that encompass intangible benefits such as improved reputation and high credibility, which provide contractors with sustainable competitive advantage.

These three categories of construction innovation are shown in the systems model in Figure 2.

Table 6 Summary of results

Causal loop	Statistical result	Interview results
	Correlation provides:	
	(Sig. at 1%) A→B:	Causal link: A→B→C
	(Sig. at 5%) B→C:	Contractors viewed an increase in innovation investments such as new IT management systems and staff training do improve their research capabilities. An increase in the level of construction productivity and quality is thus also evident.
	(Sig. at 5%) C→E:	Causal link: C→D→E All interviewees except one private client agree that improved construction productivity will decrease costs while increased construction quality will increase construction costs. Hence, clients suggest that the transferability of the innovation costs to clients differs with regard to the extent of productivity and quality benefits gained from the intended innovation.
	(Sig. at 1%) E→A:	Causal link: E→F→A 'There must be available profit to fund R&D' All interviewees agree that adequate funds are an essential asset in any innovation strategy. Without adequate profit, contractors are likely to cut down on R&D investments and transfer the money to essential survival. Specifically, contractors observe their ability to set aside certain margins for innovation and being prepared to do so is important. The foreign contractors note that financial capacity directs how far they can go in innovation.
	Correlation provides:	
	(Sig. at 1%) A→B:	Causal link: A→B→C
	(Sig. at 5%) B→C:	As established in causal loop C1 above.
	(Sig. at 5%) C→E:	Causal link: C→K→E All interviewees except one private client acknowledge that consumers are generally willing to pay for quality rather than increased productivity. However, all interviewees agree that consumers' willingness to pay for an innovation is an important consideration in contractors' innovation strategies. Causal link: E→F→A
	(Sig. at 1%) E→A:	As established in causal loop C1 above.
	Correlation provides:	
	(Sig. at 1%) A→B:	Causal link: A→B→C
	(Sig. at 5%) B→C:	As established in causal loop C1 above.
	(Sig. at 1%) C→A:	Causal link: C→G→H→J→A Contractors generally deem consumer satisfaction as basic criterion in the development of their 'brand' in the local industry. They link branding to the possibility of increased advantage in tendering of projects. Specifically for the small contractors, innovation is seen as a possible strategy for them to establish rapport with clients. Hence, with the development of increased creditability in the industry, both contractors and private clients felt that there is increased pressure on the contractors to maintain their reputation through new technologies and efficient management systems such as the implementation of IT systems.

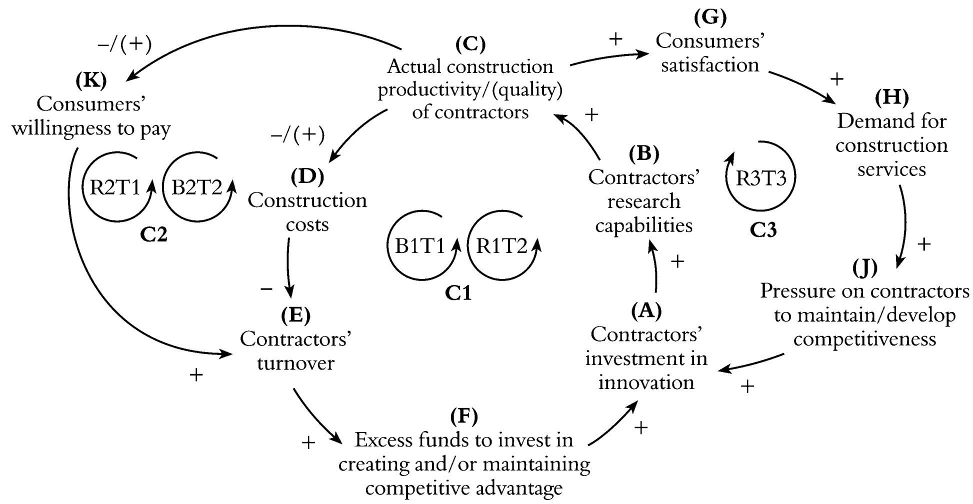


Figure 2 Impacts of innovations on construction business

As a soft variable, 'consumers' willingness to pay' was not considered in the statistical analysis. However, it was highlighted in the interviews as a significant factor in determining a suitable stakeholder to bear the cost of innovation. The interviewees suggested that quality could be sold for a premium to consumers but not productivity. Hence, although in causal loop C1, contractors that provide quality improvements face a balancing loop $B1_{T1}$, the increase in construction costs can be partially or fully transferred to consumers as depicted in the reinforcing causal loop $R2_{T1}$, in C2. This implies that contractors that provide quality improvements through innovation may do so constantly as consumers are willing to bear partial or absolute innovation costs.

For instance, Dragages Singapore Pte Ltd, a French construction firm, was engaged by the joint venture between SC Global Development and First Capital Corporation to undertake The Ladyhill project, another top-class luxurious condominium, owing to the assurance of quality although Dragages was one of the highest bidders. Therefore, contractors strategizing for immediate monetary returns from innovations must understand what clients and/or consumers are willing to pay for. Thus, Type 1 innovations require careful analysis of the target consumers.

Type 2 innovations are, for instance, innovations that improve productivity. Although such improvements do not provide immediate monetary returns on investments (depicted by $B2_{T2}$ in causal loop C2), they offer secondary monetary benefits such as the reduction of construction costs. For instance in the Bunker, Meadow Springs, Western Australia, significant cost savings were achieved from the implementation of a unique precast construction system. Additional benefits gained from this novel construction technique include an accelerated construction period and minimal time required for external and internal scaffolding. Similarly in Singapore, Kimly Construction Pte Ltd in cooperation with Poh Cheong Precast Pte Ltd for the construction of Sanutary Green condominium were not only able to reduce the amount of wet trades significantly through the implementation of combined precast and cast-insitu construction techniques but the contractors managed to deploy their sources more efficiently without relying too much on heavy equipment like tower cranes.

