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# Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology

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Interest in construction industry (CI) innovation, particularly in information communication technology (ICT), has been steadily growing with the advent and widespread use of the Internet. However, despite its potential for delivering competitive advantage, many companies have failed to effectively realize promised benefits from ICT due to misunderstanding the relationship between factors and processes influencing ICT implementation. Results from recent in-depth qualitative ICT implementation research on three construction contractors provides useful insights and practical experience of lessons learned that can be more broadly disseminated. These research results provide an ICT innovation diffusion organizational level framework with insights about how it may be applied to improve ICT adoption at different implementation stages for the CI. They suggest that strategic ICT implementation planning needs to consider issues of critical management support, technical support, supportive workplace environment and ICT users' individual-characteristics so that the framework processes offered can be effectively applied.

*Keywords:* Innovation diffusion, IT implementation, technology management

## Introduction

Information and communication technology (ICT) facilitates communication and improves integration (Bjork, 1999; Love *et al.*, 2000) enhancing productivity and service delivery. Skibniewski and Abduh (2000) reviewed the development of specific construction industry (CI) Internet applications and showed that such technology provides information services, communications and computing management benefits.

While many construction organizations attempt to gain ICT use benefits, these may be limited when few people actually adopt and use ICT because this requires user acceptance. Even with widespread ICT adoption, users will find it impracticable to communicate electronically with colleagues who avoid using ICT. Thus, organizations can lose potential productivity gains through operating with both hardcopy and electronic data. Transitioning from a paper-based to a fully electronic environment requires that users readily adopt and accept ICT.

At the highest level of abstraction, innovation has been studied at the national or corporate strategic management level. While this is useful for understanding the value of innovation and why it should be pursued, it does not help explain what is happening after an innovation initiative decision has been made and how it can be effectively implemented. This reinforces the aim of the innovation study reported upon here to more concretely explain effective innovation deployment from an implementation perspective focusing on a specific type of innovation.

This paper begins with a review of literature relating to ICT diffusion to support basic ICT diffusion knowledge. Next, the research methodology and findings are presented. Finally, a conceptual model of ICT diffusion and a framework across critical implementation phases is offered and discussed.

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## Research on technological innovation diffusion

Innovation diffusion is defined as the process in which a new idea, concept or technology has been introduced throughout a social system over a time period (Rogers, 2003). The term 'ICT diffusion' is defined in this paper as the process by which an ICT application is adopted and implemented by an organization until its expected users accept and transfer knowledge of how to use these ICT applications throughout the organization. However, this only explains what goes on at the macro level and it is of little use to those interested in how to facilitate innovation to make a positive and lasting impact at the work group or individual level.

Schumpeter (1934) discusses how innovations occur, their implications for the global economy and how firms use innovation to competitively sustain their position. Like Dosi (1982), Schumpeter saw innovation as a process following a historical path. He (1934) describes 'gales of creative destruction' occurring where past innovations are re-defined and re-invented in light of changing dynamics. He identified the impact of technological and scientific change occurring during five long waves of historical innovation advancement previously introduced and explained by Kondratieff (1935) in terms of prosperity, recession, depression and recovery phases.[1] Sundbo (1999) and Jones and Saad (2003) describe these waves: the first Kontratiev wave of 1870–1890 revolved around mechanization of the industrial revolution (Sundbo, 1999, p. 39), the fifth wave is attributed to information and communication technologies beginning in the early 1980s (Jones and Saad 2003, p141) and while this phase could be seen to have stalled with dot-com collapses of around the turn of the 21st century, the onward march of the Internet has regained its impetus. Simplistic interpretation of these waves has attracted much criticism (Sundbo, 1999; Jones and Saad, 2003), despite the convincing argument of their existence. Each new 'wave' derives from changed economic and/or global business context – as the recovery phase takes hold, 'swarms' of innovations occur.

Debate continues over the extent that innovation results from demand-pull or producer-push forces; see, for example, Rothwell and Robertson (1973) and Mowery and Rosenberg (1979). Dosi argues that 'continuous changes are often related to progress along a technological trajectory defined by a technological paradigm, while discontinuities are associated with the emergence of a new paradigm' (Dosi, 1982, p. 147). Continuous improvement drives incremental improvement either by an innovation owner's autonomous research and development (R&D) efforts, or through close integration with lead users forming a network of people that enjoy testing and validating beta versions of innovations (Von Hippel *et al.*, 1999). This process can lead to a new way of fulfilling that innovation's need. For example, 'empathic design' (Leonard-Barton, 1995; Leonard and Rayport, 1997) through working with users of an innovation involves discovering how collaboration can spark new product and process innovation paradigms. Radical innovation can 'invade' a stable business through offering better value by solving a problem in an entirely different way. Utterback (1994, p. 161) describes how document processing by typewriters was first overwhelmed by word processors in the 1980s then overwhelmed by word processing software. These examples exhibit technology-push where producers convince users to adopt their innovations, but there is also evidence of strong demand-pull through users actively seeking innovative solutions. Sundbo (1999, p. 159) argues that strategy developed by professional managers has become the dominant paradigm for today's fifth Kondratiev Wave with entrepreneurs 'discovering' and 'pushing' innovative products/services to some extent and technicians driving strategically focused R&D-based innovations to either 'push' innovative solutions or to work with lead users who 'pull' solutions by experimentation and progressive innovation improvement.

