Tailoring Competitive Advantages Derived from Innovation to the Needs of Construction Firms

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Abstract: Innovation is often classified as a cost intensive investment in the construction industry with indefinite returns. Due to the clients' tendency to award projects based on the lowest costs, innovation is often seen as an unfeasible strategy toward the competitiveness that construction firms are seeking. This study questions whether it is indeed ineffective for construction firms to develop their competitive advantage through innovation. By the application of statistical data across 18 Organization for Economic Cooperation and Development (OECD) countries and expert interviews in Singapore, innovation systems models are developed for both manufacturing and construction firms, respectively. Through comparison of both models, the results suggest that the peculiarities of the construction industry deem innovation as a poor competitive instrument for direct profits. Instead, construction firms can develop their competitive advantage through manipulating innovations that consumers are willing to pay for and innovations that would reduce construction costs. It is recommended that construction firms first utilize quality improvements to exploit consumers' willingness to pay for innovative products. This initiative would enable construction firms to improve their finances for innovation and develop their "brand" in construction products. Sustainable competitive advantage could then be firmly established when construction firms engage in productivity improvements that lead to lower construction costs and/or faster completion times. This study concludes that innovation can be a useful competitive tool if construction firms aptly strategize it in according to its competitive environment.

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Introduction

Background

Sebestyen (1989) noted the leap from traditional labor intensive methods to modern production of building materials and components of off and on-site as the industrialization of construction. This term "industrialization," has led various writers, since the 1980s (such as Hounshell 1984, Egan 1998, and Reichstein et al. 2005), to categorize construction as a traditional or low technology sector. In construction, the craft method of operation is still being used while other sectors, in particular the manufacturing sector, have modernized through interchangeable parts, then assembly lines, automation, and now robotics. Construction is thus seen as falling further and further behind the rest of the industries in terms of productivity, quality, and value for money (Miles 1996). However, Winch (2003) criticized this view, challenging the widespread assumption that there is conclusive evidence of the poor performance of the construction industry compared with other industrial sectors. Similarly, this study argues that it is not that the construction industry does not innovate but the nature of competitive advantages that innovation has to offer to the construction businesses seems inappropriate in their competitive environment.

Gann (2000) observed that construction firms, in the absence of legislation, can afford not to innovate because site based projects, with the protection afforded by transport cost, lack internal sectoral dynamics that impose competitive pressures on noninnovating firms. Burrows and Seymour (1983) observed 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. Since innovation is deemed as a cost intensive investment in the construction industry with indefinite returns, construction firms are generally not willing to incur innovation costs as part of their business expenditure (Lim and Ofori 2007). Such business stance is in contrast to the manufacturing firms where the Organization for Economic Co-operation and Development (OECD) group of countries has seen a continuous growth in innovation investments since 1990 within the manufacturing sector [Organisation for Economic Co-operation and Development (OECD) 2008].

The high levels of investments in innovation by the manufacturing sector may be due to the importance of competitive advantage required for firms to defend their position in an aggressive industry. OECD (1997) agrees, noting that innovation is a source of some advantage for the innovator where depending on the elasticity of demand, a combination of lower price and a higher

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mark-up than its competitors will allow the innovator to gain larger market share and seek greater rent. Innovation can thus be a primary source of wealth creation (Quinn 1992; Prahalad and Venkat 2004).

Nonetheless in construction, setting a premium price on construction work is not a conventional practice. To conform to price competition, contractors often move away from technological differentiation to differentiation in terms of costs. This condition is further aggravated by consumers' tendency to award projects based on the lowest costs (Dulaimi et al. 2002; Latham 2002). This however, does not imply that competitive advantage in construction is redundant, and innovation is dispensable. On the contrary, there is raising significance being placed on firms' ability to create intangible assets that are "firm" or "ownership" specific (Dunning 1993; Lim and Ofori 2007). These assets would create increasing international mobility on the part of enterprises and technologies (Lundvall 1992; Nelson 1993), removing the geographical protection of intense competition from international construction players (Lim 2007). Hence, the time is thus right for an investigation of the competitive impacts of innovation on business generally and in construction specifically. An understanding of these impacts would enable construction businesses to strategize their innovation in the manner most suited to their competitive environment.

This paper is structured as follows. After the introduction, the research aim and objectives of this study are explained. Next, as this study employs systems modeling in the early stages of its investigations, an explanation of this modeling technique is first presented. Following this, the definitions of innovation and differentiations between consumers of the manufacturing and construction industries are addressed. To understand the distinction between construction and manufacturing industries, the unique characteristics of the construction sector are highlighted. Based on these reviews, a model of the competitive impacts of innovation on the manufacturing sector is presented. The manufacturing model is then transformed, through the application of interviews of construction experts and construction statistical data, into a construction innovation model. Finally, recommendations and conclusions are presented.

Research Aim and Objectives

This study aims to investigate whether innovation is a useful mean for construction firms to derive competitive advantage. Its objectives are to: (1) highlight the different competitive impacts of innovation on manufacturing and construction businesses; (2) develop a construction innovation model portraying the competitive impacts of innovation on construction businesses; and (3) recommend innovation strategies for construction businesses suited to their competitive environment.

Systems Modeling

This study employs qualitative systems models that utilize causal loop diagrams to structure the understanding of the innovation system and to show the dynamics of the variables employed. At the foundation of the systems approach are positive and negative feedback. 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 behavior and negative feedback moderates a system toward an equilibrium position (Table 1). In this study's

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.

models, reinforcing loops are denoted by "R#," while balancing loops are denoted by "B#." The sign "#" represents the causal loop's identification number.