Therefore as portrayed in Figure 2, a Type 2 innovation presents a reinforcing loop, $R1_{T2}$ in causal loop C1. This implies that an increase in productivity can continuously reduce costs and hence improve contractors' turnover. However, as observed by Ball (1988), conservative consumers and clients may hinder the implementation of such innovations. The industry's practice of awarding projects based on the lowest cost may also render such innovations impracticable as the narrow profit margin is inadequate to sustain the innovation costs.

Nonetheless, the main competitive advantage Type 2 innovations offer lies in differentiating contractors in terms of their capabilities. However, for such competitive advantage to be sustainable, there should be a consistency that clients or consumers are able to identify, the idea of a brand. The interviewees also raised the concept of branding. These views are in line with that of Pedersen (1996) and the systems model, which suggest that the intention to innovate should be a constant purpose. These notions characterize Type 3 innovations that are depicted in Figure 2, C3, as a reinforcing loop, $R3_{T3}$. This implies that a commitment to innovation is paramount for contractors wishing to tap the benefits of Type 3 innovation. For instance, Shimizu Corporation, a Japanese construction firm, won the contract for the redevelopment of the Marco Polo Hotel into a luxury condominium although Shimizu was the highest bidder. The developers, Marco Polo Developments Limited, explained that this was because they believed that Shimizu would provide the best quality of work and safety standards as they have showcased their ability in Shimizu's SMART system (Shimizu, 2000), an automated intelligent system for high-rise building construction that has been modified and upgraded to suit various construction sites in Singapore.

The difference between Types 1, 2 and 3 innovation is that the first two are driven by the demands of consumers in terms of quality and productivity value while maintaining a highly cost-competitive market. Type 3 is more supply focused as contractors who adopt Type 3 innovations aim to predict and develop capabilities that would enable them to maintain a long-term competitive advantage. Hence, Types 1 and 2 form the basis of a reactive strategy while Type 3 supports a forward-looking strategy based on the needs of consumers. Interviewee PrC 2 suggested that contractors should constantly ask themselves this question,

> To be able to meet the demands of consumers now, and also that of the next recipient, what do I have to do to compete? What are the qualities that contractors require that attract developers?

To provide an outlook on the implications of the recommended classification of innovations to project-based organizations such as construction, Table 7 provides a brief introduction to possible business strategies at the project level.

Conclusion

The recommendation is that contractors wishing to implement an innovation strategy in their business plan should no longer classify construction innovation as product or process improvements. Instead, they should adopt this classification for strategic decision making in their businesses: innovations that consumers are willing to pay for (Type 1 innovations); innovations that reduce contractors' construction costs (Type 2 innovations); and innovations that provide contractors with sustainable competitive advantage (Type 3 innovations).

To maintain a sustainable turnover from Type 1 innovations, contractors should continuously re-examine the desires of consumers to derive the right demand signals. Since clients engage directly with consumers, a cooperative relationship would be useful in determining the tastes of the consumers. Such a cooperative relationship could mean collaboration by the contractor and the client as 'co-evaluators' of the demands and tastes of consumers, and 'co-inventors' of specialized products that meet consumers' requirements.

Table 7 Implications of the recommended classification of innovations to project based organizations such as construction

Innovation	Proposed business strategies	Specific recommendation
Type 1	Establish communication links with clients to hasten the flow of consumers' demand signals and information to company	Develop cooperative relationships with clients in the early tendering phase of the project to determine the tastes, demands and needs of the consumers. This would facilitate the selection of an appropriate innovation strategy according to consumers' willingness to pay for the output of the intended innovation. In addition, it allows contractors to develop strategies with the clients, the intentions of the contractor in developing an innovation specific for the project for shared monetary gains.
Type 2	Maximize secondary monetary returns from Type 2 innovations	Complement Type 2 innovations with good project management techniques such as early project planning at the design stage and regular project meetings with key personnel to reduce level of rework and project delays.
Type 3	Maintain a sustainable commitment to innovation	Establish the decision to implement the innovation project based on its returns over the life cycle of the innovation process or product and not on initial expenditures.
		Identify and promote to all employees the potential contributions of the intended innovation to the company's competitive advantage and long-term business strategies.
	Cultivate an innovation culture	Encourage innovation mindset among employees and introduce appro priate incentives and rewards.
		Encourage the documentation of construction work processes, especially new and novel construction methods.

Nonetheless, contractors wishing to reap all the benefits of their innovation, or which are wary of engaging in such partnerships, could adopt Type 2 innovations. However, for sustainable investment in Type 2 innovations, contractors should complement it with the development of capabilities that differentiate them from their counterparts in a manner that counts to clients. This is Type 3 innovations. These results suggest that it would be useful for contractors to tap the role of clients in the construction value chain to strategize their business directions and, specifically, types of innovations.

The practical approach proposed here can guide construction firms in their development of innovation strategies. This compliments the existing, quite well-known classification of innovations in terms of their physical characteristics and their impacts on the construction product itself. Developing a classification that is closer to the business strategies of contractors, the financial and competitive advantages of innovations will encourage contractors to strategize their innovation strategies according to their business needs. However, the findings from this study need to be augmented with further research aimed at developing cooperative partnerships between contractors and clients.

Note

1. Construction Quality Assessment System (CONQUAS), launched in 1989, is used to assess buildings based primarily on workmanship standards. The assessment is done throughout the construction process for structural, mechanical and engineering works and on the completed building for architectural works.

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