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Development of a Conceptual Model for the Diffusion of Construction Innovation

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Abstract: The study of innovation diffusion is said to be lacking for construction sector, and the low innovation level experienced in this industry warrants more studies to be done. Accordingly, the diffusion process needs to be examined and influencing factors identified because the economic benefits of construction innovations can only be realized if they are successfully diffused and adopted by potential end users. The objective of this study was to develop a conceptual model to guide the investigation of construction innovation diffusion. The frameworks developed by Roger and Brown were reviewed, beside latest research literature on construction innovations. A conceptual model was developed based largely on Brown's framework on adopter's behavior, and incorporating peculiar characteristics of construction industry. Measuring the economic success of innovation using the extent of diffusion as the dependent variable, the model consisted of ten independent factors grouped under four constructs: innovation attributes industry characteristics, adopter innovative characteristics and environmental interventions. Further empirical study is proposed using this model, which will benefit the homegrown innovation developers in construction industry.

Key words: conceptual model; construction; innovation; diffusion; industry; developers; adopter; success.

INTRODUCTION

The notion of innovation leading to competitive advantage is well supported by research findings (Hussain and Ilyas, 2011; Burgelman *et al.*, 2004; Koebel *et al.*, 2004; Jones and Saad, 2003; Miozzo and Dewick, 2002; Seaden *et al.*, 2003; Tidd *et al.*, 1997; Frambach, 1993; Tatum, C.B. 1986). Innovation has become a buzz word nowadays, which permeates throughout a spectrum of disciplines, and is often emphasized by leaders in academic, business and political circles. However, there is still no consensus on the description and meaning of innovation, and there exist many views on how it should be defined (Wan Khairuzzaman and Abdulmajed, 2005).

Generally, innovation is taken to mean something that is new, which is introduced apparently to change the current state for the better. Lundin (2008) describes innovation as "fashioning something new and of potential value from a novel idea" correspondingly, Rogers (1971, 1995) defines innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". Thus, an innovation could have existed elsewhere, but so long it is perceived as new by the potential adopter, being the first time it is exposed to him, then it is considered an innovation to him (Tabak and Barr, 1999). Cobbenhagen (2000) has accepted the criterion for innovation as new or improved products, services or processes which are "new to the company". Likewise, a supposedly better technology which is introduced to a firm to replace an existing or old technology is considered a technological innovation, even though it has been in existence for some time (Brown, 1981).

According to Wan Khairuzzaman and Abdulmajed (2005), it was Joseph Schumpeter (1883-1950) who first introduces the idea of vital role played by innovation in the economic growth, in addition to their elaboration that it as enhancement of business competitiveness whereas Holt and Edwards (2012) establish further as means of warranting business sustainability. Since then, interest has increased in the study of innovation process and management, particularly in topics relating to performance improvement and competitiveness for an organization. Today, organizations are embracing innovation in all aspects in facing competition and challenges brought about by globalization. The turbulent and competitive business environment of a globalized economy requires firms to continuously innovate so as to gain the competitive edge to sustain growth. Research establishes that devotion to innovation is vital to success and sustains competitive advantage to a business organization (Hussain and Ilyas, 2011). This is even more so now with trade liberalization, which sees new entry of more established foreign firms competing with the local firms on home ground. This implies that the

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traditional business strategy building on low cost is inadequate now; firms need to innovate to improve efficiency, quality and productivity. In other words, innovation has become the fourth competitive dimension adding on to the traditional three dimensions of cost, quality and time (Ling, 2003).

To reap the intended economic benefits, innovation must be diffused and adopted by the population. Murray (2009) explicates that the final effects of innovation diffusion are "adoption, implementation, and institutionalization". Hall and Khan (2002) further certify that "it is the diffusion rather than invention or innovation that ultimately determines the pace of economic growth and the rate of change in productivity", and they suggest that "until users adopt a new technology, it may contribute little to our well-being". Thus, the diffusion of innovation has attracted the interest of stakeholders in organizations and industries, because a successful diffusion process will result in socio-economic gains. Further, Materna (1981) reports that diffusion accounted for more than two-thirds of failures in technology transfer process, and takes up to eighty per cent of the total cost of bringing an innovation to commercial success.

