# FACTORS ENABLING INFORMATION AND COMMUNICATION TECHNOLOGY DIFFUSION AND ACTUAL IMPLEMENTATION IN CONSTRUCTION ORGANISATIONS

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***SUMMARY****: Emerging information and communication technology (ICT) introduces opportunities for improving communication to enhance effectiveness of many construction processes at each project phase as well as creating new business opportunities. Thus, perceived ICT benefits have motivated numerous construction organisations to adopt and invest in this technology. However, many construction organisations have found that the ICT investment has failed to meet their expectations. One significant problem is a lack of understanding of how to actually implement ICT into a construction organisation. This may lead to ICT implementation failure or retardation by all users within a construction organisation. In addition, a lack of focus on actual ICT implementation may explain why ICT implementation problems still occur.*
*Before substantial progress can be made to remedy deficiencies in ICT implementation, a better understanding is needed about the context and influence of a range of workplace, organisational and personal factors on ICT implementation. The general focus of this paper is directed upon ICT implementation in construction organisations, with a specific focus using results from a study of a small but indicative sample of Australian ICT literate construction organisations. An improved understanding of ICT implementation can be achieved through a general survey of the literature and then testing theory developed from the literature using a representative pool of general construction organisation. Alternatively, a narrow focus could be directed at organisations that are already well experienced in the use of ICT. The authors concentrated upon Australian construction organisations with over a decade of experience in ICT implementation so that salient lessons learned could be more readily available for dissemination more widely.*
*This paper attempts to fill ICT implementation gaps by focusing on ICT diffusion at the actual implementation stage. Its primary objective is to understand the nature of ICT diffusion within a construction organisation. It focuses on a review of the theory relating to ICT implementation. A list of 46 essential variables was developed from integration of three main theories: innovation diffusion, change management, and knowledge management. The paper also provides a brief summary of the variables tested through using factor analysis. Results indicate that these 46 variables formed 11 factors that can be grouped into management, individual characteristics, technology and workplace environment clusters.*
*The contribution that this paper makes is to rigorously identify and discuss the nature and extent of intra-organisational factors influencing ICT diffusion within large ICT-experienced construction organisations. This will be useful for those interested in this area and provides a current literature review.*

***KEYWORDS****: technology implementation, diffusion of innovation, change management, knowledge management*

## 1. INTRODUCTION

When undertaking any substantive research study, it is necessary to thoroughly review the relevant literature. One useful source of information for researchers therefore is published peer reviewed papers that outline and discuss the literature in the given topic area. Another useful source is published peer reviewed case studies and

reports of research undertaken. However, the latter suffers from problems of scope—reviewers and journal editors require limited literature review sections and a concentration upon details of the research exercise. Thus, the value undertaken by, for example, a PhD student in undertaking a literature review is lost in such papers.

This paper has as its primary goal to provide a comprehensive and rigorous review of the literature relating to ICT Diffusion. This entails presenting current theory developments that identified gaps that were addressed by the PhD thesis from which this paper was developed. As a secondary goal, a list of 46 variables that were tested by a survey are presented and results of factor analysis are briefly discussed so that readers can appreciate that the variables identified in the literature review were found to be valid and useful and have been successfully explored, tested and examined as part of the PhD examination process. A series of papers outlining results and findings from this work are in print (Goldsmith *et al.* 2003; Peansupap *et al.* 2003a; Peansupap *et al.* 2003b; Walker and Peansupap 2003; Peansupap 2004; Peansupap and Walker 2004, 2005a; Peansupap and Walker 2005c). The PhD thesis was successfully completed and awarded (Peansupap 2004) and is able to be accessed at http://adt.lib.rmit.edu.au/adt/public/adt-VIT20050331.101946/.

The structure of this paper is presented as follows. First, current practice of information technology (IT) and ICT is discussed. This is followed by a review of factors influencing ICT implementation. Next, a section on implementation of ICT as IT innovation is discussed and this leads to an argument that concepts of IT diffusion, change management and learning and knowledge sharing should be integrated to understand current ICT application practice. The next section discusses how these concepts could be integrated. The following section focuses upon five identified issues relating to actual ICT diffusion practice. Discussion on this review follows and a table identifying 46 variables that should be tested is then identified and presented. The final section presents a summary and points out limitations to the scope of the research.

## 2. CURRENT PRACTICE OF IT AND ICT IMPLEMENTATION

Information technology (IT) and ICT have recently been identified as essential tools for improving communication in construction processes and for creating new construction business opportunities. Walker and Betts (1997) argue that ICT technologies, such as the Internet and the World Wide Web (WWW), could open up opportunities for construction businesses to operate globally. Also, other studies illustrate numerous advantages and benefits of using ICT in construction (Doherty 1997; Duyshart 1997; Skibniewski and Abduh 2000).

First, ICT can support information integration and this in turn can help to reduce the volume of information processed and reduce data re-entry by transferring information through Internet/Intranet protocols. This can provide benefits throughout project phases such as design, construction, and operation (Mitev *et al.* 1996; Anumba and Duke 1997; Aouad *et al.* 1999; Björk 1999; Deng *et al.* 2001; Sriprasert and Dawood 2002a, 2002c). Second, ICT use can enhance collaboration by supporting communication among project members and sharing of information and documents, especially when team members are located in different geographical areas (Duyshart 1997; Skibniewski and Abduh 2000; Abudayyeh *et al.* 2001; Ahmad *et al.* 2002; Sriprasert and Dawood 2002b). Third, ICT use can support ‘e-commerce’ and create opportunities to extend business or provide improved customer service (Kong *et al.* 2001a; Kong *et al.* 2001b; Alshawi and Ingirige 2002; Anumba and Ruikar 2002; Skibniewski and Nitithamyong 2004).

Benefits of ICT use by construction organisations have motivated several construction organisations to adopt and invest in this technology and many recent survey results indicate an increasing trend of firms using ICT in the construction industry (Futcher and Rowlinson 1999; O’Brien and Al-Biqami 1999; Rivard 2000). However, the magnitude of ICT adoption in construction practices remains low compared to other industries (ABS 1999, 2001, 2002; ACIF 2002). The above literature explains this slow ICT uptake as being a function of:

- The complex nature of the construction industry;
- ICT Immaturity levels;
- Financial constraints;
- Poor availability of tools for evaluating benefits of using ICT; and
- A lack of understanding of the ICT implementation process.

A recent study of the International Council for Research and Innovation in Building Research (Council for Research and Innovation in Building and Construction) W78 conference papers claimed that management of IT, especially adoption and implementation, has been identified as one of the three main conference themes (Amor *et al.* 2002). Similarly, the adoption of IT innovation at the implementation stage has also been judged as the

most critical phase to concentrate upon to ensure successful technological innovation (Leonard-Barton 1988; Tornatzky and Fleisher 1990; Goodman and Griffith 1991; Attaran 2000). While the *development* of IT innovation is controlled by a relatively predictable environment (such as in a laboratory within a research and development (R&D) unit or IT department) *actual implementation* of IT is far more difficult to control because it involves the complex interaction of people in their workplace dealing with the technology. Also as an innovation is introduced, users are required to learn how to use an innovation and change the way they usually work. People tend to resist change due to habits acquired over time. This is a constraint on ICT adoption and diffusion. Such problems are compounded if the innovation concerned is unsuited to their conventional work practices (Goodhue and Thompson 1995; Mathieson and Keil 1998). For example, a project manager or an engineer may be more familiar with communicating with sub-contractors (and vice versa) via phone and fax instead of using email.

Many practitioners and academics are beginning to realise the importance of implementing IT and ICT throughout construction organisations. Recently, frameworks for strategic IT implementation were developed to provide a strategic view of IT success in construction (Jung and Gibson 1999; Peña-Mora *et al.* 1999; Peña-Mora and Tanaka 2002; Stewart *et al.* 2002). Furthermore, many studies seek to identify key drivers and barriers of IT implementation during initial adoption rather than during implementation (Laage-Hellman and Gadde 1996; Marosszeky *et al.* 2000; Songer *et al.* 2001). These research studies have adopted slightly differing approaches. Some explore barriers to IT use and adoption at the construction industry level (Tucker *et al.* 1999; Love *et al.* 2001; Stewart and Mohamed 2002). These studies agree that common barriers include low levels of IT skills and lack of IT investment. Some studies identify the various factors influencing the success of strategic IT implementation in organisations (Stewart *et al.* 2002). However, few of these empirical studies focus on factors and processes influencing ICT diffusion during the actual ICT implementation phase. To fill this gap, the research project (Peansupap 2004) reported upon in this paper was undertaken to extend our understanding of ICT implementation by applying diffusion of innovation (DoI), change management, and knowledge sharing concepts to explain intra-organisational ICT diffusion during actual ICT implementation in selected construction organisations. The integration of these three concepts can help to explain how people learn and exchange knowledge necessary for innovation diffusion and how people cope with the necessary changes in work and management practices that result from fully adopting an innovation.