Review of Literature

Innovation and Customers of the Manufacturing and Construction Industries

Innovation is defined by Lundvall (1992) (p. 8) as a potential new combination that "results in radical breaks with the past, making a substantial part of accumulated knowledge obsolete." For the manufacturing sector, innovation serves as a means of developing and sustaining core competencies through development of internal capabilities, set ups of research and development (R&D) departments and strategized research scopes and investments. Conversely for the construction industry, innovation is often stimulated by the requirement for an innovative response to an immediate problem or to meet the consumer's specific needs. In construction, every project, whether it involves new work or repair can be considered a prototype because every construction project is at a new and different site and most often for a different owner (Manseau and Seaden 2001). Construction practitioners and their clients often interpret this application of conventional construction practices and methods in new situations as innovative behavior. However, there is no evidence of continuous improvements in the industry's adoption and implementation of processes and products that such "routine innovations" should have brought about. Groak (1992) hence observed that innovation in construction businesses is often informal, unrecorded and bespoke to one project.

Nonetheless, this study argues that the lack of a planned procedure in construction, which retains the know-how for future reapplication, does not allow the deliberation and investigation process to be defined as innovation. Drucker (2002) noted that for businesses generally, innovation success is more likely to result from the systematic pursuit of opportunities than from a flash of genius. Pedersen (1996) also observed that the intention to innovate should be a constant purpose. Constancy of purpose will provide the secure atmosphere in which innovation can flourish. This study hence defines innovation as "the *purposeful* search for new knowledge and the *systematic* application of this knowledge in production."

Regarding customers of innovation, for the manufacturing sector, customers are simply individuals or households that purchase goods and services generated by the firm. They acquire goods or services for direct use or ownership rather than for resale or use in production and manufacturing. However, for the construction industry, customers vary considerably in size, interest and motivation (Ofori 1990). Ofori (1990) observed that four groups of customers are discernible in construction: public sector clients,

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Table 2. Six Factors That Shape the Nature of Innovation in Construction (Adapted from Reichstein et al. 2005)

Factors	Brief explanation
Liability of projects	Construction is largely a project based activity with temporary coalitions of different organizations attempting to achieve a task over a specific period
In situ production	Construction often involves high levels of in situ production
Liability of uncertain demand	Many projects involve the creation of highly bespoke products, focused on meeting the requirements of individual customers
Liability of smallness	The construction industry is often dominated by small firms with little or no professional staff
Liability of separation	Construction is largely a project based activity with temporary coalitions of different organizations that come together to attempt to achieve a task over a specific period. In a construction project, design is usually separate from production and production is often separate from maintenance.
Liability of assembly	The contractor is usually responsible for the assembly of a range of different components and the integration of different systems

private occupiers or end users, 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 divided customers of the construction industry into two parties. First, the term "client" designates the initiator of the construction process, the individual or group financing the project that have a direct impact on the construction company's decision to innovate. Second, the "end users" comprises the customers 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. For the ease of reference in this study, consumer is termed generally as customers of the manufacturing industry. For the construction industry, the consumer is used to define the sum of both groups of end users and clients of the industry.

Introducing the Unique Characteristics of the Construction Industry

In many studies of innovation, construction is seen as a low performing sector, exhibiting low rates of innovative activity (Gann 1994; OECD 2000). Ball (1988) argued that construction is not backward, but simply different. Schultmann and Sunke (2006) compared the characteristics of recovery strategies in manufacturing and construction industries, showing that recovery in construction is far more complicated than in manufacturing. Nam and Tatum (1988) compared the characteristics of constructed products with those of manufacturing, arguing that five specific differences limit the development of construction technology, these being: immobility, complexity, durability, costliness, and high degree of social responsibility. Reichstein et al. (2005) following Nam and Tatum (1988) identified six factors that shape the nature of innovation in construction (Table 2). Both Reichstein et al. and Nam and Tatum cited these characteristics as creating a "locked system" in which innovation, or changing the status quo, becomes difficult. Nonetheless, recent symposiums have identified that innovation in construction is becoming the

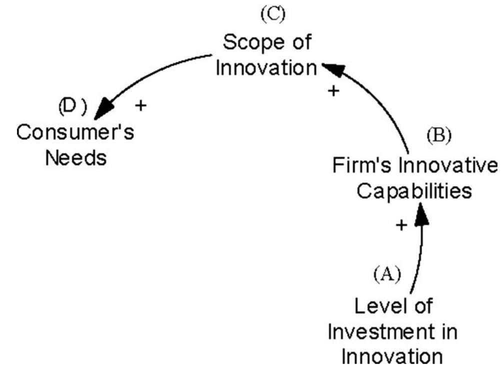

Fig. 1. Increasing innovation capabilities through investments

principal competitive tool for businesses to achieve market penetration and increased profitability (National Research Council of Canada 2001). To further examine these views, the following sections briefly discuss the competitive impacts of innovation on manufacturing businesses generally and their implications when the unique characteristics of construction are considered.

Increasing the Scope of Products and Services

One of the advantages that innovation provides for businesses is the ability to diversify or reinvent their products and services to meet the desires of consumers. To increase the scope of products and services through innovation, there is a need to develop the capabilities to do so. Milford (2000) observed that learning to innovate is strongly related to the availability of capital investments for plant and equipment. With available investments, firms are able to improve their ability to develop new products and processes and achieve superior technological and/or management performance (Rangone 1999).

For instance, Sony Corporation believes that innovation is essential to growing their businesses. It has seen increasing growth in its innovation investment since 2001, investing ¥543.9 billion (estimated $5.04 billion) in R&D in 2007 alone (Sony Corporation 2007). This high level of innovation investment enables Sony to pursue a broad range of technologies, including those intended to support existing products and services, such as high definition related technologies for the home and mobile electronics sector, and those that will create new markets, for example shifting from inorganic to organic materials in its electronics production (Sony Corporation 2004).

To present these concepts into useful feedbacks, systems modeling is used. As presented in Fig. 1, an increase in firm's investment in innovation (A) would lead to an improvement in its innovative capabilities (B). This in turn could widen the firm's scope of innovation (C). An increase in the firm's scope of innovation would thus improve their ability to meet consumer's needs (D).