The construction industry is said to be low in innovation level. According to Bröchner (2011) the productivity increase indicator especially related to construction innovation in the construction industry is regularly perceives as low. This is particularly so in the developing countries, for example Malaysia, which has singled out the slow adoption of new technologies as one the main reasons (CIDB, 2005). Though the availability of construction innovations in local market is not lacking, the author has observed a phenomenon of selective adoption of imported innovations by the construction firms. This has resulted in the slow diffusion of homegrown innovations, thus affecting the local innovation developers.

Literature on innovation and its diffusion in construction is limited; it is a discipline that is least researched (Abudayyeh *et al*., 2004). While the study of construction innovation has shown an upward trend judging by the number of recently published papers found in literature search, specific studies relating to the diffusion aspect have remained low. Larsen (2005) reports that while study on construction innovation has gained popularity, the focus on its diffusion process is only a recent phenomenon as stated further by Kale and Arditi (2010) through their elaboration of the diffusion model of technology innovation in computer aided design (CAD). Accordingly, Dieperinka *et al*., (2004) further affirm that most studies tend to focus on the feasibility of a particular technology, and few try to explain the diffusion of technology throughout the society. Besides, the inconsistency in findings obtained from the innovation diffusion studies carried out in other disciplines has necessitated separate studies to be carried out for the construction industry.

Relating to the problem statement discussed above, the objective of this study is to develop a conceptual model to guide the study on effective diffusion of homegrown technological innovation in construction industry.

There are six phases in the innovation-development process model proposed by Rogers (1995) as depicted in Figure 1. The principal focus of this study is the diffusion/adoption phase. It is a crucial phase to any organizations in the innovation process, because the socio-economic benefits of an innovation can only be realized after it is diffused and adopted by potential end users.

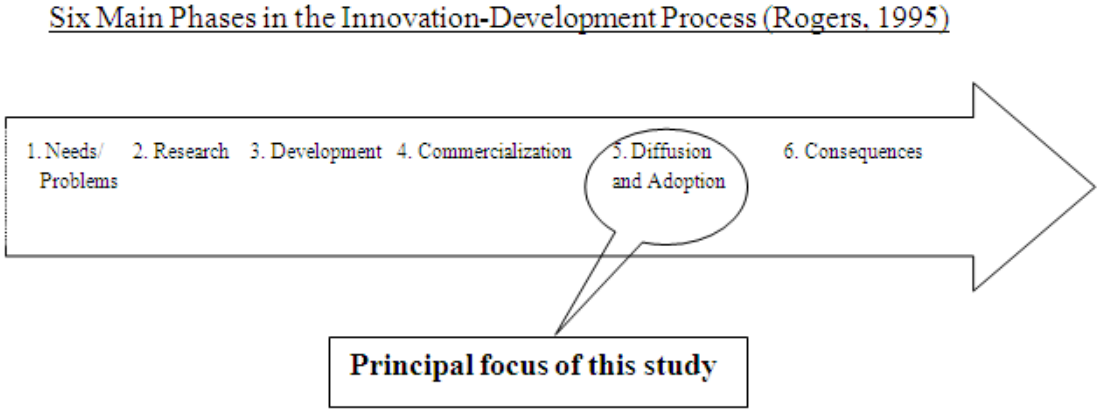

Fig. 1: Principal focus of this study

It is necessary to emphasize at this juncture that the study is about the diffusion process of innovation, and is not on technological innovation *per se*. Thus, the principal focus is on the diffusion and adoption phase of the innovation process. The pre-activities to this phase such as research and development of innovation is not the primary concern, but is described at times for supporting an argument.

The diffusion of innovation is defined by Rogers (1995) as "the process by which an innovation is communicated through certain channels over time among the members of a social system". The diffusion is a process because an innovation is passed on to individual adopters over a period of time, and from one locale or one social group to another. From Rogers *et al* (2005) continuous elaboration that diffusion happens as intricate

network, which overlap, multiple and manifold among the diverse society; the diffusion of innovation also possesses a spatial and temporal aspect of the dynamic distributional characteristics associated with an innovation.