## 3. REVIEW OF FACTORS INFLUENCING ICT IMPLEMENTATION

Before focusing on ICT diffusion at the actual implementation stage, it is essential to review the current research related to factors influencing ICT implementation within construction research. Earlier research studies identify and evaluate a range of variables contributing to success of initial adoption and actual ICT implementation. These studies mainly focus on barriers and drivers from the initial adoption view. For example, Laage-Hellman & Gadde (1996) identify EDI implementation barriers in the Swedish construction industry. Marsh & Finch (1998) and Marsh & Flanagan (2000) investigate drivers and barriers of Auto-ID adoption from both industry and organisational views. Marosszeky *et al.* (2000) investigate the causes of low levels of adopting ICT that show risk factors related to adoption and implementation of ICT. Whyte & Bouchlaghem (2001) study the issues and process that influence VR implementation. Songer, Young & Davis (2001) focus on social barriers to IT innovation (such as 3D, data warehouse, engineering applications, web, data management) across organisations. Stephenson & Blaza (2001) concentrate on organisational change that influences the success of IT implementation. Appendix 1 presents an historical summary of case studies reported from 1996 to 2004 of drivers of and barriers to IT adoption and implementation at the *industrial and organisational* view grouped by technological, individual, managerial, and other ICT adoption and implementation issues.

From the *factor research* view, Appendix 1 presents results from previous research related to initial ICT adoption and general ICT implementation from both industrial and organisational perspectives. These are based on identifying factors that affect only the early stage of ICT diffusion and provide a useful indicator of the decision-making rationale at the initial adoption stage. However, these studies lack detailed insights into the nature and degree of the impact of variables that influence actual implementation. These factors can be classified as individual characteristics, technological characteristics, managerial and organisational support, and the nature of knowledge sharing in the workplace environment. Furthermore, data collected for the appendix table were mainly drawn from top management and IT managers so these studies may only reveal and concentrate on strategic management issues rather than reveal important operational implementation issues. Therefore, rather than focusing on factors related to *initial adoption*, the research project reported upon in this paper was focused on factors influencing ICT at the *actual implementation* stage.

Although the research studies in the appendix table were mainly focused on factors influencing construction ICT implementation, few have focused on the *users' perception* of ICT implementation (Mohamed and Stewart 2003). For example, Stewart and Mohamed (2002) identified barriers to IT implementation in developing countries. Nitithamyong and Skibniewski (2003) identified 36 success/ failure factors and 34 variables measuring success/failure in implementing of web-based construction project. Huang *et al.* (2003) identified the criteria for IT adoption decision within construction industry. Stewart et al. (2004) studied barriers/problems of IT implementation but these factors were mainly focused upon the initial adoption decision-making process rather than on the *actual implementation* of ICT. Further, no research appears to have been undertaken on factors drawn from construction innovation diffusion, change management and learning and sharing knowledge perspectives that could fill the identified gap in our understanding of the ICT *implementation* process—that is, what is taking place when ICT applications are being implemented. To overcome this knowledge gap it is necessary to extend the identification of traditional DoI variables by integrating other variables from change management, and sharing and learning concepts because ICT implementation is concerned with people-related as well as technical issues. Thus, it was necessary to identify these variables in order to understand how they may influence current IT innovation diffusion processes, in particular ICT application. Three main research questions were established:

1. What are the essential factors that influence ICT diffusion at actual ICT implementation within large Australian construction organisations?
2. To what extent have these ICT diffusion factors been experienced by ICT users within large Australian construction organisations?
3. How do these ICT diffusion factors influence the diffusion processes within large Australian construction organisations?

## 4. IMPLEMENTATION OF ICT AS AN IT INNOVATION TASK

Actual ICT implementation involves complex technical and social issues. Many practitioners believe that ICT implementation failures occur due to technical issues rather than social issues (Griffith *et al.* 1999). However, recent studies by Björk (2002) and O'Brien (2000) suggest that technical problems may have limited impact on individual adoption of ICT. More recent innovation research is leading us to the conclusion that innovation implementation failure is not so much a function of the characteristics of the innovation itself but may depend more on the way that innovation implementation occurs. It was found, for example, that ICT implementation needs to be managed and structured because ICT is a critical facilitator of success of other ICT innovation diffusion initiatives (Green and Hevner 2000). Thus, overlooking principles of ICT implementation (such as knowledge transfer through technology and by people) may cause failure of general IT innovations and also ICT.

To examine the concept of managing an actual ICT implementation, factors and processes need to be identified, however, this paper will focus only on factors at the actual implementation stage. These factors were identified from the integration of three theoretical concepts—innovation diffusion, change management, and knowledge sharing and learning. This study aims to identify key factors that influence ICT diffusion amongst experienced ICT users who currently adopt and use ICT within large construction organisations.

Therefore, it is essential to answer the question why the integration of variables from innovation diffusion, change management, and knowledge sharing and learning helps to explain the ICT diffusion during actual implementation. First, the innovation diffusion concept identifies variables that impact on the initial ICT adoption—technological characteristics, communication channels, and social issues that may be considered to be generally stable, static or slow to change (Rogers 1983; Tornatzky and Fleisher 1990). These variables influence ICT users' adoption decisions. However, during a continuous ICT implementation exercise more dynamic variables come into play. Change management and knowledge sharing and learning influences provide a dynamic change phenomenon that can strengthen or weaken the innovation diffusion process. A number of factors or variables that may impact on ICT diffusion can be derived from the literature on these theories. Change management variables that may affect IT and ICT diffusion can be grouped into motivation, training and technical support, supervisor support and open discussion categories (Senge *et al.* 1999; Galbraith 2002). In addition, variables from knowledge sharing and learning literature (Nonaka and Takeuchi 1995) also provides a basis for the development of skill among ICT users (Attewell 1992; Davenport and Prusak 1998) and also skill and knowledge transfer through communities of practice (Gallivan 2000; Wenger and Snyder 2000). As a result,

the integration of these three theoretical bodies of knowledge can assist us to better understanding both the nature of static and dynamic variables that influence ICT diffusion at the actual implementation stage.

## 5. REVIEW OF THREE CONCEPTS RELATED TO ICT IMPLEMENTATION

### 5.1 IT diffusion concept

Rogers' (1983) generic innovation studies identified personal characteristics, innovation characteristics, and organisational characteristics attributes as principal factors influencing DoI. Meta-analysis of 75 studies by Tornatzky and Klein (1982) related to innovation implementation revealed that three out of ten main characteristics influencing innovation adoption and implementation were: relative advantage, compatibility, and complexity. Moore & Benbasat (1991) also used DoI theory to develop an assessment tool to measure individual perceptions that impacted on IT innovation adoption. Their study highlights and confirms key variables that influence IT diffusion, being relative advantage, compatibility, ease of use, demonstrability, image, visibility, trailability and voluntariness.

Other studies focus on attributes that impact on or predict the rate of adoption by individuals or organisations (Astebro 1995; Teng *et al*. 2002). Astebro (1995) studied the use of electronic mail systems (EMS) in four main departments in a large Swedish manufacturing company and found that social and management factors influence the rate of EMS diffusion. His data fitted with the basic DoI model. Also, Teng, Grover & Guttler (2002) studied twenty IT innovations in 313 large American firms and developed a diffusion model including both internal and external factors that explained the pattern of diffusion. The significance of their study findings was that different IT innovations provide different patterns of diffusion.

Other research has attempted to add the related learning (Attewell 1992) and social interaction variable to a DoI model. For example, Attewell (1992) added the learning perspective into innovation theory and argues that innovation diffusion requires organisational learning in which users gain knowledge about IT innovation use.

Some factors seem to have a different impact when they occur at different stages. For example, Cooper & Zmud (1990) determined that the managerial interactions influenced an inventory control system throughout diffusion stages. However, such interactions only influenced the introduction rather than actual implementation of that particular innovation. Kwon (1990) identified separate prior and post-implementation DoI stages and found that interpersonal communication and innovation maturity are two key factors influencing technology infusion. Infusion is defined as the final stage of IT implementation whereas adoption is defined as the introduction stage. Earlier IT innovation diffusion research studies have been applied to inter-organisational adoption that occurs within project-based organisations. They focus on the inter-relationships between organisations that influence the use of technology within industry. However, few of these studies have been focused on understanding how to diffuse ICT within a construction organisation after ICT organisational adoption—defined as the *actual implementation* stage (Regan and O'Connor 2000; Whyte and Bouchlaghem 2001).