Although understanding consumers' needs is key in innovation, several writers (Prahalad and Hamel 1990; Christensen 1997) pointed out that in the manufacturing sector, consumers often lack the foresight to provide the basis for new products. Hence, for the manufacturing sector, technologies are often developed through R&D and then tested on the market. Freeman (1989) terms this as "technology push." For the manufacturing firm, control over core products is critical as it allows the firm to shape the evolution of its products and end markets (Prahalad and Hamel 1990).

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This is in contrast to the construction industry where consumers are often placed at the center-stage of the innovation process (Miller et al. 1995; Nam and Tatum 1997; Gann 2000). Reichstein et al. (2005) observed that for the construction sector, demand usually depends upon fixed capital investment decisions, where clients and several stakeholders often play a significant role in shaping the design and the production processes. This "liability of uncertain demand" (Table 2) tends to limit the influence construction firms have over their own future markets. Freeman (1989) termed this as "market pull," whereby markets signal their requirements to technologists, who respond with new or improved products. Where innovation makes "no sense" to clients and other key decision makers within the project team, attempts to promote innovation are either ignored or subsequently starved of resources (Dougherty and Hardy 1996). The aspect of client's involvement in the innovation process thus depends on the degree to which the client perceives there to be benefits to them in innovating. Clients concerned with budgets and completion times are likely to shrink from innovation (Ivory 2005). For the construction sector, understanding consumer's needs and their willingness to invest in innovation, either in monetary values, time or other critical resources, is important in developing their advantage over rivalries.

Consumer's Willingness to Pay

In economics, the concept of "maximizing utility" for an individual dictates that when a consumer's needs are increasingly being met, he would be willing to pay more for the product till his optimum utility is reached (Broadman et al. 2001). This economic concept is important in innovation where studies of innovation in manufacturing have long stressed the positive influence of the consumer on innovation (Lundvall 1992).

For instance, BMW automobile manufacturer has reinvented its production line to provide "mass customization" to its customers where customers are able to make as many changes to their car as they want until a cut-off point: 6 days before their car goes into production. By maximizing consumer's utility, tapping on their willingness to pay for customized products, BMW was able to sell nearly 1.4 million cars worldwide in 2006 bringing $65 billion in revenues (Gumbel 2007). Another example is Dell's make-to-order system which enables customers to "build" their personal computers to their own requirements. Customers are also able to provide direct and immediate feedback to suppliers concerning quality and reliability of their components. This system has enabled the Dell Company to sell $5 million of products on-line every day, building a $14 billion business in 14 years (Manufacturing and Technology News 1998).

Structuring these logics into a systems model, Fig. 2 presents that innovation is able to provide enterprises with the advantage of developing a scope of capabilities that enables the expansion of products and services that consumers require (C). A positive response of the innovation in regards to the needs of consumers (D), will increase consumer's willingness to pay for the innovative product (E). This would improve the innovating firm's profit and once again, increase the level of investment in innovation (A). This logic completes the motivation for firms to invest in innovation (Fig. 1), structuring R_M1 as a reinforcing loop that is able to create constant investment in innovation through received profits.

However, the dissimilar consumer base between the manufacturing and construction industries drives different competitiveness

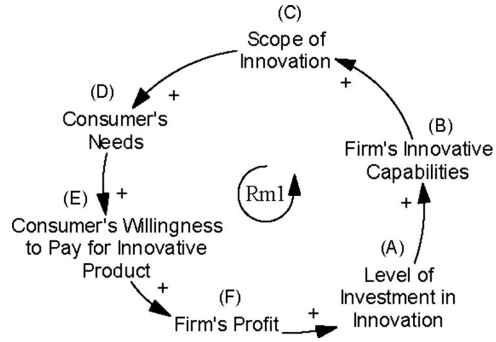

Fig. 2. Impact of consumer's willingness to pay on innovation

for both industries. For manufacturing, mass production is possible as there are numerous consumers who demand the same product. Even for customized services, mass customization is possible as customers are merely building their merchandise from standardized units of products. When the innovative products sold are highly demanded by consumers, supernormal profits can be reaped through economies of scale, providing further funds for innovation. Hence, for manufacturing enterprises, the ability to develop their innovating capabilities is in itself, a form of competitive advantage as it provides them with the continuous financial capability to defend their market and compete with rivals.

Nonetheless, for the construction firms, the target receiver of the innovation is often limited to a single project, for a single consumer (see Liabilty of Projects and Assembly, Table 2). In addition, due to the Liability of Separation (Table 2), the transfer of lessons from one project to another is problematic given that teams often disband at the end of projects. These episodic natures of activities in construction often limit the opportunity for construction firms to reap the "economies of repeatability" from their innovation outputs (Davies and Brady 2000). A single construction client would provide inadequate monetary funds to finance an innovation project and there are no incentives for the client to develop the construction firm's capability to do so.

For the construction firms, understanding what consumers are willing to pay for innovation is not only an important source of innovation finance but also a necessary element for construction firms' innovation strategy. Craig and Roy (1999) and Lim and Ofori (2007) observed that consumers' emphasis have been placed on the quality of building products and the reduction of defect rectification. These aspects suggest that consumers and thus construction firms' scope of innovation are influenced by productivity and quality of the end product.