Conceptual Model Of Innovation Diffusion:

The research process adopted for this study followed that proposed by Sekaran (2003). Through author's observation and work experience, the area of research interest was identified. This area of interest was reinforced by unstructured interview with business associates and preliminary survey of literature. This led to the definition of problem statement. According to Sekaran (2003), problem definition is "a problem as any situation where a gap exists between the actual and the desired ideal states". The problem that had been identified is the slow diffusion of home-grown construction innovation.

Further in-depth literature review followed after problem definition enables the development of a theoretical framework to guide the progress of this study. Sekaran (2003) said that theoretical framework "is a conceptual model of how one theorizes or makes logical sense of the relationship among several factors that have been identified as important to the problem".

Rogers's (1995) Framework On Rate Of Adoption:

Rate of adoption is a dependent variable which most innovation developers will be concerned, because it is a reflection of the extent of diffusion of an innovation. While diffusion has two dimensions: temporal and spatial, rate of adoption only measures the relative speed that an innovation is adopted by members of a social system (Rogers, 1995). Rogers (1995) has suggested five explanatory variables that influence the rate of adoption, and they are: perceived attributes of innovations, type of innovation-decision, communication channels, nature of the social system, and extent of change agents' promotion efforts.

In Rogers's framework as shown in Figure 2, these five variables impact directly the rate of adoption, and they jointly determine its outcome. In addition, the interaction between the innovations attributes and the communication has the crucial impact on the rate of adoption. The innovation developer is essentially a change agent, whose promotional efforts are intended to influence the decision-making process of potential adopters. Rogers (1995) concedes that the change agents' promotional efforts could be drastically reduced once the rate has achieved between three and sixteen percent adoption, a stage where they are said to have won over the opinion leaders to assist in the diffusion process.

The attributes of innovation are instrumental in getting the potential adopters interested in an innovation during the persuasion stage. The five attributes proposed by Rogers (1995) are relative advantage, complexity, compatibility, observability and trialability. Out of these five attributes, relative advantage and complexity are more relevant to industrial technologies. In most cases, technology compatibility reduces its complexity when adopted for use by an organization. As for attributes of observability and trialability, they are commonly used in the promotion of consumer products with the objective of reducing the degree of uncertainty, and to gain the confidence of potential adopters. Industrial innovations are usually massive and not always in product form, thus trialability is seldom being regarded as a critical attribute.

Three types of decision-making are proposed: optional, collective and authority. It is conceived that the decision-making will slow down if more people are involved in it, as in the case of an organization. In this respect, the organization structure and culture have significant impact on the decision-making process. For nature of the social system, Rogers (1995) suggests the degree of network interconnectedness and its norms. This can be taken to mean the characteristics of an industry if the research focuses on the diffusion of innovation within an industry.

Referring to Figure 2, Rogers (1995) says that the adoption of an innovation, hence its rate, is dependent on the adopter's behavior (i.e. independent variable I and II), beside the influence of change agents' efforts and information flow. Rogers has mentioned organizational decision-making process, which is related to organization structure, but is silent with regard to organizational culture on innovation. Another point that has been noted is the absence of external intervening forces other than those from the change agents. To Rogers (1995), diffusion is essentially a communication process, and this explains why elements relating to economic and marketing considerations have not been focused upon.

Rogers visualizes the diffusion as a process of communication during which information flows from one person to another, from a social group to another, or from one locale to another. The decision to adopt is made solely the responsibility of adopter. As such, categorization of adopters into several groups with specific characteristics is deemed able to explain their adoption behavior. Rogers (1995) argues that the decision-making process is linear with discrete stages as the information flow through it and the members in a social group communicate with each other. Thus, the rate of adoption, which is measured by the number of adopters, is said to be influenced by perceived attributes of innovation, type of innovation-decision, communication channels,

nature of the social system, and extent of the change agents' promotion efforts. All these factors are associated with information flow and communication.