The primary focus of this paper is on how to effectively apply innovation diffusion to enhance the management of ICT implementation within a construction organisation. However, a review of literature reveals gaps in DoI theory. First, traditional innovation diffusion theory is focused on the adoption of IT innovation by independent users who can decide whether to adopt or reject using it. The situation is different with the diffusion of IT within an organisation, in which the organisation adopts IT innovation and then encourages and facilitates its use to expected users. In this case, user response to DoI will depend upon the organisational decision. Second, traditional innovation diffusion theory is focused on actual implementation factors and processes. A factor research approach mainly focuses on the primary factors that influence the adoption decision whereas process research approach focuses on the series of processes that occur in the R&D department. Very little research has been conducted on the secondary factors and processes that influence the actual implementation after the adoption decision has been made. This may be why many IT implementations fail.

### 5.2 Change management concept

IT implementation related problems were viewed as change management constraints relating to organisational behaviour and processes and/or users' behaviour. Change management constraints occur because IT management often only focuses on technical problems rather than organisational problems (Humphrey 1989). Markus, and Benjamin (1997) claim that the failure of IT change derives from the traditional belief of managers and IT experts that technology is a *'magic bullet'* and so they neglect the essential role of people in any change

management task. However, solving technical issues can minimise users' resistance to technological innovation. Martinko *et al* (1996) argue that IT implementation failure is more likely to occur because of *'user's resistance'*, as it involves change of users' behaviour to handle new tools. Thus, IT implementation success is often realised by managers who understand the management of technological change (Mckersie and Walton 1991; Regan and O'Connor 2000, p.361). Therefore, we focus on change constraints grouped into barrier categories such as individual users, group users, and organisational, management, and technology influences.

The change management concept highlights three main issues. First, the concept of change management is required as an additional IT implementation process. Second, it is a dynamic activity that facilitates and maintains continuous change. Third, it involves interaction between strategy, structure/process, technology and people. The interaction of each factor provides the basic understanding of how change occurs. However, it is also necessary to focus on how to manage and control change. In addition, change-related IT implementation is unavoidable. Thus it is essential to understand how change should be managed in relation to the introduction of IT within an organisation (Regan and O'Connor 2000). Senge et.al. (1999) identify the learning concept as a key part of managing change within organisations and propose four key management issues: (1) motivation, (2) training and technical support, (3) supervisor support and rewards, and (4) open discussion and learning environment. The details of each factor will be discussed in section 6.

## 5.3 Learning and knowledge sharing concept

The third concept involving IT implementation is learning and knowledge sharing. As mentioned earlier, IT implementation needs users to learn how to operate new IT tools. Therefore, learning should be part of intra-organisational IT implementation diffusion (Attewell 1992). Learning may occur as self-learning, learning from an expert, or learning from peers. Self-learning often involves access to written sources or through experience—trial and error. Self-learning is dependent on personal characteristics and IT experience. Learning from domain experts is a viable alternative way of learning that is dependent upon knowledge, expert availability and quality of communication between experts and novices. This is traditionally provided through formal or informal training, short courses, or university courses. Learning from peers occurs when users share personal experiences. This occurs when peers have high confidence levels in using IT. Learning from peers is a useful source of IT implementation support where people have specific operational questions that require a rapid and effective response to address a specific, usually urgent, problem. Formal learning occurs when organisations formally provide knowledge resources that facilitate delivery of IT knowledge into and within the organisation, for example training and technical help desk IT support. Informal learning occurs during social interaction. Communities of practice (COPs) generate knowledge networks that enhance and sustain competitive advantage and they are also used to help COP members actually use ICT tools. Etienne Wenger defines communities of practice as 'groups of people informally bound together by shared expertise and passion for a joint enterprise' (Wenger and Snyder 2000, p.139).

## 5.4 Integration concepts of innovation diffusion, change management, and learning and sharing knowledge

Through analysis of the intersection of these bodies of knowledge, gaps in current knowledge about ICT diffusion in the construction industry can be identified. Theories of innovation diffusion, change management, and sharing and learning were used to develop an initial framework for influencing users' diffusion of ICT within construction organisations in FIG. 1. Diffusion success is determined by factors that influence technology adoption and by the way in which potential users within organisations adopt the technology. Roger's (1995) diffusion model identified technological characteristics, communication channels, social systems and diffusion rate as factors affecting innovation adoption. The innovation diffusion rate depends on the first three factors (Rogers 1995). However, ICT innovation diffusion within an organisation requires its management to facilitate and encourage people to adopt an ICT initiative. An organisation can do this through its actions: motivating staff; providing appropriate training and technical support; and ensuring supervisor support and open discussion (Senge *et al.* 1999).

FIG. 1 illustrates static factors of innovation diffusion that include factors that influence the ICT adoption decision. First, the characteristics of technological innovation (i.e. relative advantage, ease of use, compatibility) are the primary criteria that influence the individual's adoption decision. Second, communication channels (i.e. mass media and personal communication) facilitate ICT diffusion by disseminating information regarding the

application and by pooling individual experience. Third, the social context (i.e. type of users, leader opinion and culture issues) can also influence an individual's adoption decision on technological innovation by personal and social behavioural interaction. Based on the description of static factors, these factors are used to determine the primary individual's adoption decision. However, these factors fail to explain the dynamic nature of the adaptation processes that drives technological innovation into an organisation.

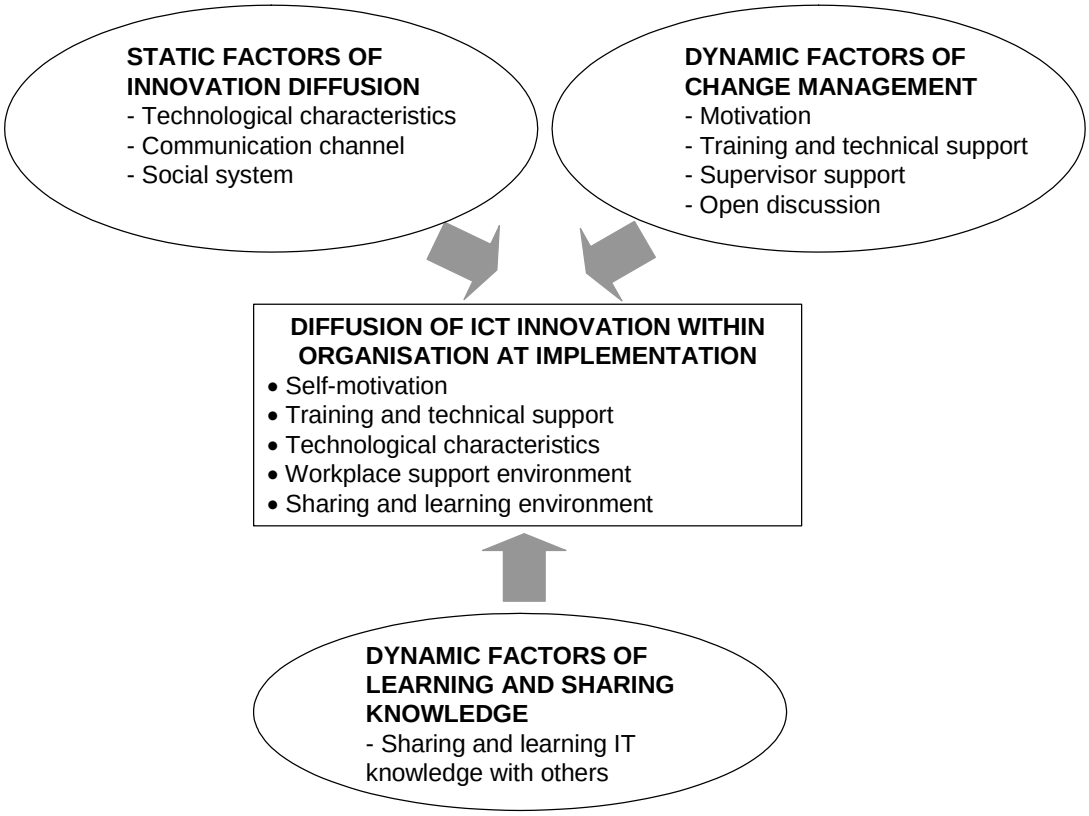


*FIG. 1: Integration of factors related to ICT diffusion*

Dynamic factors of change management and the learning and sharing of knowledge compliment static factors that facilitate ICT diffusion. Dynamic factors consist of motivation, training and technical support, supervisor support, an open discussion environment and the sharing and learning of IT knowledge with others. These factors involve supportive change mechanisms that facilitate ICT diffusion within an organisation. Integrating both static and dynamic factors help us better understand ICT diffusion within an organisation. Integration of the three main concepts (innovation diffusion, change management, and learning and sharing of knowledge) can be grouped into five aspects involving ICT diffusion at the actual implementation stage—self-motivation, training and technical support, technological characteristics, workplace support environment, and a sharing and learning environment.