There has also been keen interest in the way that innovators search for solutions to problem using government-sponsored innovation through military R&D, universities or large corporate R&D facilities (Nelson and Winter, 1977). Nelson and Winter (1977, p. 54) introduced the issue of business strategy as being important to innovation. Dosi (1988, p. 1158) expressed interested in the dynamics of industry and technologies and their impact upon innovation and competitive advantage arguing that 'firms generally learn at different rates, with modes and behavioural rules specific to their history, internal organization, and institutional context'. Later the focus of innovation research shifted to models of innovation that embraced multiple factors rather than the earlier push-pull dichotomies (Jones and Saad 2003, pp. 149–50) that stressed strong integration of organizational and people networks and relationships as well as the accumulation of knowledge about how to innovate (Cohen and Levinthal, 1990).

Innovation also forms part of an organization's competencies complementing the resource-based view of the firm (Grant, 1991) and how its knowledge base and change capacity can be harnessed (Utterback, 1994; Conner and Prahalad, 1996; Grant, 1996; Sundbo, 1999; Slaughter, 2000; Jones and Saad, 2003; López, 2005) to provide both price competitive

advantage by enabling more cost-effective processes or by adding value to products/services offered (Porter, 1985) – particularly in the internet age (Porter, 2001). The strategic impact of innovation compliments the concept of firms having dynamic capabilities that are idiosyncratic and often path-dependent, assembled from its experience of experimentation and innovation that combine deliver implement innovation (Teece *et al.*, 1997; Eisenhardt and Martin, 2000). However, ICT strategic implementation in the CI could be seen as being defensive and reactive because clients and supply chain partners increasingly rely upon these tools – thus, failing to use these tools makes a firm unattractive.

Three innovation diffusion theories for individuals and groups deciding to adopt an innovation has been studied (Harkola, 1995; Larsen and Ballal, 2005). Cohesion theory states that social proximity of previous and potential users influences the likely potential users' subsequent decision to use that technology (Harkola, 1994, p. 21). A recipient respects the expertise and advice of the influencer, often through social or professional networks. Emmitt (2001) describes how architects and specifiers respond to building product technical representatives and act as gatekeepers where the opinion leaders exercise strong power in adoption decisions. Structural equivalence theory holds that adoption decisions are made on the basis of people searching for innovation solutions by closely monitoring those they deem to be equivalent in status/role so that they allow others to 'show the way' and they are content to be early majority followers (Rogers, 2003, p. 283). Threshold innovation theory holds that adoption is regulated by the nature and strength of influence of group influence in communities (Granovetter, 1978). This also recognizes the strength within social networks where a small number of influential members can tip the balance in favour of a decision. This has more recently led to numerous explanations of how a tipping-point is reached (Granovetter, 1978; Gladwell, 2000; Kim and Mauborgne, 2003). Larsen and Ballal (2005, p88) gathered data from 264 construction professionals, architects builders and engineers and analysed innovation motivation patterns, they concluded that at the diffusion opinion forming stages, cohesion more strongly influenced that structural influence but at the decision adoption stage, a personal awareness threshold theory dominated. Clearly, adoption-decision influences vary over the stage of the diffusion process.

Innovation diffusion plays an important role in theories describing information technology (IT) implementation (Rogers, 2003). It can be studied using both factor and process approaches (Fichman 1992). The first approach focuses on the 'what': key factors influencing adoption and diffusion whereas the process approach focus relates to the sequence of the 'how' of adoption and diffusion. In addition, the unit of technological innovation adoption could be grouped into macro, meso, and micro levels (Iivari, 1993). Macro level innovation theory focuses on organizational adopters. Micro innovation level theory focuses on the individual adoption and meso innovation is classified in between these previous two focusing on an organization as consisting of series of individual adoptions.