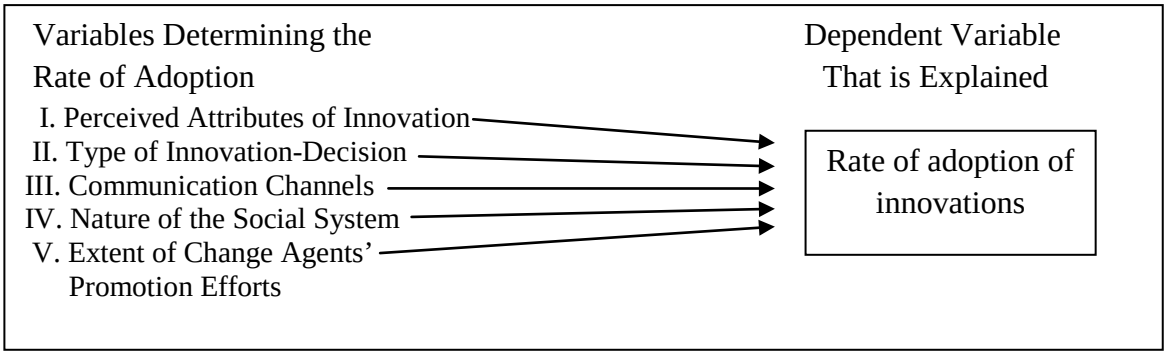

Fig. 2: Rogers's framework on rate of adoption (Rogers, 1995)

Rogers's (1971) theory is said to focus solely on the adopters of innovation, or the demand side of innovation (Brown, 1981). As such, it has ignored influence of factors from the innovation developers and promoters, which constitute the supply side of innovation. This constitutes a deficiency in his theory because the recent research has emphasized on a holistic approach in diffusion study (Brown, 1981; Hall and Khan, 2002; Koebel *et al*., 2004). The categorization of adopters into distinct groups is too simplistic in explaining adoption behavior as it excludes external influencing factors, particularly those from the environment external to the adopters. Further, the linear decision-making process is being criticized as unrealistic (Drury and Farhoomand, 1999; King and Anderson, 2002; Winch, 1998), because in reality the process can be iterative, with overlapping of various stages.

Rogers's theory is said to be relevant only to consumer innovation (Brown, 1981), which may not be directly applicable to technological innovation. Unlike consumer innovation, which Rogers (1995) feels can be improved by better communication and more efficient flow of information, technological innovation adopted by business clients and entrepreneurs are subjected to more consideration and influenced by external factors. Brown (1981) attempted to address this deficiency in his theory of innovation diffusion by including the supply side of innovation.

Brown's Framework on Adopter Behavior:

The framework developed by Brown (1981) is intended for diffusion of technological innovation among firms. It differs from the diffusion of consumer innovation, which is considered by Rogers (1995) and focuses on communication and information flow process. In this framework, the diffusion of technological innovation is viewed from the perspective of the adoption behavior of the firms using the innovation. Brown (1981) thus examined the actual usage of innovation in contrast with Rogers's framework in which the perceived innovation attributes are emphasized. According to Brown (1981), the adoption decision is influenced by four main factors: characteristics of the innovation, industry characteristics, institutional effects, and firm characteristics. The framework is depicted in Figure 3.