## 6. ISSUES RELATED TO ACTUAL ICT IMPLEMENTATION FROM INTRA-ORGANISATIONAL DIFFUSION PERSPECTIVE

The framework of understanding ICT diffusion at the actual implementation stage consists of five main areas: (1) self-motivation; (2) training and technical support; (3) technology characteristics; (4) environment for workplace support; and (5) a knowledge sharing environment. These five aspects were developed from the literature related to IT/ICT implementation[1], innovation diffusion, change management, and knowledge management (sharing and learning focus). They are discussed in more detail below.

[1] Throughout this section the reviewed literature for IT refers to applications that include ICT. Thus the more general representation of this has been to use IT/ICT to indicate this dual or inclusive concept.

## 6.1 Self-motivation

After an organisation decides to adopt IT/ICT, it is essential to focus on the actual implementation process that involves the encouragement and support of its adoption and use by potential IT/ICT users (Eason 1988; Regan and O'Connor 2000). During the actual implementation period, IT/ICT use remains dependent upon the individual's decisions whether to accept or reject the application. This is in turn affected by the degree of motivation. Egbu, Gaskell & Howes (2001) found that users perceived themselves as the major motivational force behind IT/ICT use. It is interesting to understand what might motivate individuals to use an IT/ICT system. From the literature review, the motivation associated with the use of IT/ICT might be grouped into two main categories: user's characteristics and user's attitudes (Davis *et al.* 1989; Coffin and MacIntyre 1999).

### 6.1.1 Personal/Individual characteristics

One motivation behind an individual's IT/ICT application use is their characteristics, such as self-confidence, enjoyment of learning and their previous foundation IT skills. Users with high self-confidence levels are more likely to use and adopt IT/ICT applications than users with low self-confidence (Murphy *et al.* 1989).

Murphy, Coover & Owen (1989) defined self-efficacy as an individual capability and skill relating to their job while self-confidence may be defined as a user's belief in their capability to use a skill. Users who have a high level of confidence in IT/ICT use for example might not necessarily have a high self-efficacy but high self-confidence can lead to their IT/ICT use. O'Brien (2000) argues that users with high levels of self-confidence, for example, are more likely to adopt and use web-based project applications. As a result, self-confidence could be a basic element of self-efficacy that initially motivates individuals to use IT/ICT applications.

Furthermore, an individual's characteristics such as their enjoyment of learning how to use IT /ICT applications can motivate their use and adoption. However, previous studies found that perceived enjoyment has an insignificant relationship with the use of IT, although this can have an direct impact on the individual's IT use performance (Davis *et al.* 1989; Igbaria *et al.* 1996). Songer, Young & Davis (2001) also support the argument that users' willingness to learn influences IT/ICT implementation.

Finally, Igbaria, Iivari & Maragahh (1995) found that previous experience has an direct influence on the use and adoption of IT/ICT. Individuals are able to use their existing IT skills to perform the task. They found that computer experience is likely to improve a person's perceptions and belief of the usefulness of the IT/ICT by enhancing their beliefs in their ability to master the challenge and to reduce any fears. Björk (2002) also found that different users' attitude and skills have different influences on the use and adoption of online document management systems. However, lack of existing IT/ICT computer skill and experience of IT/ICT may lead to a delay in actual IT/ICT implementation (Love *et al.* 2001; Stephenson and Blaza 2001; Stewart and Mohamed 2002; Nitithamyong and Skibniewski 2003; Thorpe 2003).

### 6.1.2 User's attitudes

User's motivation to use IT/ICT might also be related to their attitude toward technology such as perceived clear advantage of use, ease of use, relevance to their job, and professional credibility. The first two variables 'clear advantage' and 'ease of use' are found to be associated with their IT/ICT use. Rogers (1983) found that a perceived clear advantage is an important technology characteristics that generally influences innovation diffusion. Davis, Bagozzi & Warshaw (1989) proposed a technology acceptance model (TAM) that predicts a user's intention to use IS. The result shows that perceived usefulness and perceived ease of use are essential variables motivating the use of word processing technology in an education environment. Similarly Igbaria, Parasuraman & Baroudi (1996) found that usefulness and ease of use motivates professionals and managers to use computers and that users are more likely to use and adopt computer technology if they think that it is useful to improve their productivity and performance and Igbaria and Tan (1997) suggest that IT/ICT adoption by an organisation might affect both individual and organisational productivity. Also, IT/ICT use may build professional credibility whereby users use technology because they would like to perform their work using more 'cutting-edge' technology. Moore & Benbasat (1991) found that image variables, e.g. prestige, high profile and status, are key elements influencing users' adoption.

## 6.2 Training and technical support group

Training is a primary organisational IT/ICT diffusion factor because it helps users understand how to best use and adopt IT/ICT applications. Training was found to be an essential factor in information system (IS) success

during the implementation stage (Compeau and Higgins 1995; Alp *et al.* 1997; Carlopio 1998; Akins and Griffin 1999; Sackton 1999). Similarly, Nelson and Cheney (1987) found that training influences users' ability and acceptance of IS because they take time to learn and use only a few IS capabilities. Also, their lack of skill and training was found to be an important barrier to business accessing the Internet (ABS 2002). Likewise, many construction case studies found that lack of training is a key barrier to adopting and using IT/ICT applications (Songer *et al.* 2001; Stephenson and Blaza 2001; Weippert *et al.* 2002b).

Nelson (1991) argues that because there is a limit for everyone to learn all aspects of business knowledge, training should provide specific skills that are related to users' need and work processes. User behaviour also affects the training needs of users classified as 'pragmatists' (O'Brien 2000), so it is important to assess users' training requirements to reduce the knowledge gap between what they already know and what they need to know to best perform their job through undertaking a personalised user needs analysis (Nelson *et al.* 1995). The assessment of training not only assists the organisation in understanding the knowledge gap but it also improves the effectiveness of training (Carlopio 1998). For example, training assessment helps trainers to prepare both the context and level of training to ensure compatibility with users' need. Nelson (1991) also suggests that the organisation needs to assess knowledge and skill requirements necessary for users to perform their job. He found that IS personnel need organisational knowledge such as business objectives and goals whereas end-users require specific IS-related skills such as the use of applications.

Users need time to actively participate during the training program because they generally do not have time to learn beng busy with or distracted by their work duties (Senge 1992; Huysman *et al.* 1994). This lack of time restricts the effectiveness of implementing a change initiative (Senge *et al.* 1999). People are reluctant to commit their time to learning and training if they have no time to practise and reflect. Staff in construction organisations can feel especially limited in their time to effectively learn to use new IT/ICT applications (Whyte and Bouchlaghem 2001). To improve their use of IT/ICT applications, learners should be provided with enough time to develop their skill and familiarise themselves with any new system (Akins and Griffin 1999; Sackton 1999).

It is also necessary to provide technical support for solving problems when using an IT/ICT application (Markus and Keil 1994; Prescott and Conger 1995). Trevino & Webster (1992) studied factors influencing use of email and voice mail. They found that positive use outcomes depend on the type of technology, ease of use, and technical support. Technical support also depends on managerial support.

Motivation of users to learn and apply IT/ICT in their job has also been recently studied. Training programs should provide quality training that avoids disinterest and boredom (Wilson 1997). Therefore, the quality of training is an essential factor influencing IT/ICT use. Wilson (1997) found that most users applied only 20% or less of an email application function. Thus, training could increase IT/ICT user efficacy levels and improve their performance because self-learning have limitations. For example, although a manual such as "quick reference guide" can provide an understanding of how the software functions work, it rarely describes how functions can be applied to effectively perform an individual's job. Therefore, users still require actual training and group support to help them clearly understand how to effectively use an IT application. Users also need technical support to solve problems when using an IT/ICT application because technical support helps users to solve problems (Kueppers and Schilingno 1999). This can be provided by technical support groups, a help desk group, groups who develop in-house applications, or by specialist software support organisations.