Competitive Advantage

As discussed, the act of innovating can provide a firm with the capability to capture a substantial level of market share or create an entirely new market opportunity that enables a firm to reap supernormal profits. The slow response of competitors to such innovation strategies will yield competitive advantage to the firm. Placing these logics into systems modeling (Fig. 3), a firm that is able to better meet their consumers' needs than its rivals (D) could gain a large share of the market demand for the product (G). This enhances the firm's competitiveness (H), which will in turn compel the firm to invest more in innovation (A). For example, Apple knew that mobile phones were becoming music players and thus rivals to their iPod products. Thus, Apple developed the iPhone to enable the company to enter the mobile phone

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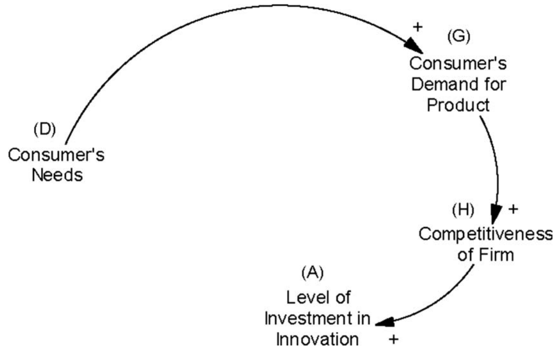

Fig. 3. Improving firm's competitiveness through innovation

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industry as a defensive strategy (The Economist 2007). Similarly in the construction industry, Obayashi developed the first Automated Building Construction System (ABCS) for reinforced concrete building construction. Obayashi developed the ABCS in face of the raising sophistication of the construction industry and the need to continuously provide advance technical proposals to win construction project bids (Obayashi Corporation 1996).

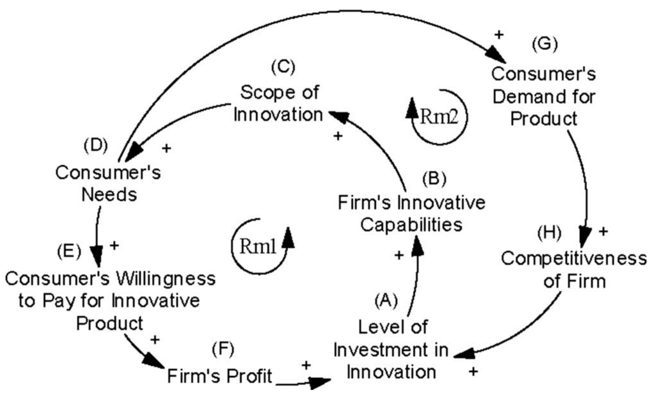

Fig. 4. Competitive impacts of innovation on manufacturing enterprises

Incorporating Fig. 3 with Fig. 2, a model of the competitive impacts of innovation on the manufacturing industry is presented in Fig. 4. Causal loop R_M2, presents consumers' positive reaction to product or process improvements. This reinforcing nature of R_M2 suggests that understanding and meeting demands of consumers may lead to a continuous investment in innovation by the manufacturing firm.

Summary of Factors

Table 3 summarizes the factors considered in this study. This is to enable readers to have a concise understanding of the key factors considered.

Table 4 provides the measurement framework of the factors presented in Table 3. This framework operationalizes the selected factors to enable the statistical investigation and development of the logics considered in the Construction Innovation Model.

Research Method

A quantitative approach, Pearson's correlation, is selected to analyze the operationalized factors presented in Table 3. The Pearson's correlation is selected as it is able to measure the strength of the relationship between any two variables. In addition, the sign of the correlation coefficient provides the direction of relationship between two variables, positive (+) or negative (−), as presented in the models. Positive coefficient signifies that an increase in variable *A* will lead to an increase in variable *B*. Negative coefficient signifies that an increase in variable *A* will lead to a decrease in variable *B*. This is representative of the concept of link polarity developed by Sterman (2000) and employed in this study (Table 1).

The system model also encompassed some nonmeasurable variables that could not be statistically operationalized. The Pearson's correlation analysis is thus further supported with a qualitative interview approach to verify the logics presented by the "soft variables" and to gather additional information regarding the feedbacks of the systems models.

Table 3. Contrast of Innovation Practices between Manufacturing and Construction Firms

Factor	Manufacturing	Construction
Investments in innovation	Innovation serves as a means of developing and sustaining core competencies in manufacturing enterprises	Innovation investment is hindered by the intense cost competition faced by the construction industry
Profitability of innovation	Profit is an important driver of innovation	The low profit margins received by construction firms deem investments in innovation an improbable strategy
Scope of innovation	Firms' scope of innovation is influenced by the product's ability to achieve first mover advantage and satisfaction of consumer's needs	Firms' scope of innovation is influenced by productivity and quality demands of clients
Innovative capabilities	Manufacturing firms' innovative capabilities reside in management's ability to consolidate corporate wide technologies and production skills into competencies that empower the firm to adapt quickly to changing opportunities (Prahalad and Hamel 1990)	Due to the liability of separation there is a tendency to reinvent processes on each new project and some of the detailed technical activities performed on one project may be difficult or impossible to transfer to new projects
Consumers' willingness to pay for innovation	Technology push: firms are often focused on technological novelty to capture consumers' demands	Market pull: firms are often focused on clients' requirements of low cost and high quality aspects of the end product
Competitive advantage	Innovation provides firms with possible reactive strategies to prevent losing market share or proactive strategies to gain a strategic market position relative to their competitors (Linde and Porter 1995) and possibly improve profitability	The intense cost competition of the industry drives construction firms to move away from the need to differentiate themselves in terms of technological capabilities toward differentiation in terms of costs

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Table 4. Variables Measurement Framework

Factor	Measurement framework	Source of measurement
Profitability of construction firms	Annual turnover of construction firms	Turnover data are obtained from the OECD, which defines turnover as the actual sales in the year (OECD 1993). Profit level of domestic contactors can be deduced by subtracting domestic contractors' annual expenditure from their turnover. However, international data on contractors' annual expenditure is not available. The alternative to this approximation is to conduct a survey of all contractors in each country, which is not a probable methodology for this study. Hence in this study, turnover is not truly a proxy of profit but an approximation of the level of profit of domestic contractors.
Investment in innovation	Annual R&D expenditure of construction firms	The R&D expenditure data approach adopted in this study follows the guidelines set in the OECD's *Frascati Manual* (OECD 1993) that is applied in the leading countries where R&D expenditure is used as a proxy for measuring innovation.
Scope of innovation-labor productivity	Percentage change in construction value add per person employed	Construction productivity is the efficiency of an entity, such as workers or machines, in producing value-added products or profits. It is the ratio of the industry output or production on its input. Labor productivity is thus measured as value added at constant prices over the total number of persons engaged as defined by the OECD (1993).
Scope of innovation construction quality	Statistically nonmeasurable variable	Due to the inability to find a suitable numerical proxy for this variable, an interview approach is undertaken to verify its significance and role in the systems model.
Innovative capabilities	FTE[a] value of R&D personnel in construction	FTE is defined by the *Frascati Manual* (OECD 1993) as providing the true volume of R&D. It is a measurement of the man-year utilization of intangible and nonreplicable knowledge residing in researchers. Hence, it is a useful measure of the innovation capability of firms.
Consumers' willingness to pay for innovative products	Statistically nonmeasurable variable	Due to the inability to find a suitable numerical proxy for this variable, an interview approach is undertaken to verify its significance and role in the systems model.
Competitive advantage of construction firms	Statistically nonmeasurable variable	Due to the inability to find a suitable numerical proxy for this variable, an interview approach is undertaken to verify its significance and role in the systems model.