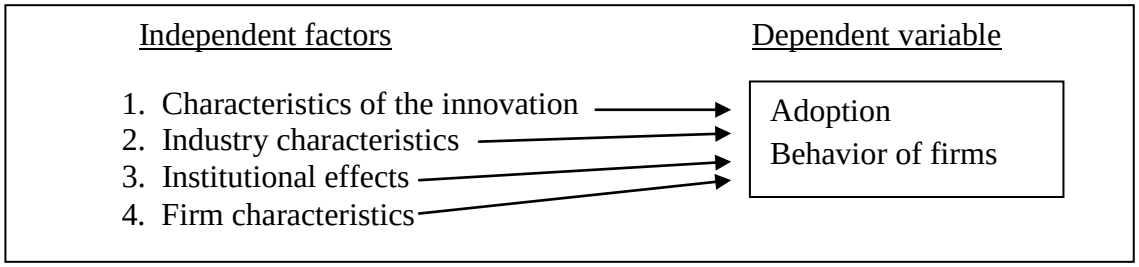

Fig. 3: Brown's (1981) framework on adopter behavior

Under the characteristics of innovation, Brown (1981) has singled out profitability or cost savings and the required investment. The technological innovation that replaced an existing technology must bring about relative advantage in terms of cost saving thus leading to profitability. In addition, the required investment is another consideration, which suggests that the innovation needs to be less complex thus reducing the investment in software and hardware.

The industry characteristics highlighted by Brown (1981) are the competitive structure of the industry and the nature of previous technological investment. The competitive structure of the industry affects adoption of innovation as firms fear to be fallen behind competitors in the bandwagon phenomenon. The next characteristic hinges on the argument that innovation improvement is continuous, and the firms expect existing technology to become obsolete eventually. Thus, the investment on technology shall determines its replacement time; a higher investment to acquire a more sophisticated innovation is likely to last a longer time before being replaced as compare to a lower investment for lower range innovation. By this argument, the nature of previous technological investment will determine the adoption of replacement technological innovations.

Brown (1981) says institutional effects such as societal concerns will affect the adoption of certain innovations. In the construction industry, the high social responsibility associated with construction products is an example of institutional effects. In addition, public pressure on construction activities is another example, which sometime can end up in political interferences. More about the institutional effects will be explored in the later sections on construction innovations.

The last factor is firm characteristics, which includes firm size, the aggressiveness and innovativeness of management, and the level of information relating to the innovation. The size of a firm in relation to its innovativeness and hence its adoption decision-making is well documented. Generally, it is deemed that larger firms have better advantage over smaller firms in the adoption of innovation. This can be explained by the availability of resources to bear the costs of innovation and risks of failure. On the aggressiveness and innovativeness of management, Brown (1981) says are characteristics found more in medium-size firms. The argument being that these firms are motivated to grow and improve their competitiveness than larger firms. As with regards to the level of information, larger firms with better absorptive capability possess more technical information which facilitates them in decision-making. This information could be specialized in nature that gives them better advantage.

Rogers's (1971, 1995) Framework Versus Brown's (1981) Framework:

Rogers (1995) measures the outcome of rate of adoption, and Brown (1981) on the other hand measures the adoption behavior of firms. Nevertheless, both measures are related to the diffusion-adoption process, which can be used to determine the successful adoption of innovation. It is noted that in both frameworks, there are similarities in the selected influencing factors such as those related to innovation characteristics, the environment of diffusion process and the adopter's characteristics.

Brown (1981), however, has included the supply side factors into his theory with three additional perspectives beside the adoption perspective found in Roger's theory. The four perspectives incorporated into Brown's (1981) framework are the adoption perspective, the market and infrastructure perspective, the economic history perspective, and the development perspective. The responsibility to adopt is now shifted from the adopters, as in the case of Rogers's theory, to the innovation developers or diffusion agencies. In this respect, Brown's theory is more relevant to this study. The Brown's framework on the adoption behavior includes factors relating to the characteristics of innovation, industry, institution and adopting firms. In addition, Brown's framework is intended to explain the diffusion pattern of technological innovation based on the adoption behavior of adopting firms. It measures the actual adoption rather than the innovation perceived to be better for adoption in the case of Roger's framework.

Brown's framework is more relevant to this study as it focuses on the diffusion of technological innovations among firms. However, it is too generic and intended for all industries and various technological innovations (Brown, 1981). For specific industry, particularly the construction industry known for its peculiar characteristics, it is necessary to identify specific factors in innovation, industry, institution and firm.