Criticism of innovation research centres on producing confused findings that are not easily compared to explain why successful innovation happens (Nelson and Winter, 1977; Wolfe, 1994; Sundbo, 1999). Standard categories and concepts, case study context, as well as the focus of study domain needs to be clear to enable valid comparisons to be made. Wolfe (1994, p. 406) suggests, 'researchers must clearly address:

(1) which of the various streams of innovation research is relevant to a research question;
(2) the stage(s) of the innovation process upon which a study focuses;
(3) the types of organizations included in a study;
(4) how a study's outcome variable (e.g. adoption, innovation, implementation) is conceptualized; and
(5) the attributes of the innovation(s) being investigated'.

Wolfe provides guidance on these streams (1994, p. 407). Diffusion of innovation (DOI) research addresses patterns of how innovation spread throughout a studied group of adopters. Organizational innovativeness (OI) addresses the determinants of how innovation occurs – focused upon the organization. Process theory (PT) addresses the process of innovation and how and why adopters carry out innovation. Stages of innovation have been classified in various ways. Wolfe (1994, p. 410) notes 10 stages: idea conception, awareness, matching, appraisal, persuasion, adoption decision, implementation, confirmation, routinization and infusion. Roger (2003, p. 199) offers five stages; knowledge, persuasion, decision, implementation and confirmation. The outcome of the study reported upon in this paper was specifically focused upon PT for the actual implementation stage of the ICT application's deployment. Innovation attributes are further discussed in the research section.

IT management, especially adoption and implementation, is identified as of significant current interest to construction management researchers (Amor *et al.*, 2002) with ICT adoption being linked to IT strategic management (Smith and Betts, 1999), technology adoption decision-making (Mitropoulos, 1996;

Mitropoulos and Tatum, 2000), strategic planning for IT investment (Peña-Mora *et al.*, 1999) and strategic IT implementation (Stewart *et al.*, 2002). Although there has been several research attempts to develop an implementation framework, technology adoption problems remain in the CI such as time and cost overruns and users' resistance (Love *et al.*, 2001). These could be resolved by organizations having an improved understanding of the technological diffusion process based on a PT research approach (Wolfe, 1994, p. 407).

The technology adoption decision within organizations is usually authorized by a group of senior managers, therefore the key question of ICT adoption should be focused on how to ensure that expected users accept and use ICT in their work processes. Several concepts explain users' acceptance, such as the technology acceptance model (TAM) (Davis *et al.*, 1989), theory of planned behaviour (TPB) (Taylor and Todd, 1995) and diffusion of innovation (DOI) (Rogers, 2003). These can be considered as generic innovation adoption models because they explain individuals' independent behavioural intentions in adopting or rejected technology (Fichman, 1992). Gallivan (2000) argued that generic innovation adoption models may not be applicable under the following circumstances:

- Adoption within organization where expected users are mandated to adopt;
- Adoption is dependent on multiple adopters; and
- Adoption requires extensive training to upgrade users skills.

As generic adoption models rely on voluntary adoption decisions by individuals, they may be less suitable in explaining complex organizational adoption decisions (Gallivan, 2000). Successful technology adoption within organizations needs top-level implementation support and encouragement of expected users to individually adopt and use the technology. To overcome the generic innovation adoption approach, Fichman (1992) recommends integrating DOI with other theories such as critical mass (Markus, 1987), absorptive capacity (Cohen and Levinthal 1990), and organizational learning (Attewell, 1992). Similarly adoption of technological innovation into organizations can be seen as a change initiation process.

Innovation diffusion within an organization requires change management to facilitate and encourage people to adopt ICT initiatives. Organizations can do this through: motivating staff; providing appropriate training and technical support; and ensuring supervisor support for an open-discussion sharing environment (Senge *et al.*, 1999). Peansupap (2004) integrated the concept of DOI (Rogers 2003) with change management (Senge *et al.*, 1999) and identified 11 factors influencing ICT use and adoption. Factors were clustered into management (M), individual (I) and technology (T) groups that impact upon ICT diffusion with each of these being influenced by the impact of the workplace environment (E). Individual and environment group factors generally had a high impact upon ICT diffusion with management and technology group factors having a slightly above moderate impact.

According to Cooper and Zmud (1990), organizational adoption and its implementation consists of six stages: initiation; adoption; adaptation; acceptance; routinization; and infusion. This stage model has been used for measuring technology adoption maturity based on the characteristics of each stage (Damsgaard and Scheepers, 2000). Figure 1 shows the generic innovation diffusion stage model divided into two stages: initial adoption and actual implementation. The first stage, initial adoption, focuses on diffusion of the innovation at the organizational level. It consists of three sub-processes: knowledge awareness; persuasion; and decision adoption. The second stage, actual implementation, focuses on individual/group adoption and diffusion. Carlopio (1998) argued that diffusion at the individual/group level should follow a similar process to that of the organization level with feedback to the organizational level. He adapted the Roger's (2003) model and proposed five stages of innovation diffusion at the group/individual level: (1) knowledge awareness; (2) facilitating structure; (3) persuasion; decision and commitment; (4) fine tuning and refining; and (5) confirmation and re-utilization.