[a]FTE=full time equivalent—methodology based on *Frascati Manual* (OECD 2002).

Statistical Analyses

To validate the relationships in the systems model (Fig. 4), Pearson's correlation was used. Statistical software Statistical Package for the Social Sciences (SPSS) version 11.5 was used to calculate the bivariate correlations. The interpretation of the Pearson's correlation results was analyzed at two levels. First, the significance and direction of relationship between two key variables, such as the positive relationship between the "level of investment in innovation" (A) and "firm's innovative capablities" (B) (Fig. 4) would be established. 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 owing to the presence of soft variables. For instance, the indirect relationship of X on Z (through Y) can be represented as $X \rightarrow Y \rightarrow Z$ where Y is known as the mediator. For example in Fig. 4, the relationship between "Level of Investment in Innovation" (A) and the "Scope of innovation" (C) is through the mediator of Firm's innovative capabilities (B).

Park et al. (2004) offered two interpretations of such a relationship. First, the effects of X on Z are completely mediated by Y. For example, the level of investment in innovation (A) may lead to an increase in firm's innovative capabilities (B). This in turn would cause an increase in contractors' scope of innovation (C). Second, X affects Y and Z directly. For instance, level of investment in innovation (A) causes an increase in both firm's innovative capabilities (B) and scope of innovation (C). Kelloway (1998) observed that one of the conditions for a mediator test is that X and Z are significantly related.

Data Collection

The OECD is an international organization that brings together the governments of countries committed to democracy and the market economy to support sustainable economic growth, raise living standards and assist other countries' economic development through the identification of good practice and coordination of domestic and international policies (OECD 2009). 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 (OECD 2006). This study employed the organization's established international standards on surveys, collection, and interpretation of innovation and R&D data in its statistical analysis through the utilization of OECD statistical data from "SourceOECD," an online database for researchers and students in institutions subscribed to OECD online library. The main data sets that provided most of the required data are the Main Science and Technology Indicator and OECD Science, Technology, and R&D Statistics (OECD 2009).

The OECD collects statistical data on many countries, including those that are not listed as their member countries. However, this study selects its sample of countries based on the list of OECD member countries, as the statistical data on these countries are more comprehensive and spans over a larger number of years. This study selected the countries from the year that provides the highest number of OECD countries with sustainable OECD statistical data. Most of the OECD member countries' data are consistent from 1993. In 1993, 17 out of a total of 24 OECD member

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Table 5. Minimum Number of Interviewees for Each Selected NSI Actor

Group	Stratum	Abbreviation	Designation	Minimum number of interviewees	
Domestic contractors	Small	SC 1	Owner	Total number of interviewees for "domestic 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		
Grand total of minimum number of interviewees					18

countries provided the complete set of data required. Hence, the final sampling frame consists of 17 OECD member countries, and Singapore where expert interviews were conducted. This provided 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, 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 are based on the guidelines of the OECD's *Frascati Manual* (OECD 1993). Since these 18 countries only provided adequate data for all proxies up to 2003, the period of analysis was the 11 years from 1993 to 2003 over 18 countries. This provided a total of 198 data points.

Research Design for Interviews

Interviews were conducted in April 2007 over a timeframe of 2 months. Semistructured interviews (Tan 2004) with an interview guide were performed. This method of interview enables the interviewer to guide the interviewees' discussion by a well-prepared framework of themes, while allowing new questions to be brought up during the interview as a result of what the interviewee says. This provides the flexibility required by the interviewer to systematically understand the innovation practices and strategies employed by the construction enterprises.

Two main groups of actors were interviewed: main contractors and construction clients. Main contractors were divided by their geographical origin: domestic and foreign contractors. Domestic contractors are further categorized by their firm size: small, medium, and large contractors. These classifications enable the identification of any characteristic differences in the contractors' perception of construction innovation. Construction clients were divided into two stratums of public clients and private clients. To allow the interviewees to remain anonymous, each interviewee is identified by his or her stratum code followed by an identification number. The profiles of the interviewees are presented in Table 5.

Due to resource limitations, the interviews were conducted only in Singapore. Interviewees were selected through convenience sampling as the nature of questions require the interviewee to be a top management person who understood the firm's business strategies and vision. Hence, personal contacts were used. Twenty-two potential interviewees were contacted and only 18 agreed to participate. The two reasons for declining participation were interviewees' unwillingness to share their business strategies and their feeling that their companies do not engage in innovation. The interviews took place in the interviewees' business premises. Each interview lasted between 30 min and 2 h. All interviews were recorded to correct the natural limitation of the researcher's memories and her intuitive interpretation.

Daymon and Holloway (2002) observed 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 of the six stratums, no more interviews were conducted. A total of 18 construction practitioners were interviewed.

Results

Empirical Results

To verify the relationships between the factors considered in Fig. 4, four variables are statistically considered: Turnover of construction firms, construction firms' investment in innovation, construction labor productivity, and research capability of construction firms. The variables: consumers' willingness to pay for innovative products, scope of innovation—construction quality, and competitive advantage of construction firms, are not statistically considered as they could not be easily quantified.