## 6.3 Technology characteristics

Technology characteristics influence IT/ICT diffusion processes and are an important element influencing IT/ICT adoption. According to Rogers (1983; 1995), innovation attributes supporting diffusion are: relative advantage, compatibility, trial and experiment, observability, and an innovation being perceived to be superior to the item or process being replaced.

Tornatzky and Klein (1982) found that innovation characteristics have a relationship with innovation adoption-implementation. By using a meta-analysis of articles, their results indicated that three innovation characteristics - compatibility, relative advantage, and complexity - had been frequently found to be factors influencing technology adoption and implementation. Relative advantage attributes also have an influence on users' perception of technology (Igbaria *et al.* 1996; Lederer *et al.* 2000). In addition, Ramamurthy (1994) found that compatibility has a positive influence on organisational IT/ICT adoption and implementation. For example, IT/ICT that was designed to replicate manual or paperwork is easy for users to accept because they feel familiar

with the work patterns. Therefore, the higher the compatibility with users' existing work, the more likely it is that the users become familiar with a system. However, ICT use is not limited to duplicating manual and paper work systems but involves work process re-designing or re-engineering. Thus, to improve organisational productivity, most current IT/ICT systems require complex change management projects.

Other technology attributes are speed, reliability and accessibility. Speed makes users feel that they are gaining a real benefit and improving their productivity by using IT/ICT technology compared with previously used systems. Thompson, Higgins & Howell (1991) argue, resource allocation is a key factor in IT/ICT use. If users feel that applications lack speed and reliability or if users are not provided with necessary access to use an ICT application (due to resource limitations such as money for high speed links, current technology or compatible equipment/software) then they may not be willing to use them.

## 6.4 A supportive environment workplace

It can be argued that workplace environment characteristics such as commitment, open discussion, personal anxiety and frustration also affect ICT diffusion.

### 6.4.1 Commitment

The IT/ICT diffusion process can be seen as a process of change within an organisation (Wolek 1975; Senge *et al.* 1999), so we need commitment from both users' and their organisation (Newman and Sabherwal 1996). Individual commitment focuses on end-users who devote themselves to using ICT whereas organisational commitment focuses on top managers who support end-users to use IT/ICT. Without individual commitment, IT/ICT implementation success could not be achieved. Ginzberg (1981) argues that users' involvement in IS implementation is a key driver of IT/ICT success. A basic requirements of IT/ICT adoption is the need to directly or indirectly persuade users to commit and involve themselves with using IT/ICT. An organisation's top management also needs to be committed to support and allocate adequate resources for ICT technology investment. Numerous examples of lack of organisational commitment has been shown to lead to IT project failure (Lenoard-Barton and Sviokla 1988; Thompson *et al.* 1991).The same likely occurs with ICT.

### 6.4.2 Open discussion

Open discussion helps to improve work productivity via the reporting of system difficulties. Furthermore, open discussion helps managers better understand problems or difficulties experienced by those operating IT/ ICT applications so that strategies can be devised to address deficiencies (Senge *et al.* 1999). Not only discussion about difficulties but also suggestions for improvement is important in system improvement. The former focuses on the basic problems of using systems. The latter focuses on responding in order to effectively use applications. This shows the benefit of providing an environment for making suggestions to improve the IT/ICT use. As a result, open discussion in the organisation might be an important variable supporting ICT diffusion.

### 6.4.3 Personal anxiety and frustration

One ICT diffusion inhibitor such as frustration or anxiety might develop from a negative user's response when using computers (Carlopio 1998). Igbaria and Parasuraman (1989) found that computer anxiety has a negative impact on users' attitude toward microcomputers, especially when it is difficult to use IT systems or that they can only be partially used. This most likely also applies to ICT. Users may feel anxious or frustrated when their inefficient or restricted their use of IT systems makes them feel inadequate, so this may result in them avoiding further IT/ICT application use (Igbaria and Chakrabarti 1990).

## 6.5 Sharing and learning environment

Innovation diffusion needs a sharing and learning organisational environment. Everyone within an organisation tacit job performance knowledge. Learning and sharing knowledge among staff is important for innovation diffusion. Rogers (1996) argues that learning is a key factor in innovation development. He suggests that training and development should be shifted to an experiential style of learning. Grantham & Nichols (1993, p.202) state that "*organisational learning occurs when people in an organisation collaborate to share their different visions, knowledge, experiences, and skills*". Organisational learning is a key IT/ICT implementation factor when IT/ICT application development is frequently subject to change (Attewell 1992; Fichman and Moses 1999). Learning benefits construction organisations to improve their performance, establish new strategy, and revise their organisational form to reflect the current context.

Tacit knowledge, grown from users' experience, is a valuable organisational asset (Nonaka 1995; Davenport and Prusak 1998). Ideally, sharing tacit IT/ICT knowledge built from users' experience can improve IT/ICT use within organisations and suggest how to use IT/ICT more effectively (Gibson and Smilor 1991). Carlopio (1998) explains that personal change may be best influenced by co-workers, friends, family, peers etc. Collegial help and mentoring is one way that knowledge sharing can most effectively occur because experienced users can give strong support by assisting novices to use IT/ICT applications through knowledge transfer. Therefore collegial help strongly influences change in an organisation (Senge *et al.* 1999: 345). Compeau and Higgins (1995) argue that peer and collegial support is vital. This can be activated through groups of colleagues, some highly expert in what has been referred to as a community of practice (Gallivan 2000; Wenger and Snyder 2000).

Integrating innovation diffusion, change management and learning and shared knowledge concepts led to the focus of the research reported upon in this paper on the five main issues. TABLE 1 provides a summary of the literature review relating to these five main issues.

## 7. DISCUSSION

The literature review highlights several interesting emerging views of ICT implementation. First, it provides a framework (see Figure 1) for in-depth understanding of the impact of factors that influence ICT implementation during actual implementation of these initiatives. This framework comprises five key issues. These are: self-motivation, training and technical support, technological characteristics, workplace support environment, and sharing and learning environment.

*TABLE 1:List of selected literature supporting five main issues relating ICT diffusion*

| **Five main issues relating ICT diffusion** | **Literature** |
|---|---|
| (1) Self-motivation | • Clear advantage and ease of use (Davis *et al.* 1989)<br>• Usefulness and ease of use (Igbaria *et al.* 1996)<br>• Self-efficacy and personal confidence (Murphy *et al.* 1989)<br>• Enjoyment on learning (Davis *et al.* 1989; Igbaria *et al.* 1996)<br>• Previous experience (Igbaria *et al.* 1995) |
| (2) Training and technical support | • Quality and time of training (Compeau and Higgins 1995; Alp *et al.* 1997; Akins and Griffin 1999; Sackton 1999)<br>• Technical support (Markus and Keil 1994; Prescott and Conger 1995; Kueppers and Schilingno 1999) |
| (3) Technology characteristics | • Compatibility, relative advantage, and complexity (Tornatzky and Klein 1982; Rogers 1983; Ramamurthy 1994)<br>• Users' perception of technology (Igbaria *et al.* 1996; Lederer *et al.* 2000) |
| (4) Workplace support environment | • Personal commitment (Ginzberg 1981; Newman and Sabherwal 1996)<br>• Organisational commitment (Lenoard-Barton and Sviokla 1988; Thompson *et al.* 1991)<br>• Provide enough resource (Thompson *et al.* 1991) |
| (5) Sharing and learning environment | • Sharing and learning among staff (Compeau and Higgins 1995)<br>• Community of practice (Gallivan 2000; Wenger and Snyder 2000)<br>• Organisational learning (Attewell 1992; Fichman and Moses 1999; Walker and Lloyd-Walker 1999)<br>• Open discussion (Senge *et al.* 1999)<br>• Personal anxiety and frustration (Igbaria and Parasuraman 1989) |

Self-motivation and a supportive workplace environment are important enablers of ICT diffusion at the actual implementation stage. IT/ICT use relies on the individual's decision whether to adopt or reject an application, this is affected by the degree of their motivation. Self-motivation such as pure enjoyment of learning may facilitate an individual's behaviour to adopt and learn how to use ICT during its actual implementation (Davis *et al.* 1989; Igbaria *et al.* 1996) as does previous experience (Igbaria *et al.* 1995). Furthermore, a supportive workplace environment evidenced by organisational commitment also encourages individual's adoption of ICT. The need for training and technical support, predominantly delivered by people, is confirmed by other research studies in construction (Laage-Hellman and Gadde 1996; O'Brien 2000; Love *et al.* 2001; Stephenson and Blaza

2001; Tucker *et al*. 2001; Whyte and Bouchlaghem 2001; Weippert *et al*. 2002a). Training and technological support directly affects end users at the actual implementation because it provides them with the background knowledge of ICT that helps users to solve problems of using ICT.