The research reported upon here adapted the innovation diffusion stage models and extended the models by integrating the factors and processes with innovation stages. The model also shows the sequence of factors influencing each process of adoption and diffusion. The details of factors and processes will be described in each innovation stage. As the model was developed from ICT diffusion case studies drawn from large IT-experienced construction organizations, it facilitates better understanding of ICT adoption factors influencing diffusion through the ICT adoption and diffusion process. This model may also assist construction organizations to plan and monitor their ICT diffusion initiatives: feedback from participants and from seminars on the proposed model indicates that this model may also be applicably (extended) many emerging technologies.

## Research method

As a preamble to this study, quatitative data was gathered to identify factors influencing ICT diffusion

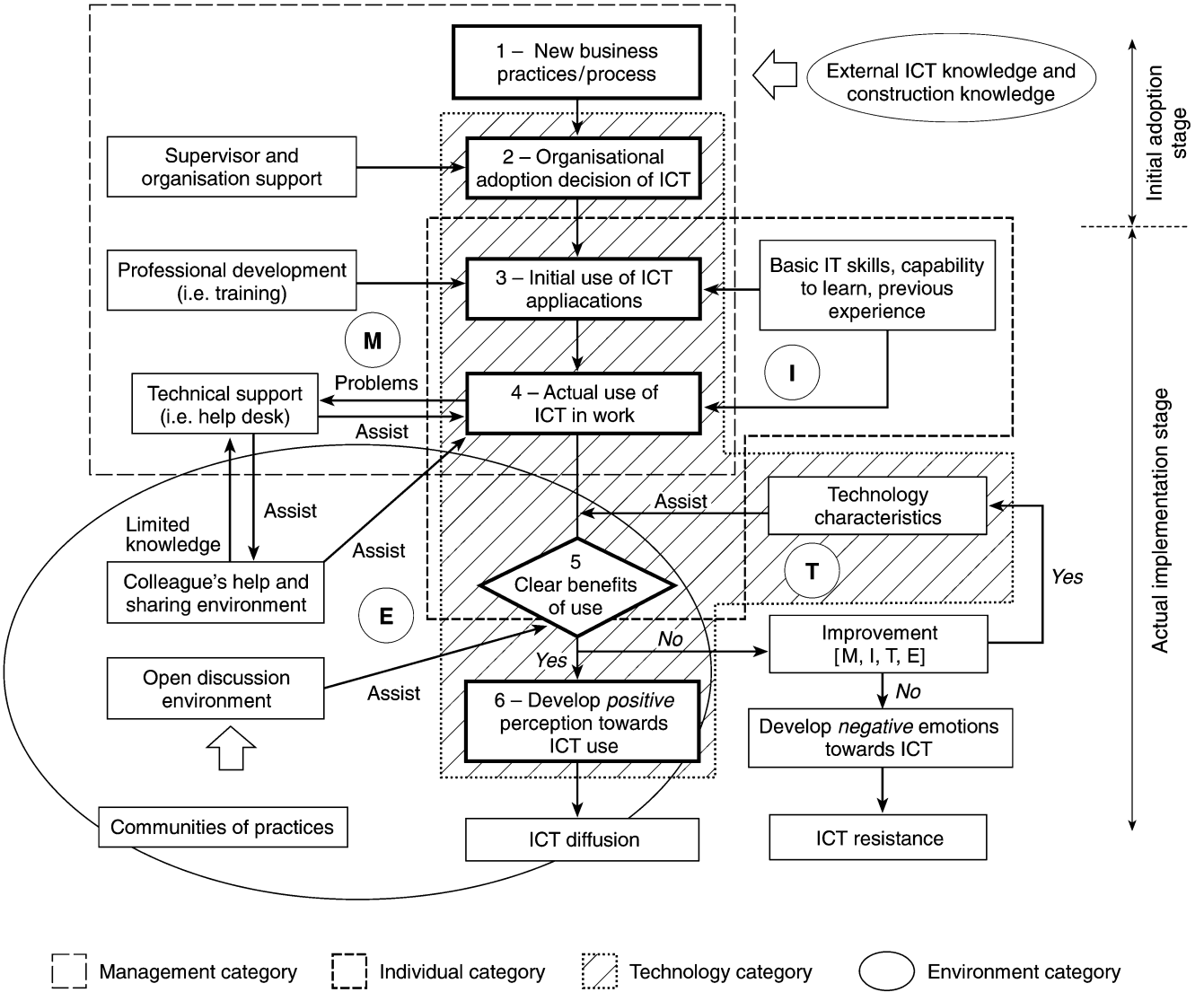


**Figure 1** The framework of ICT innovation diffusion within an organization

within three large scale construction organizations comprising a major construction contractor, a government public works department and a leading global engineering consultant that were experienced and sophisticated ICT users to explain how they influence the ICT diffusion processes for details, see Peansupap (2004).