Diffusion Studies On Construction Innovation:

Despite the increasing number of disciplines involved in the diffusion research, diffusion studies conducted on construction innovations are relatively recent and limited (Bröchner, 2011; Koebel *et al*., 2004; Emmitt, 1997; Shook, 1997). While construction is sometime deemed to be similar to manufacturing in the study of innovation process, some diffusion scholars say that it is very different in industry characteristics and production processes (Nam, 1990; Hampson, 1993). Some characteristics of construction that make it unique are location-dispersed sites, high project cost, complexity of products and processes, high failure risks, limited number of repetition in production, and immobility of final products (Nam, 1990; Hampson, 1993). In addition, the ad hoc nature of project team has created arm-length relationship in team members, which affect the sharing and retention of knowledge and information of innovations. Thus, it is necessary that specific diffusion studies need to be conducted on construction innovations, and their diffusion within the industry (Koebel *et al*., 2004). The objective of this section is to review the latest diffusion studies so far conducted in the construction industry to guide the direction of this research.

Literature on diffusion studies relating to the construction industry is comparatively limited and concentrated in developed countries, with the United States leading the rest. It is noted that the studies carried

out in the United States focus more on the residential building sector (Shook, 1997; Toole, 1998; Goverse *et al*., 2001; Koebel *et al*., 2004), with some addressing the heavy civil engineering sector (Nam, 1990; Harkola, 1994). Studies from other developed countries such as Canada, United Kingdom and Australia tend to target the general construction industry. Table 1 shows the latest literature on diffusion studies of construction innovations.

The characteristics of the construction industry and the unique features of construction products have prompted the researchers to identify new variables that influence the diffusion process. Factors such as procurement practice, cyclical market, project-based relationship, high social responsibilities, and a government regulated industry, are just some of the different issues that the construction researchers have focused, or need to focus in their studies as highlighted in Table 1. Ten important factors influencing diffusion of construction innovations were identified from previous research, namely relative advantage, complexity, high social responsibility, cyclical market, traditional procurement practice, innovative culture, innovation champion, clients' involvement, regulatory control and public pressure.

Table 1: Diffusion studies in construction

Authors	Research Focus	Factors influencing diffusion
Nam (1990)	The process of product innovation in the building and heavy sectors of the U.S. construction industry	Innovation champion ; and innovative organisation culture.
Harkola (1994)	Diffusion of construction technology: in a Japanese firm	Interpersonal communication; and opinion leader.
Mitropoulos (1996)	Decision-making by construction firms in the adoption of technologies	Regulation
Blackley and Shepard (1996)	Diffusion of incremental innovations among 417 homebuilders	Industry characteristics (cyclical market; industry fragmentation); building codes; regulation; and firm size
Emmitt (1997)	The diffusion of innovations in the building industry in UK	Extension of Rogers' Diffusion Theory was found to be relevant in explaining the diffusion of building products among architectural firms in UK.
Shook (1997)	Innovation and the U.S. residential construction industry – an integrated model of determinants of firm innovativeness for engineered wood products	Product attributes.
Arditi *et al*. (1997)	Study of innovation rate in construction equipment over 30 years	Innovation characteristics.
Toole (1998)	Uncertainty and home builders' adoption of technological innovations	Uncertainty reduction
Slaughter (1998)	Implementation of construction innovations	Innovation attributes (safety and quality improvement); incremental innovation (complexity); and high social responsibilities.
Winch (1998)	General investigation of innovation in the British construction industry	Structural features of industry - cyclical market
Sexton *et al*. (1999)	Diffusion mechanisms for construction research and innovation into small to medium sized construction firms.	Firm size.
Gann *et al*. (2000,1998)	Investigates energy efficient housing regulation impact on innovation	Imposed regulations.
	Interview 30 construction firms to understand innovation in construction	Industry characteristics (discontinuous teamwork); and building codes (performance specification)
Barrett *et al*. (2001)	Innovation in small construction firms	Industry characteristics (cyclical market and traditional procurement practice)
Seaden and Manseau (2001)	Public policy and construction innovation.	Public policy (rules and regulation); and relative advantages of innovation
Ling (2003)	Managing the implementation of construction.	Traditional procurement practice (adversarial relationship); and innovative culture
Taylor and Levitt (2004)	Systemic innovation diffusion in project-based industries. Case study on US residential homebuilding industry.	Innovation type (complexity of innovation).
Koebel *et al*. (2004)	The diffusion of innovation in the US residential building industry	Relative advantage in technological attributes; complexity of innovation; cyclical market; traditional procurement practice (adversarial relationship); and building code
Blayse and Manley (2004)	Key influences on construction innovation	Cyclical market; procurement practice; and client's involvement
Chan *et al*. (2004)	Exploring critical success factors for partnering in construction projects	Procurement practice.