Technological characteristics influence users' learning, use and adoption of IT/ICT (Tornatzky and Klein 1982; Rogers 1983; Ramamurthy 1994). For example, if the technology is simple to use, it is easier to adopt. Other characteristics such as functionality, reliability and accessibility influence users' motivate to adopt and use IT/ICT. However, if the technological characteristics are more complex, users should be encouraged and supported to develop positive self-motivation through motivation by others from their workplace environment.

Earlier researches in construction IT highlight the importance of a sharing and learning environment that should be a feature of ICT implementation. Linking knowledge about construction practice and IT programming was found to be a critical implementation success issue (Whyte and Bouchlaghem 2001). Developing sharing and learning encourages the organisation to become a 'learning organisation' that diffuses ICT knowledge through its staff within the organisation (Attewell 1992; Fichman and Moses 1999; Walker and Lloyd-Walker 1999). The level of sharing and learning can also be improved by developing of communities of practice (Gallivan 2000; Wenger and Snyder 2000) that create an open discussion environment Senge *et al.* (1999).

*TABLE 2: List of variables in five main issues relating ICT diffusion*

| No. | Variables related to self- motivation | No. | Variables related to self- motivation |
|---|---|---|---|
| V1 | Personal confidence | V9 | Clear advantage of using ICT for communication between teams |
| V2 | Enjoy exploring new tools | V10 | Clear advantage of using ICT for coordinating teams |
| V3 | Enjoy learning from others | V11 | Receive professional credibility |
| V4 | Basic skill of using ICT | V12 | Relevance to personal job |
| V5 | Receive tangible reward | V13 | Response rate of ICT |
| V6 | Receive intangible reward | V14 | Functionality of ICT |
| V7 | Clear advantage of using ICT for decision-making | V15 | Accessibility of ICT |
| V8 | Clear advantage of using ICT for communication within team | | |
| **No.** | **Variables related to training and technical support** | **No.** | **Variables related to training and technical support** |
| V16 | Supervisor encourages the use of ICT | V24 | Ease of use ICT |
| V17 | Personal capability to learn ICT | V25 | Speed and Reliability of ICT |
| V18 | Enough quality of training | V26 | Mentoring support |
| V19 | Enough time for training | V27 | Compatibility with previous system/ work procedures |
| V20 | Flexibility for learning | V28 | Trial and experiment ICT |
| V21 | Work procedure support | V29 | Easy to observe benefit of using ICT |
| V22 | Sufficient time to think | V30 | Better than previous system |
| V23 | Technical support | | |
| **No.** | **Variables related to workplace support environment** | **No.** | **Variables related to workplace support environment** |
| V31 | Organisation commitment (resources) | V36 | Person feels safe on openly discusses about ICT problems |
| V32 | Personal commitment | V37 | Colleagues feel safe on openly discusses about ICT problems |
| V33 | Trust in supervisor when making mistakes | V38 | Feel pressured to be effective in using ICT |
| V34 | Difficult, complex or frustrating to use ICT | V39 | Supervisor openly suggests how to improve ICT application |
| V35 | Personal anxious about ICT use | V40 | Organisation openly suggests for ICT improvement |
| **No.** | **Variables related to knowledge and information sharing** | **No.** | **Variables related to knowledge and information sharing** |
| V41 | Organisation support for sharing ICT experience | V44 | Help and Explain to others (Mentoring) |
| V42 | Provide tangible rewards in sharing ICT experience | V45 | Colleagues formally help on using ICT |
| V43 | Provide intangible rewards in sharing ICT experience | V46 | Colleagues informally help on using ICT |

Based upon the literature review, 46 factors were identified and tested using a survey gathering quantitative data that was analysed using factor analysis. It is beyond the scope of this paper to provide full details of the testing method or results, readers can refer to Peansupap (2004) or (Peansupap and Walker 2005c; Peansupap and Walker 2005b). However the process undertaken can be summarised as follows.

A survey of three ICT sophisticated construction organisations in Australia participated in a survey during early 2002. One organisation is a major construction contractor undertaking large projects within Australia and overseas. This contractor is one of the largest 8-10 contractors in Australia undertaking a variety of building and engineering projects. The second organisation is a global engineering consultancy and the third organisation is a government (state level) public works organisation. All three organisations are sophisticated experienced ICT users with decades of experience in using IT. The organisations were approached and they agreed to distribute the questionnaire internally and to publicise the web-based collection web link. The total number of respondents was 117. There were 35 respondents from the public client organisation (group A), 39 respondents from the construction contractor (group B), and 43 respondents from the engineering consultant (group C). All three organisations used ICT and because the analysis was centred upon ICT adoption and use, the data was pooled to enable factor analysis on the basis of analysis of the type of IT/ICT application used by the organisations. Rigorous analysis using ANOVA to measure between-group ICT and general office software use confirmed that the three groups shared a high level of ICT and standard office administration IT software experience. According to Coakes et al (2001), factor analysis is a technique used to reduce a large number of measured variables that help explain a process into small highly related groups of variables called factors. It can be applied to an exploratory study to summarise variables into main representative factors. However, there are some requirements to test data to ensure that factor analysis is an appropriate statistical technique to use. Correlation coefficients of each variable should have at least one factor that is above 0.30 (Pallant 2001). All variables had correlation coefficients of more than 0.30. Additionally, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy value was 0.737 (well above 0.60) and the Barlett's test of sphericity value was significant (p=0.0001). Therefore, the use of factor analysis was deemed suitable.

*TABLE 3: The mean value of the eleven factors*

| Factor Description | Means Score | Rounded Means |
|---|---|---|
| **Individual (I) Factors** | | **3.8** |
| F3: Supporting Individual/Personal Characteristics | 4.145 | 4.2 |
| F2: Clear Benefits of ICT Use | 4.105 | 4.1 |
| F9: Positive Feelings towards ICT Use | 3.623 | 3.6 |
| F10: Negative Emotions towards ICT Use[1] | 1.780 | 1.8 |
| **Environment (E) Factors** | | **3.9** |
| F6: Supporting Open Discussion Environment | 3.928 | 3.9 |
| F8: Supporting Colleague Help | 3.895 | 3.9 |
| **Management (M) Factors** | | **3.2** |
| F5: Supervisor and Organisational Support | 3.808 | 3.8 |
| F1: Professional Development and Technical Support | 3.277 | 3.3 |
| F7: Supporting Tangible and Intangible Reward | 2.423 | 2.4 |
| **Technology (T) Factor** | | **3.5** |
| F4: Supporting Technology Characteristics | 3.703 | 3.7 |
| F11: Frustration with ICT Use[1] | 1.690 | 1.7 |

[1]*Negative factors, therefore a low value implies high emotions towards ICT applications*

Data was analysed using a principal component and varimax rotation for factor extractions. A pairwise rather than listwise selection method of cases was used because this questionnaire allowed respondents to select a 'non-applicable' response as well as the 1 to 5 value. As a result, the number of cases in variables ranged from 102 to 117. The result of factor analysis indicated 11 factors with an Eigenvalue exceeding 1, explaining cumulative 70.45 % of variance. In addition, varimax rotation was used in explain these factors. The result of this rotation showed that forty-six variables were grouped into eleven factors. Cronbach's Alpha ($\propto$) analysis was conducted to examine the reliability of variables in one factor (Hedderson 1991; Pallant 2001). Cronbach's Alpha is used to

measure how well variables can be constructed into one single factor and Factors 1-10 fell within the 0.60 or greater range indicating that these were reliable and that factor 10 was marginally reliable. While factor 11 is discussed, it has debatable reliability. Readers interested in further details about the data gathering and analysis should refer to (Peansupap 2004; Peansupap and Walker 2005b).

The 11 factors derived from the factor analysis are grouped into management, individual characteristics, technology and workplace environment clusters illustrated in Table 3 below.

It is interesting and significant to note that the mean values of the factors based on 1 = low and 5 = high that the factors at the high level (4 or close to 4) mainly related to the ICT application be of demonstrable usefulness, and that there was adequate human infrastructure to support users to use the technology through organisational and workplace collegial support.