Case study qualitative research can be grouped into three broad categories: exploratory, descriptive, and explanatory (Neuman and Kreuger, 2003). A descriptive case study approach was chosen to obtain rich qualitative data from the participant's viewpoint using multiple sources of data for unearthing what was happening as well as how and why it followed a particular trajectory (Yin, 1994). Three ICT-experienced construction companies that have been using ICT applications for several years were targeted among those listed in the Business Review Weekly (BRW) Australian Constructors Association Annual Report (BRW, 2001) and one of these took part in the preamble study. There are approximately 13 construction companies that managed projects of AUD$00's millions cost with company annual turnovers exceeding AUD$500 millions during the year 2001. This research investigated ICT adoption and diffusion practices of three top-tier Australian construction contractors from that BRW list selected on availability and the opportunity to conduct interviews with them.

Wolfe (1994, p. 406) recommends describing innovation attributes. The study focussed upon intranet and ICT groupware used by organizations that had been

experienced with diffusing IT and general-purpose office management software tools. While users were not immediately familiar with the ICT applications being diffused, they had IT experience. These ICT innovations were mandated by the organizations for use and they became perversely embedded as part of the normal work processes often replacing outdated manual paper-based processes. Innovations were operationally central, of low complexity and packaged within administration routines. The unit of analysis was focussed upon the ICT application users' implementation experience.

Table 1 presents Interviewees grouped into five levels: IT strategists (senior level management champion and initiative driver) implementers (given the task of encouraging diffusion of the ICT groupware initiative), project managers (responsible for construction teams on projects using this technology), site engineers, and site foremen (both direct users of the technology in co-ordinating the physical and administrative work being undertaken on-site).

Data collection discussions with senior IT managers reveal the strategic adoption of ICT applications at the organizational level. Semi-structured interviews were conducted with the ICT implementer or ICT manager involved in rolling out the ICT application at the group or individual level. Experienced users in each case were also requested to discuss their experience of factors influencing their adoption and ICT application use. A grounded theory approach (Glaser and Strauss, 1967; Locke, 2001) was followed, supplemented by the preamble research phase, to the organizational adoption (initial adoption) and individual adoption (actual implementation) perceived experience. Discussion of the initial adoption of the applications is focused on how the ICT application was actually implemented and how expected users were introduced to, and encouraged to accept and use ICT tools for their normal work activities. Seminars were conducted to validate the analysis with feedback stimulating further debate.

**Table 1** Categories of interviewee in the three case studies

| Interviewee | Case study | | |
|---|---|---|---|
| | CSA | CSB | CSC |
| IT strategist | 1 | 1 | 1 |
| Implementer (L1) | 1 | 1 | 1 |
| Project/engineering manager (L2) | 4 | 1 | 1 |
| Site engineer (L3) | 1 | 3 | 2 |
| Foreman (L4) | 1 | 1 | 1 |
| Total | 8 | 7 | 6 |

## Case study research findings

Each contractor aimed to gain competitive advantage through investing in ICT groupware communication and co-ordination applications for processing requests for information (RFI), and document management that allowed users to access, exchange and search information from anywhere at any time. Each organization had a different trajectory in positioning themselves to adopt and implement the ICT applications. While objectives for ICT adoption in all three cases were similar, their adoption processes were different. Peansupap (2004) summarized findings of the ICT adoption study as follows:

- CA and CB chose to embrace a proactive strategy of ICT adoption whereas CC selected a reactive strategy of ICT adoption;
- ICT adoption in CA and CB was influenced by both demand-pull and technology-push while this in CC was more influenced by technology-push than demand-pull.
- The adoption decision in CA and CB was centralized (top-down direction) whereas the adoption decision in CC was decentralized (top-down and bottom up)
- The adoption of ICT in all three cases was supported by group of top business managers and senior IT managers.
- The adoption approach in CA was defined as in-house development, CB development was based on in-house development plus IT consultancy, and CC relied on outsourcing (the external web-based service)
- In the three cases, it was difficult quantify ICT adoption benefits and use, however, users expected to gain benefits from adopting ICT in terms of improving team communication, information exchange, document repository, and a project register of past events.