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Table 6. Pearson's Correlations Results

		Construction firms' investment in innovation	Construction labor productivity	Research capability of construction firms	Turnover of construction firms
Construction firms' investment in innovation	Pearson's correlation sig. (two-tailed) *N*	1			
		—			
		198			
Construction labor productivity	Pearson's correlation sig. (two-tailed) *N*	0.223[a]	1		
		0.002	—		
		198	198		
Research capability of construction firms	Pearson's correlation sig. (two-tailed) *N*	0.942[a]	0.180[b]	1	—
		0.000	0.011	—	
		198	198	198	
Turnover of construction firms	Pearson's correlation sig. (two-tailed) *N*	0.231[a]	0.142[b]	0.081	1
		0.001	0.046	0.257	—
		198	198	198	198

[a]Correlation is significant at the 0.01 level (two-tailed).

[b]Correlation is significant at the 0.05 level (two-tailed).

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From the Pearson's correlation results presented in Table 6, all variables tested are significantly related to one another except for the relationship between two variables: "research capability of construction firms" and "turnover of construction firms." Hence, the final systems model would not portray any direct relationship between these two factors.

Interview Results

Table 7 provides a summary of the responses gathered from the interviews. Views of construction practitioners are categorized and discussed in line with the specific issues of this study.

From the interview results, it is observed that one of the reasons for contractors' slow uptake of innovation strategies is due to the general trend that returns on innovation of construction processes is not commensurate with the risks of the investment. All domestic contractors interviewed noted that monetary risk is the most significant risk factor to consider in R&D. Other risks cited in the interviews included time, inadequate expertise, fast changing technology and imitation by competitors that shorten the lifecycle of inventions. These risks are similar to the factors identified by Nam and Tatum (1988) and the hindrances of innovation as discussed in this study.

The views of interviewees on the notion of Power (2000) of a link between consumer satisfaction and consumer loyalty in the construction industry were mixed. All contractors interviewed generally stated that competitive pricing is a more important determinant in winning a project rather than the dependence on consumers' loyalty. Nonetheless, they agree that in the long-term, branding is a valuable asset in providing the edge in winning construction projects.

Regarding "Consumer's Willingness to Pay for Innovation," all contractors interviewed agreed that when their companies' productivity and quality improve, there would be an increase in the demand for their company's services in Singapore. However, of the 18 construction practitioners interviewed, 17 agreed that quality does increase construction costs, whereas productivity should reduce it. Only 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.

The importance of construction firms' commitment in innovation was frequently raised in the interviews. Respondent PuC 1 observed "Many [contractors] are not committed. There are even instances of contractors giving up halfway through a collaborative R&D project with BCA (Building and Construction Authority). Respondent PuC 3 observed, "Contractors always provide the same reasons of 'No time. No money.'" Respondent PuC 1 suggested that "Management involvement is very crucial. Management must believe in it (R&D) and must think that there is need to do so."

Construction Firm's Innovation Model

This section discusses the development of the Construction Firm's Innovation Model based on the foundation of the Manufacturing Firm's model (Fig. 4). The statistical results validate significant and positive relationships between the three pairs of factors: "Turnover of Construction Firms with Construction Firms' Investment in Innovation," "Construction Firms' Investment in Innovation with Research Capability of Construction Firms," and "Research Capability of Construction Firms with Construction Labor Productivity." This implies that as portrayed by the logic $A \rightarrow B \rightarrow C$ in both manufacturing and construction innovation model (Figs. 4 and 5, respectively), and in accordance to the observations discussed in the literature review of Milford (2000), innovation is indeed strongly related to the availability of capital investments.

Nonetheless, reviewing the interview results, the Construction model differs from the Manufacturing model in terms of the importance of innovation costs on the firms. The literature discussions suggest that this may be due to the market pull nature of the construction industry, as opposed to the manufacturing industry's technology push characteristic. Reichstein et al. (2005) observed that in construction, clients often play a significant role in shaping the design and production process. Hence, unlike consumers of the manufacturing industry, construction clients can influence the cost of construction. In strategizing their competitiveness, innovating construction firms can either choose to bear the innovation costs solely [depicted by the negative relationship between Construction costs (J) and Firms' profit (F)] or transfer the innovation costs to consumers by submitting a higher tender price (depicted by the logic $E \rightarrow F \rightarrow A$ in Fig. 5). To structure this

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Table 7. Summary of Interview Responses