Park *et al.* (2004)	Dynamic modeling for construction innovation	Innovation champion.
Chiang and Lok (2005)	Clients driving innovation in Hong Kong public housing construction.	Innovation champion; and client's involvement
Manley *et al*. (2005)	Implementing Innovation on Commercial Building Projects in Australia	Clients; building regulators (rules and regulation); and social responsibility (high risk)
Panuwatwanich *et al* (2009)	Core results of innovation diffusion process among architectural and engineering design firms of construction industries	Firms' strong support on the culture of innovation and its facilitation enhance innovation design practices upwards-downwards diffusion within the construction industries
Kale and Arditi, (2010).	Diffusion model of technology innovation of Computer Aided Design	Internal influence that increases with time plays a key role in the diffusion of CAD technology innovation.

The proposed conceptual model for the diffusion of construction innovation is based on the ten factors that were grouped under the four headings, namely the innovation attributes, industry characteristics, adopter innovative characteristics, and environmental interventions as shown in Figure 4. The proposed conceptual model followed mainly the framework on the adopter behavior developed by Brown (1981), with minor changes. Thus, environmental interventions were similar in meaning to the institutional effects (Brown, 1981), but the innovative characteristics of adopting firms were focused here instead of firm characteristics (Brown, 1981). The concept of innovation attributes was adopted from Rogers (1995).

Consistent with the study objective, the model focused on the extent of diffusion as the dependent variable. Essentially, it was theorized that the interaction among factors of Innovation Attributes, Industry Characteristics and Adopter Innovative Characteristics initiated the diffusion process. The extent of diffusion was caused by the forces of technology push and demand pull created by the interaction. Moderating factors of Environmental factors were theorized to influence the diffusion process much later, resulting in significant changes.

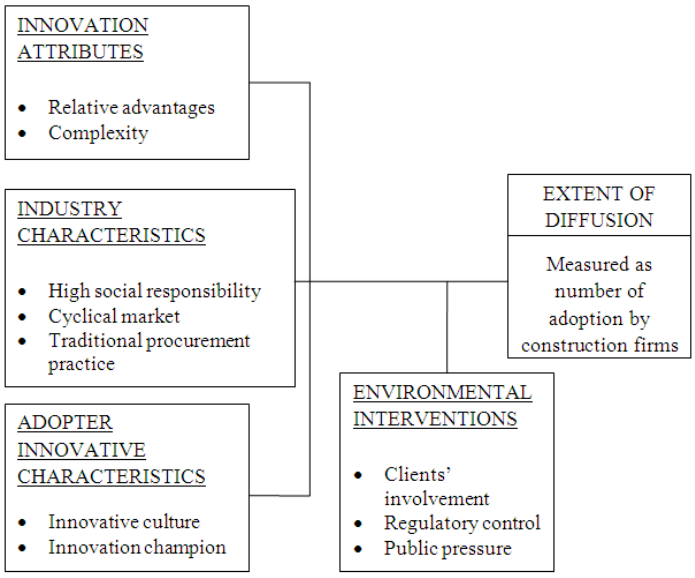

Fig. 4: Proposed conceptual model of diffusion of construction innovation

Conclusion:

A model for diffusion of technological innovations in the construction industry has been developed. It is likely to benefit the construction industry in better understanding of the diffusion process and mechanism involved, which is lacking in previous studies. To examine the diffusion and low adoption of homegrown innovations, it is suggested that an empirical study be carried out so as to identify significant factors that influence the diffusion-adoption process. More effective diffusion of innovations will benefit the homegrown innovation developers if catalytic factors peculiar to local characteristics are identified in future study.

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