Although the nature of ICT adoption for the three cases was quite different for proactive and reactive strategic adoptions, the implementation of the ICT application was similar for supporting management, technology and supporting individual users. While most of three cases' participants believed that collegial and knowledge-sharing ICT environments are the main factors influencing the actual implementation, these were informally valued as being essential elements of organizational implementation.

CA's actual implementation focus was on: IT training and technical support; technology fit; and senior management support. Most respondents received 3–4 hours training with strong help-desk

support. Top management was interested in developing ICT applications for enhancing work-processes with functionality and simplicity being key factors required to encourage user acceptance. Senior project managers supported the ICT diffusion by encouraging users, helping them solve ICT use problems and providing feedback comments to ICT developers. CA participants had strong computer skills, clear ideas of the benefits of using ICT applications, and self-confidence in adoption and use for their daily work. A sharing and learning environment sustained ICT diffusion by helping ICT supporters and users understand and continuously improve ICT initiatives.

ICT implementation in CB focused on training, and implementer and senior management support. Before any projects began, all respondents received 3–4 hours of training from an ICT implementer who also took an additional role in helping ICT use though help-desk support. Some users expressed difficulty contacting the help-desk by phone to get quick responses so they directly contacted the ICT implementer. Organizations provided each user with a computer, an Internet connection and user account. Senior management support included project-by-project job responsibility with two construction project managers providing ICT application role-model team encouragement. However, one design project manger argued that ICT applications have not supported his project. Expected users also complained about implementation process issues, being satisfied with the concept of ICT use, but complaining about barriers to their technology use – 'ICT application is based on 56k Internet connection, but there are several terminals in office use that share Internet connection…It takes a long time for downloading drawing file'. Respondents were satisfied with the content of training but different backgrounds and skill levels affected individual learning outcomes. Unclear benefits of ICT use resulted in users wasting time learning non-essential modules; though one project had many experienced users who could influence new users' ICT acceptance. Training provided common ICT-use understanding, but users needed to learn and practice before gaining tangible benefits.

Actual implementation in CC was influenced by training and implementer support. Most participants were satisfied with training that took approximately one hour and 30 minutes to provide an initial understanding of the ICT application (considered to be straightforward). The implementer used trial projects to help users familiarize themselves with the applications. The Implementer strongly influenced and helped on-site users as part of his role. Thus, users felt confident to ask for help from him. Suitable computer and Internet network infrastructure was provided as well as an innovative project manager who had an enthusiastic personal interest in ICT and encouraged subordinates to use ICT applications through making time to help user's solve their problems. CC's ICT objective was to fully support project communication and co-ordination (document management system that included daily work lists, drawing register and correspondence) within and between project teams. System responsiveness was reliable but was governed by the Internet connection speed. Participants had enough computer background knowledge and clear benefits of using ICT to feel it simple to use providing suitable benefits. Most participants felt that CC facilitated a good collegial-help environment on construction projects with a supportive implementer plus other ICT assistance. They shared stories and discussed how to improve ICT use – people felt sufficiently safe to openly ask questions and fearlessly discuss any difficulties encountered when using ICT.

Case studies conclusions and quantitative study Peansupap (2004), indicates that the main implementation process focused on training and technical support, senior management support, user characteristics, and ICT characteristics. Training and technical support and ICT characteristics were formally managed but support from senior management or project managers, characteristics of users, and a sharing and open discussion environment was informally managed.

## Framework of ICT innovation diffusion

The ICT diffusion framework for managing technology adoption and diffusion is illustrated in Figure 1. The model is presented in two stages: initial adoption and actual implementation. It illustrates key relationship categories: management (M), individual (I), technology (T) and environment (E) that influence diffusion processes. Thick-lined numbered elements highlight organizational ICT diffusion processes. M (management) focuses on the influence of management and organizational support, IT professional development, and technical help desk support. I (individual) focuses on the influence of personal/individual characteristics such as IT skill, capability to learn, and pervious experience of IT. T (technology) focuses on the influence of technology characteristics such as functionality, speed, and accessibility. E (environment) focuses on the influence of the workplace environment such as open discussion and sharing knowledge about ICT.

The model indicates (thick-lined elements) how ICT diffusion takes place from initial adoption to actual implementation through six key ICT diffusion processes:

(1) developing new business practices/processes;
(2) organizational adoption of the ICT decision;
(3) preparing for the initial use of ICT applications;
(4) reinforcing the actual use of the ICT applications;
(5) clarifying benefits of ICT application use; and
(6) developing a positive perception towards ICT and ICT diffusion.