	Satisfaction of consumers' needs	Competitive advantage through innovation	Consumers' willingness to pay
Large and medium domestic contractors	Large and medium contractors generally agree that when their companies' productivity and quality improve, there would be an increase in the demand for their companies' services in Singapore. Hence, the factor of "consumer needs" is often considered in their business strategies.	Large and medium contractors observe that innovation offer nonmonetary returns such as recognition and prestige that differentiates their companies from the rest. They recognize that such "branding" provides increased competitive advantage during tendering procedures.	The large and medium contractors perceived the market in Singapore to be too small and the availability of projects is declining. They question the willingness of consumers to pay for advanced technologies that may improve the productivity of the construction process.
Small domestic contractors	The small contractors generally viewed innovation as a strategy to establish rapport with clients. They also noted that the ease of introducing novel processes or products increases with increasing prior work engagements with the client.	Small contractors feel an increased pressure to maintain their competitiveness by developing new technologies and efficient management systems. However, they consider imitation by innovating partners or competitors a substantial risk. Hence, price competition is still the most widely used business strategy for small contractors.	Small contractors consider consumer profiling, the identification of their target market segment, an important business strategy. Through consumer profiling, they would be able to understand the demands and monetary stimulus of the client.
Foreign contractors	Foreign contractors view innovation as an important tool in attracting customers. It portrays the organization as a forward-looking and high capability company that is able to satisfy consumers in complex projects. With increased know-how and experience, contractors are able to catch new market trends. This enables them to be the first in satisfying their customers' demands and further develop consumers' confidence in their service.	Foreign contractors agree that innovation investments such as new IT management systems and staff training do improve their research capabilities. However, these require large investments funds. Hence, foreign contractors observe that their financial capacity directs how far they can go in innovation.	FC 3 provided an example of the Far East Organization to portray consumers' willingness to pay for quality: The Far East Organization was able to sell its developments at higher prices by proclaiming that their Construction Quality Assessment System (CONQUAS[a]) scores are high. From this, it appears that quality could be sold for a premium to consumers.
Private and public clients	Private clients generally have the perception that foreign contractors are of a higher caliber than domestic contractors. Hence, similar to the responses of domestic contractors, private clients felt that there is increased pressure on the contractors to maintain and create their competitive advantage through new technologies and efficient management systems such as the implementation of IT systems. Public clients view the ability to meet the basic needs of end users as the most important factor in selecting a suitable contractor. Basic needs include price competitiveness and safety.	Private clients view innovation by contractors as a valuable way to improve the "status" of the company in the eyes of the client. For private clients, providing advance technological construction methods is a good way of attracting the attention of clients. However, the key word to such advancements is "proven" technologies. Public clients agreed that the need to justify the use of public funds on novel construction technologies that requires larger funds inhibits the adoption of innovation processes and products on public projects.	All clients except one private client acknowledge that consumers are generally willing to pay for quality rather than increased productivity. They agree that improved construction productivity will decrease costs while increased quality will increase costs. They also suggest that the transferability of innovation costs to clients differs with regards to the extent of productivity and quality benefits gained from the intended innovation. Thus, they agreed that consumers' willingness to pay for an innovation is an important consideration in contractors' innovation strategies.

[a]CONQUAS launched in 1989 in Singapore, and 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.

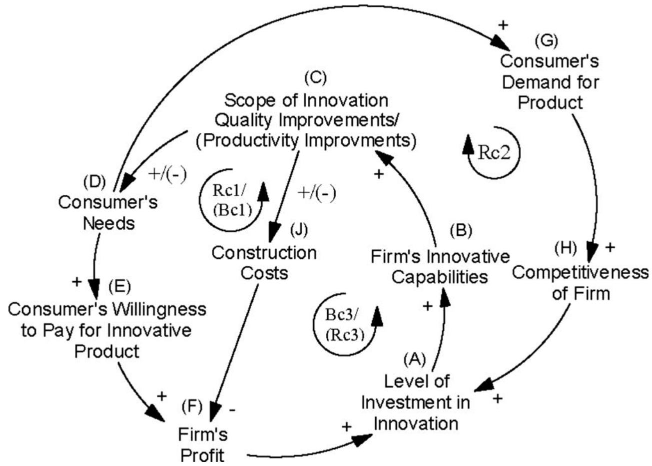

Fig. 5. Competitive impacts of innovation on construction enterprises

difference in the Construction Model, a variable "construction costs" (J) is considered in the model through a third causal loop $B_C3/(R_C3)$ (Fig. 5).

In the Manufacturing Firm's Innovation Model (Fig. 4), it was highlighted that manufacturing firms' ability to develop their innovation capabilities is in itself a competitive advantage as the returns on investments provide further funds for continuous growth of their enterprises through innovation. It was argued earlier that construction firms do not have such advantages due to differing consumer base. However, this is based on the notion that construction firms have to "sell" their innovation to consumers. Nonetheless, there can be two "end products" from construction innovations.

First is the improvement of the quality of the constructed product. The logics for the competitive impacts of quality improvements on construction are represented by the causal loops whose abbreviations and causal signs are not in brackets. The interviews present that consumers are generally willing to pay for quality improvements. Looking at causal loop R_C1, Fig. 5, when construction firms engage in innovations that provides quality improvements (C), they would be meeting the needs of consumers (D). This leads to a positive consumers' willingness to pay for innovative product (E), which would improve construction firms' profit. This implies that the increase in construction costs (J) due to innovation investments in quality improvements (presented in causal loop B_C3), can be partially or fully transferred to consumers by satisfying consumers' needs (D) in causal loop R_C1. The logic for R_C1 is similar to that of R_M1 of the Manufacturing Model depicting manufacturing firms' ability to transfer partial or total innovation costs to consumers. This results advocate the view of Craig and Roy (1999) and Lim and Ofori (2007) that consumers of the construction industry are focused on quality products. This implies that construction firms that provide quality improvements through innovation may do so constantly, as consumers are willing to bear partial or absolute innovation costs (J). 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, a top-class luxurious condominium, due to the assurance of quality although Dragages was one of the highest bidders (Lim and Ofori 2007).

Second is the productivity of the construction process. The logics for the competitive impacts of productivity improvements on construction are represented by the causal loops whose abbreviations and causal signs are in brackets. The interviews results present that consumers are unwilling to pay for productivity improvements. Nonetheless, the statistical results validated that construction productivity has a positive relationship with construction firms' profit (Table 6). These results can be explained with case studies such as in the Bunker, Meadow Springs, Western Australia, significant cost savings were achieved from the implementation of a unique precast construction system due to an accelerated construction period that reduced labor costs and equipment cost hires, including minimal time required for external and internal scaffolding (Lim and Ofori 2007). In Singapore, Kimly Construction Pte. Ltd. in cooperation with Poh Cheong Precast Pte. Ltd. for the construction of Sanutary Green condominium construction experienced improved productivity through the implementation of a combined precast and cast-insitu construction techniques. With significantly reduced time required for wet trades, contractors managed to deploy their resources more efficiently including reduced reliance on heavy equipment like tower cranes (Lim 2007). Therefore, although construction firms are unable to "sell productivity" (depicted by the negative relationship between construction productivity (C) and consumer needs (D) in causal loop BC1, Fig. 5) such improvements can enhance construction firms' competitiveness through the reduction of construction costs (J) (causal loop R_C3).