## 8. SUMMARY AND LIMITATIONS

This primary aim of this paper was to provide the rationale, citing the literature relating to ICT initiatives undertaken in the construction industry, for the need of a study of ICT adoption strategy and actual implementation to fill identified gaps in the existing literature relating to our understanding of what factors pose barriers or enablers to actual ICT adoption. The discussion of construction ICT implementation provided detailed insights from the literature to help us understand what these ICT implementation drivers and barriers might be, however, most studies in the literature were shown to lack focus on the actual ICT implementation phase. This suggested a need for research into both innovation diffusion factors and an ICT implementation processes approach. The paper also provided relevant findings from a recent PhD study to help plug the identified gap in the extensive literature review. The paper thus helps us to understand how to encourage and manage the process of *actual implementation* of ICT diffusion within construction organisations. The study results reported upon was limited in scope, namely the sample size was focussed upon large IT-literate and sophisticated construction organisations in a well-developed economy (Australia). The results reported upon can not necessarily be generalised because we acknowledge that respondents were already experienced IT/ICT users to the extent that they are all computer literate with many years experience using IT applications for their professional and administrative work tasks. However, important insights were illustrated by the nature of the 11 factors identified as impacting upon ICT implementation, further the literature provided substantiating evidence that people-related factors are crucial in effective ICT implantation, support at the personal, workplace level and organisation level is clearly needed.

Identified potential ICT diffusion variables were developed from three main theoretical concepts: innovation diffusion, change management, and knowledge sharing and learning. One contribution that this paper has made is that it identifies and summarises the literature so that other researchers in construction IT/ICT diffusion and implementation can confidently follow. The literature supports results from the study survey reported upon in this paper to indicate the strong people-related infrastructure that needs to be established with full organisational support to provide the necessary drivers and inhibit barriers to ICT adoption at the implementation phase. Our study was confined to a specific context and other researchers need to empirically explore other contexts. For example research needs to be undertaken to establish whether the strength of impact for identified factors may differ significantly for smaller organisations or a less IT-literate workforce or whether a different set of factors affect ICT diffusion at the implementation phase of an ICT initiative.

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## *Appendix 1- Literature review related to ICT adoption and general ICT implementation (from 1996 to 2004)*

| Literature review | Research aim and method | Issues |
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| (Laage-Hellman and Gadde 1996) | **Aim**: Identified barriers of EDI implementation in the Swedish construction industry. They found that both organisational and technical issues influence EDI adoption at both industrial and organisational levels.<br>**Method**: Case study of one large Swedish construction company | **Technological**: Standardisation of communication and information exchange; Lack of uniform codes; Lack of applications that support EDI; Require upgrade both hardware and software to use EDI.<br>**Individual & social:** Lack of IT competence among staff on construction site; Small number of EDI adopters from project partners.<br>**Managerial:** Requires change in business processes and procedures; Lack of interest and knowledge of EDI benefits; Lack of top management support; Organisational support barriers; Lack of long-term relationship among project partners |
| (Marsh and Finch 1998; Marsh and Flanagan 2000) | **Aim**: Investigated the driver and barriers of Auto-ID adoption from both industry and organisational perspectives<br>**Method**: Survey of 80 responses including 26 from manufacturers and suppliers, 25 from small-medium size firm and 29 from contractors | **Individual & social:** - Employee resistance<br>**Managerial:** Lack of awareness about IT benefits; Development costs are prohibitive (hardware, software and training); The benefits of IT are difficult to justify; Unclear about performance benefits from IT investment; High incidence of technologically conservative organisations; Short-term relationship leads to avoiding IT investment; Lack of motivation of other organisations to adopt when others will be benefit;<br>**Other**: Client failed to enforce the technology; Too many IT products/components to make decision |
| (Marosszeky *et al*. 2000) | **Aim**: Identified causes of low levels of adopting IT showing adoption and implementation of IT risk factors.<br>**Method**: Fieldwork interview on people from large, medium, and small contractors and phone interview with suppliers. | **Managerial:** Limited skills and vision in strategic IT use at organisational level; Perceptions of financial risk; Lack of precedent clear benefits of IT investment.<br>**Other**: Construction industry fragmented; Low level of trust between potential collaborators |
| (O'Brien 2000) | **Aim:** Identified issues related to the implementation of project web sites<br>**Method:** Observation of the use of project web technologies in construction companies | **Technological**: Password barriers/authorisation of information access; Limitation of technology benefits for all.<br>**Individual & social:** Range of user behaviours (pragmatist and innovators) leading to unclear benefits of IT use; Over expectation of IT functionality<br>**Managerial:** Resistance of change; Need for new job description; Technology champion; Communication density<br>**Other**: Legal issues; Level of technology maturity; Problems of cost and technological barriers tends to decrease. |
| (Zipf 2000) | **Aim**: Suggested key success of technology initiatives<br>**Method**: Case study based on the use of project web technologies in the engineering department of the Port Authority of New York and New | **Managerial:** Management commitment; Technology leadership; Needs assessment; Budget and resource allocation; Establish business flow; Hardware and software evaluation; Organisational acceptance of change; Pilot project initiative; Support training. |

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| | Jersey | |
| (Tucker *et al.* 2001) | **Aim**: Developed a framework that consists of factors related to IT implementation performance measurement<br>**Method**: Case study of best practice in the Australian construction industry. | **Technological**: Tangible/Intangible benefits; User utility; Project management functions; Information technology<br>**Managerial:** Strategic impact; Coordination and integration; Value adding |
| (Songer *et al.* 2001) | **Aim:** Focused on social barriers of IT innovation (3D, data warehouse, engineering applications, web, data management) across organisation<br>**Method**: The survey analysis was based on 69 individuals from 34 companies from the construction industry institution (CII) in the US | **Technological**: Incompatibility<br>**Individual & social:** Supervisor's willingness; Subordinate's willingness; Individual barriers (staff) * most of respondents perceived themselves willing to learn but they ranked the staff and corporate culture (their environment) as major barriers.<br>**Managerial:** Cost of implementation; Corporate culture; Incompatibility; Unperceived benefits/value; Lack of training.<br>**Other**: Respondents of construction industry show the interest on the investment of data management (rationale). |
| (Whyte and Bouchlaghem 2001) | **Aim**: Identified issues and process that influence VR implementation.<br>**Method**: Interview based on CAD managers in three regional offices | **Technological**: Lack of database standard and VR model; Lack of system support; Take time to generate VR; Slow frame rates to display VR; Unexpected technical problems; Significant different practice between CAD and VR.<br>**Individual & social:** Users involvement<br>**Managerial:** Uncertainty about the projects; Pressures of work; Lack of resources; Organisational support.<br>**Other**: Successful uptake of IT requires both strategic decision making by top management and decision making by technical managers.<br>- The role of middle manager can be to coordinate business people and technical people.<br>- Require the need of different type of IT innovation in a range of construction organisations.<br>- Discontinuing maintaining the relationship between developer and in-house development can lead to the unresolved IT |
| (Stephenson and Blaza 2001) | **Aim:** Focused on organisational change that influences IT implementation success.<br>**Method:** Interview with staff on Integrated Management Information System (MIS) within a medium sized construction firm | **Technological**: Lack of system compatibility to support cross organisation functionality<br>**Individual & social:** Resistance to change; Not enough existing skill base; Fear of unknown; Lack of user involvement<br>**Managerial:** Senior management resistance; Lack of planning and communication (only focus on short term goal); Lack of share vision; Not enough training; Cost of investment; Organisational fit |
| (Love *et al.* 2001) | **Aim**: Explored barriers of implementing e-commerce in small and medium construction companies<br>**Method**: Unstructured interview of 20 Australian small-medium organisations in | **Technological:** Lack of suitable IT infrastructure; Not enough IT benefits; Data and information security problems<br>**Individual & social:** Users' lack of IT skills; High turnover of employees; Fear of job loss; Reluctance to make work changes; Users' resistance.<br>**Managerial:** Indirect or hidden cost; Difficulty to measure benefits; Lack of commitment from other |