### Process 1: development of new business practices/processes

Senior managers recognize that the potential ICT application may provide strategic improved core business competences through cost leadership and differentiation (Porter, 1985; Björnsson and Lundegård, 1993) by improving productivity through reducing time and cost to transfer, store and search for information and/or delivering a differentiation competitive advantage. CA used ICT as part of its knowledge management system differentiating it from the approach adopted by CB or CC.

ICT innovation persuasion occurs when a champion attempts to convince senior executives and managers that adopting a potential ICT application is of organizational strategic importance to support business requirements by proposing scenarios and benefits of adopting it. Champions with strong background knowledge of both construction processes and the ICT application can develop a clear relationship between ICT benefits and the business need. Once the champion receives the authorization to continue, the process of persuasion can be repeated through an ICT diffusion implementation committee, as was the case with each case study. These committees consist of the champion and representatives from senior executives, managers and IT managers, along with the IT development teams involved in the ICT adoption decision. Initiation of ICT diffusion at the organizational level depends upon a champion who has sound ICT knowledge, a good background in construction procedures and processes, and being in an influential management role. The first two champion characteristics are based on his/her innovation knowledge and resources, whereas the management role appears to be an important influencing element to adopt the innovative idea.

### Process 2: organizational adoption of the ICT decision

The adoption decision stage consists of exploring how the ICT applications' adoption influences existing business processes. Existing ICT software that delivers the identified benefits might influence the selection process of that particular ICT application. In the early stages of ICT evolution, the ICT application in the market might be designed for general purposes rather than specific construction work processes. This presents two approaches to ICT adoption. The first is to develop an in-house ICT application if there is no suitable available application whereas the second choice is to adopt an external ICT innovation process that provides a best fit for the organization's needs. The adoption decision is based on matching an available ICT application to construction processes after undertaking a cost/benefit analysis (including non-financial benefits). The ICT diffusion implementation committee usually makes the adoption decision based on detailed technical advice, often after conducting trials.

### Process 3: Preparing for the initial use of ICT applications

This process prepares expected users to learn and understand the ICT application at the group/individual level. The organization should facilitate groups and individuals to develop a background understanding of the ICT application's key features and how these might benefit them perhaps through a 'road show'. Facilitating ICT background understanding requires an 'implementer'. Implementation may be similar to promoting knowledge awareness but it is more focused on capability and benefits of ICT use issues to facilitate user feedback on the ICT application. Knowledge awareness is a two-way process in which knowledge is transferred from the initiating group to targeted users and targeted users provide feedback for possible improved preparation and ideas on how to best deploy the ICT application.

Case studies indicate that some project managers were risk-averse in adopting ICT on their projects and might block project-level ICT adoption even though the ICT application had been generally adopted by the organization. Project manager commitment to initially use ICT applications is essential for potential ICT diffusion success at the project level.

Training develops practical understanding of ICT application use. Most participants received training conducted by a trainer (with a clear and practical understanding of the ICT application's use) before their 'live' use to avoid learning by trial-and-error. Users in all three case studies recorded high-level satisfaction with training provided but made suggestions for improvement:

- Providing practical examples;

- Deploying targeted skills assessment and needs analysis;
- Application trials; and
- Providing adequate reference materials.

Case study data indicated that group and individual user's experience plays a key role in users understanding how to best deploy ICT applications. Users with basic computer skills usually develop an understanding of the ICT application quicker than those who lack the skills because this helps them to increase their absorptive capacity (Cohen and Levinthal, 1990). A supportive manager, training, and users' computer skills background appears to influence an ICT application's use.

### Process 4: reinforcing the actual use of the ICT applications

Actual continued ICT application use occurs when users routinely accept and engage the ICT innovation with adaptation occurring to suit work process constraints. This results from organizations providing training and a supporting ICT infrastructure. Staff may need to adjust their behaviour and procedures to accommodate ICT use and requires overcoming problems with ICT functions, resources, and other technical problems. The actual-use phase requires active communication and feedback between users and ICT initiative developers to help minimize possible gaps between planned and actual ICT use. Transition to this stage involves support at four levels: management, the individuals, technology and the environment.