The reinforcing nature of R_C3 implies that an increase in productivity (C) can continuously reduce costs (J) and improve contractor's profit (F). However, as discussed earlier, conservative construction clients and consumers may hinder the initial implementation of such innovations as often "proven" success is a key concern for novel construction technologies.

Nonetheless, the interview results (Table 7 and Interview Results) collectively demonstrated that the main competitive advantage that quality or productivity improvements of construction firms offer lies in differentiating contractors in terms of their capabilities. Concerning this competitiveness, the Manufacturing Model and the Construction Model have similar logics. In the Manufacturing Model, causal loop R_M2, presented a positive consumers' reaction on a product or process improvement, improves the competitiveness of the enterprise. Likewise, the contractors interviewed believed that innovation offers nonmonetary benefits such as branding that differentiate them from their rivals.

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 the Shimizu's SMART system (Shimizu 2000). This is an automated intelligent system for high-rise building construction that can be modified and upgraded to suit various construction sites in Singapore.

The reinforcing nature of the causal loops R_M2 in the Manufacturing Model and R_C2 in Construction Model also supports the notion of Pedersen (1996) that the intention to innovate should be a constant purpose. For competitive advantage to be sustainable, there should be a consistency that consumers are able to identify. This is the concept of branding which the interviewees have raised. This consistency would enable firms to create a "brand" that consumers are able to identify with and hence enable the firms to maintain their competitiveness. Similarly, Power (2000) has confirmed that there is a link between consumers' satisfaction and consumers' loyalty in the construction industry.

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Findings and Recommendations

This study questions whether innovation is a useful means for construction firms to derive competitive advantage. The construction innovation model presents that there can be two end products of innovation: productivity and quality improvements. Due to their differing impacts on costs, they offer different competitive tools for construction businesses.

To initiate innovation, investments funds are required. The interview results and construction model present that providing quality improvements would satisfy consumers' needs and tap on their willingness to pay. Therefore, construction firms should consider using quality improvements as an initial innovation strategy to acquire the required investments funds for innovation. As the causal loop for this logic is a reinforcing one, this implies that construction firms that provide quality improvements through innovation may do so constantly as consumers are willing to bear partial or absolute innovation costs. The interview results also suggest that to maximize this competitive advantage, it is important for construction firms to develop cooperative relationship 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 intended innovation.

Regarding productivity as an end product of innovation, the construction model presents productivity as a hidden benefit for construction firms who wish to improve their competitiveness. Productivity improvements can facilitate construction firms in reducing their construction costs. However as portrayed in the models, consumers are unwilling to pay for productivity improvements. The interview results show that the transferability of productivity improvement costs to consumers is dependent on the consumers' business strategies. In the real world, consumers mainly reap the benefits gained from productivity through earlier sales or rental revenues. Nonetheless, not many consumers will be willing to pay an upfront premium for productivity either in terms of accepting higher tender prices or discounting the consumers' product price, when there are no guarantees of such returns. To consumers, 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 others. As long as contractors are able to complete projects within the contract time, productivity is not a specific requirement but a bonus. Productivity is not a tangible product that clients can sell to their end users. Hence, they do not usually pay for it.

Instead, improved productivity is a tool that enables construction firms to develop a consistency of character that consumers are able to identify with. This competitiveness enables them to create their brand, an asset that would facilitate construction firms in long-term strategic growth through empowerments such as enhancement of their negotiation power and improved ability to compete for projects. Therefore, although improved productivity through innovation does not enable construction firms to compete through the industry's conventional price competition, it enables construction firms to differentiate themselves from the competitors. Such competitiveness encompasses the use of tactic knowledge which Porter (1990) terms as advance factors that competitors could not easily imitate. Nonetheless as discussed in the interview results, to develop such competitive advantage, it is important that contractors are determined and committed to establish initial and long-term financial investments and priorities in innovation.

This study has identified that the increased cost of investment in innovation would instigate the lost of competitiveness of construction firms due to the intense price competition faced by construction firms. However, in response to the research question, the results suggest that the ability to develop innovation capabilities is in itself a competitive advantage. The development of such capabilities will enable the construction firm to build a systematic application of knowledge gained from each project, providing long-term sustainable competitiveness for the firm. The key to successful innovation is thus to identify the right type of innovation for the right phrase of firms' innovation strategy. This echoes this study's definition for innovation, the purposeful search for new knowledge and the systematic application of this knowledge in production.

Conclusions

As mentioned in the introduction, construction businesses should strategize their innovation in the manner most suitable for their competitive environment. The implication of the finding is, in the price competitive environment of the construction industry, construction firms' cost competitiveness would decrease with direct investments in innovation. However, construction firms should still consider investing in innovation due to gains in other forms of competitiveness such as reduced construction costs, higher productivity or improved reputation.

The analysis and comparison of both manufacturing and construction innovation systems models have shown that the type and intensity of competitiveness construction firms can derive from innovation depends on consumers' willingness to pay for innovative products. The traditional classification of product and process innovations in the construction industry has been silent on the impact of this factor on innovating construction firms. Hence, the knowledge contribution of this study is in highlighting the innovations that construction firms can derive direct monetary returns from and those that provide intangible but sustainable competitive advantages, such as a "brand name" or improved technological capabilities that better meet the demands of consumers. By bringing out these aspects of innovation and highlighting their critical impact on contractors' innovation strategies, this study has provided a positive step toward opening the black box for both the consumers and contractors.

Despite of the results gained, there are several limitations in this study. First, it did not account for the different R&D structure of the countries it has investigated. Second, due to constraints on the length of this paper, the proxies selected for the operationalization of the factors have not been given adequate justification. Third, it assumes that investments in innovation will lead to successful development and implementation of product or services. However, this may not be always true in reality. To further develop the concepts in this study, this study recommends future research to explore and identify the changes in the competitive advantages that innovation offers to construction firms when other construction stakeholders, such as upstream designers or downstream suppliers, are considered.

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