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| | Victoria | project participant users; Reluctance to change business practices; High investment cost.<br>**Other**: Financial constraints such as short-term benefits; High cost of maintenance; Productivity decline; Cost of training; Market uncertainty. |
| (Thorpe and Mead 2001) | **Aim:** Described information transfer in project-specific web sites.<br>**Method**: Three case studies of project website were collected on push and pull information. | **Individual & social:** Planning and training; Technology champion<br>**Managerial:** Project participants refused to use technology<br>**Other**: Information overload from all users' commitment to project web use |
| (Weippert *et al.* 2002a) | **Aim:** Identified critical factors for ICT implementation success<br>**Method:** Survey and interview of five case studies (an 'e-project' case and four cases of 'Project Center') by evaluating seven criteria of ICT implementation success in five case studies | **Technological:** System compatibility; Data accessibility; Reliability; Capability<br>**Individual & social:** Internal users and project participants commitment; User involvement; Quality and accuracy of information and data input<br>**Managerial:** Supported by developers, implementers and researchers; Create a feeling of trust (reliability, relevance, need, etc.) for users; Ensure users provides quality and accuracy information to system; Users involvement; Training and technical support; Champion or IT driver.<br>**Other**: Legal issues (i.e. authenticity, integrity, confidentiality). |
| (Björk 2002) | **Aim:** Observed the current users of EDMS<br>**Method:** Review the EDMS studies | **Technological:** Slow Internet connection; Communication Standard<br>**Individual & social:** User resistance; Different users' attitude and skills<br>**Managerial:** Motivation; Training of users |
| (Stewart and Mohamed 2002) | **Aim**: Identified barriers to IT implementation in developing countries<br>**Method:** Pilot survey investigates 20 respondents from engineers, project managers, architects and others<br>* Respondents show moderate use of ICT such as email, LAN, online remote network but none use web-based project in this sample | **Technological:** High cost of IT; Quality and quantity of IT infrastructure; System incompatibility<br>**Individual & social:** Lack of IT skill and support IT; Computer literacy<br>**Managerial:** Low level of IT awareness; Lack of leadership; Cost-driven strategy and client lack knowledge of IT benefits; Low profits margin; High work load activity<br>**Other:** Language barriers; Industrial fragmentation |
| (Thorpe 2003) | **Aim:** Provided a practical view of ICT implementation problems<br>**Method:** Case study of ORCM (online remote construction management) on road construction projects. The data are collected from survey and interview of ORCM | **Technological:** Perceived slowness of the Internet; Lack of the local Internet connection; Slow bandwidth and network traffic -> fail to send/attach large file with email; Slow Internet connection; Information and data security.<br>**Individual & social:** People's trust in electronic transaction; Low user satisfaction and perceived benefit of use; Lack of computer literacy; User reluctance.<br>**Managerial:** Cost of system implementation; Obtain the full commitment of others |
| (Mohamed and Stewart 2003) | **Aim:** Evaluate users' perceptions on the web-based communication<br>**Method:** Survey measures users' perspective on operation, benefits, user orientation, strategic | **Technological:** Operational perspective: Benefits perspective; Technology/system perspective; Strategic perspective; User orientation perspective |

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| | competitiveness, and technology system. The data are based on 42 project participants. | |
| (Alshawi and Ingirige 2003) | **Aim:** Reviewed the five cases that currently use project web technology and identified the benefits and problems<br>**Method:** Five case studies of project web technology were interviewed on the background, benefits and problems. | **Technological:** Incompatibility of system; Difficulty to send large file sizes and security of system<br>**Individual & social:** Different IT skill and competence; Lack of project partner commitment<br>**Other:** Benefits: Improve speed of information transfer and enhance communication; Support decision-making; Reduction of delivery and copying cost; Reduce the storage space for paper work; Summary of the benefits of using project web sites related to construction phases: tendering, design & construction and trading (e-commerce) |
| (Voordijk *et al.* 2003) | **Aim**: To understand the factors that lead to the success and failure of ERP in large construction firms by focusing on the fit between the following pairs of elements in ERP implementation: (1) business strategy and IT strategy, (2) maturity of the IT infrastructure and the strategic role of IT, and (3) the implementation method and organisational change.<br>**Method:** Case study of three main business units in a large Dutch-based construction firm. | **Technological:** Fit between maturity of IT infrastructure and strategic role of IT<br>**Managerial:** Fit between business and IT strategy; Fit between implementation methods and change process in organisation |
| (Huang *et al.* 2003) | **Aim:** Identified the criteria for IT adoption decision within construction industry (initial adoption)<br>**Method:** Online survey questionnaire was used to collect data. The analysis is based on the 63 respondents that consist of IT consultants, software development organisation, architectural, structural and engineering, transportation, and other industries. | **Technological:** Relative advantage i.e. Compatibility, Complexity, Observability or trialability, Technologies opportunities, Centrality, Cost, Communicability, Divisibility, Profitability, Social approval and image, Voluntaries, Result demonstrability, Visibility, Preparedness<br>**Individual & social:** Characteristics of key individual<br>**Managerial:** Characteristics of organisational structure i.e. Innovativeness of organisation, Characteristics of communication environment, Organisational training and learning, Management attitude, External environment, Leadership<br>**Other:** Supply chain change; Process adjustment resulting from the company growth; Process adjustment resulting from increasing complexity of high tech facilities; Client demand and other process problems; Market pull |
| (Gyampoh-Vidogah *et al.* 2003) | **Aim:** Explored the issues of information management, vision of the future, and the impact of efficiency<br>**Method**: Open-ended interview was used to collect the data from three case studies of construction companies. Each company | **Technological:** System incompatibility; Storage problems; Searching and retrieval problems.<br>**Individual & social:** Internal culture; Social uncertainty; Unchanging individual dominants; Reaction to technology and utilisation of employee potential; Lack of motivation to adopt technology; - Employee potential not utilised to best advantage; Lack of internal champion; Lack of management commitment.<br>**Managerial:** Cost escalation and paper waste; Poor access to information; Labour intensive; Delays and misunderstanding; Lack of corporate systems |

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| | provided four participants including senior partners and contract managers. In addition, follow-up interviews and seminars were conducted to explore in-depth issues. | |
| (Nitithamyong and Skibniewski 2003) | **Aim:** Identified 36 success/ failure factors and 34 variables measuring success/failure in implementing of web-based construction project management system (PM-ASP)<br>**Method:** 10 expert opinions ranked factors. | **Technological:** Type of hosting service in terms of: Number of users, Ease of use, Output quality, System reliability, Data quality and reliability, Data security, Frequency of update, Integration among functions, Internet access availability and bandwidth<br>**Individual & social:** Prior experience i.e. Team attitude toward IT/PM, Adequacy of training, Users involvement during planning, Computer experience and literacy, Frequency of use<br>**Managerial:** Existence of champion; Ability of project manager; Project complexity; Type of owner & contracts; Project size and duration; Level of top management support; Alignment of technology with business objective; Knowledge of construction business; Technical competency; Promptness of responses |
| (Villeneuve and Fayek 2003) | **Aim:** Developed a prototype project web technology and identified the benefit of using this to solve information management problems.<br>**Method:** Case study to describe the functionality of a project web technology site and provides a guideline for system implementation. | **Technological:** Immaturity of technology; Existing communication tools; Barriers of control by password restriction comparing to other technology such as fax, phone; Security and legality of data<br>**Individual & social:** Acceptance and resistance of user; Different experience in working with online collaboration<br>**Managerial:** Commitment from all users to gain full benefits<br>**Other:** benefits of using PWS are: * reducing project cost and saving time, * improving the construction partnership, * immediate and easy access to information and documents, * real-time collaboration and sharing documents between both intra- and inter-organisational staff. |
| (Nitithamyong and Skibniewski 2004) | **Aim:** Reviewed current web-based project management services in the market.<br>**Method:** Literature reviews on web-based project management systems | **Technological:** System reliability; System security; Lack of software interoperability; Internet access and band width problems; Password barriers; Not enough technological functions; Density of communication channels.<br>**Individual & social:** Resistance to change<br>**Managerial:** Difficulties in quantifying costs and benefits; Collaborative maturity<br>**Other:** Legal issues of electronic transaction; Data ownership after project completion |
| (Stewart *et al.* 2004) | **Aim:** Determined the barriers/problems of IT implementation into industrial level, organisational level, and project level.<br>**Method:** Survey questionnaire is used to collect data from 140 construction professionals from AEC. | **Technological:** Security and privacy issues; Poor inter-operability<br>**Individual & social:** Resistance to change by staff; Low technology literacy of some participants; Fear of change and uncertainty.<br>**Managerial:** Low level of IT awareness; Reluctance by management to invest in innovation; Lack of IT strategic planning; Lack of perceived return on investment; Conservative business practice; Limited resources available to small and medium enterprises; Tight project time frames; Limited IT expenditure on projects; Lack of leadership<br>**Other:** Construction industry fragmented; Security and privacy issues. |