Technical support such as an IT help-desk is most important in assisting potential ICT adopters when they have problems in using the ICT application. An IT help-desk can help these potential adopters to find the right answer to specific questions or requirements they might have during their ICT use and be used as a feedback tool. In CB and CC, IT staff that are involved with the ICT development teams also operated the IT help-desk and were in a good position to quickly and knowledgably assess problems as they arose. CB's IT help-desk staff responded to problems via phone and email. CA used an electronic web board and allowed potential adopters to enter concerns on their Intranet using this forum to discuss problems of using ICT applications by providing a community help facility forum for a community of linked users to share knowledge and learning among ICT adopters as a community of practice (Wenger *et al.*, 2002, p. 24). Implementers can solve common ICT application problems and assist during the initial use and implementation of the ICT application at the construction project level. In CB and CC, an implementer is employed to help new potential ICT adopters on construction sites. Most participants agreed that the implementer was a key ICT diffusion resource depending on the size of the construction project and the number and ICT-sophistication levels of adopters on the project. If staff have experience and a sufficient capability in using the ICT application then an implementer may be needed at the beginning of the project but then experienced adopters could take over this role to help each other on basic ICT use problems. This may be described as a 'collegial environment'.

The group factor in Figure 1 'individual category' indicates that personal learning capability has a strong influence on the actual use of an ICT application. Most users agreed that when they encountered problems they tried (as long as they had sufficient time) to learn how to solve the ICT application problems by themselves.

During the actual ICT application use, ICT application technology characteristics, i.e. functionality, easy of use, accessibility and connection speed may facilitate or hinder adopters' ICT application diffusion because it can reduce users' learning time.

### Process 5: Clarifying benefits of ICT application use

This occurs when members have understood the positive outcome of using a technological innovation (and limitations that they may face) and have accepted it to the extent that they embed its use into their work routines. Two-way communication between ICT users and senior managers/project managers promotes a clear understanding of how the ICT application assists or inhibits users' work. ICT users' commitment is essential because they have to change procedures causing temporary discomfort and inconvenience. The ICT application's characteristics should support and maintain system reliability. Also, the system should be designed to cater for increased number of users. Therefore, the organization should make sure that the ICT application performance retains its functionality, reliability and speed so that it is not degraded.

Adopters need to understand the important outcome of sharing their experience by explaining how they use the application to achieve a more practical result than previous approaches adopted for doing their work. The workplace environment needs to be free of recriminations or any sense of failure to understand how to use the ICT applications so that when difficulties arise (data-line access, or transfer speed, or user-interface perceived as confusing or difficult to use etc.) these problems are addressed.

### Process 6: developing a positive perception towards ICT and ICT diffusion

Positive perception towards ICT and its diffusion reaches a stage where users adopt the ICT application as a part of their work processes moving to a stage of infusion whereby a continual cycle of fine-tuning, improvement and evaluation takes place. Adopters attempt to convince others of their positive experience becoming what von Krough *et al.* (2000) calls a 'knowledge activist'. These people effectively transfer knowledge about an innovation as well as motivating others, often through using role-model behaviour for adopting and adapting the knowledge in question. At this stage, management support should focus on the issue of facilitating the creation and maintenance of conditions that enhance the ICT users' experience of benefits of the ICT application's use.

## Discussion and conclusions

Innovation theory was discussed with clear focus on the actual implementation stage. A supportive model of ICT diffusion was presented to explain ICT diffusion and a two-stage (initial adoption actual implementation) six-process framework to effectively implement ICT innovations was explained. The case study work focussed upon IT-experienced construction contractors, so the framework's general applicability limitations must be acknowledged. However, the literature reveals that the CI is increasingly becoming more IT literate so the framework presented may be tested more broadly and could be found to offer a practical approach to ICT diffusion within the described context.

Senior management was shown to be in a pivotal position to strongly influence the initiation and implementation stages of ICT diffusion. First, they mould the initial organizational adoption phase by making resources available and demonstrating their high level of commitment. In the next diffusion process stage they encourage potential users to adopt and use ICT in their daily job through adaptation of the application and its acceptance, routinization and infusion into normal workplace practices. This actual implementation stage requires a supporting management, technology, individuals, and a collegial environment. Figure 1 indicates the decision point at process 5 where clear benefits of use are questioned. Infusion of the ICT application can take place if ICT-use benefits are accepted and routinized. However, if the benefits of ICT use are unclear or rejected, then improvement in the management, technology or workplace environment needs to be instigated.

The contribution that this study offers is that it clearly illustrates the dynamics of ICT diffusion within the case study organizations than has been evident in the literature. Implications for the CI of this study are that while the M and T factors illustrated in Figure 1 are well recognized, the I and E factors have only recently been shown to be critical to successful ICT diffusion. The model framework of ICT diffusion – consisting of six processes in two stages and supported by the literature – suggests that senior managers need to pay a substantial amount of energy and effort on ensuring that ICT users develop skills that reinforce I factors as well as facilitating a workplace environment that enhances the impact of E factors.

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## Note

1. Due to the Roman script transformation of his name he often is cited as Kontratiev though his (cited) work appears as Kondratieff.

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