UNDERSTANDING THE ICT INNOVATION DIFFUSION PROCESS OF LARGE AUSTRALIAN CONSTRUCTION CONTRACTORS

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ABSTRACT: It is recognised that using information and communication technology (ICT) in the construction industry offers numerous productivity advantages. To obtain these benefits, many construction organisations are starting to invest in ICT, however, many still lack an understanding of how to effectively diffuse this technology. This paper aims to explain those factors that influence the diffusion process. Case studies were undertaken of projects involving us to extensively collaborate within three large construction contractors in order to understand the nature and process of ICT adoption and diffusion within their construction organisations. We used semi-structured interviews used to collect data from IT managers, implementers and professional ICT users. We offer a conceptual model of ICT diffusion to explain the relationships between various factors influencing the ICT diffusion process.

Keywords - innovation diffusion, IT implementation, and technology management

1. INTRODUCTION

Information and communication technology (ICT) is identified as an effective facilitator for enhancing construction communication and improving information integration (Björk, 1999; Love, MacSporran & Tucker, 2000). Research studies suggest possible ICT applications that may be applied in the construction industry to improve service delivery and productivity. Tam (1999) and Deng et al. (2001), for example, developed a prototype ICT system that can be used to manage and transfer project information and enhance project communication. Our case studies identified several commercial applications in use. Skibniewski and Abduh (2000) reviewed the development of Internet applications (academic and commercial products) for specific use in the construction industry. They found that Internet technology, especially web-based applications, provide information service, communications and computing management benefits.

We argue that while many construction organisations attempt to gain the benefits of ICT by investing in this technology, there may be limited if few people who *actually* adopt and use it. Like other communication technologies such as phone and fax, ICT requires *acceptance* by users. Even within organisations where many users adopt ICT, they will find it difficult to communicate or transfer electronic information to their colleagues who avoid using ICT. Under this situation, organisation may lose any overall productivity gain because people have to work with both paper and electronic data. One way to decrease duplication during the transition from a paper-based to a fully electronic environment is to ensure that users adopt and accept ICT as quickly as possible. Thus, ICT management of technology adoption and diffusion is pivotal.

The structure of this paper begins with a review of literature relating ICT diffusion to support the basic knowledge of ICT diffusion. Next, the selection of research methodolgy is discussed and explained. Then, the findings from the case study is used to illustrate a summarised

perception of factors' influence on the diffusion of ICT innovation from the case study. Finally, the proposed conceptual model of ICT diffusion is discussed.

2. PREVIOUS 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, 1995). In this paper, the term "*ICT diffusion*" is defined as the process in which an ICT application is adopted and implemented by an organisation until expected users within that organisation accept and transfer their knowledge of using these ICT applications throughout the organisation.

Recently, management of information technology, especially adoption and implementation, have been identified as one of the three main themes in CIB W78 conference papers (Amor et al., 2002). This demonstrates the significance of this research. Also, ICT adoption in construction research has been linked to IT strategic management (Smith & Betts, 1999), technology adoption decision-making (Mitropoulos & Tatum, 1999; 2000), strategic planning for IT investment (Peña-Mora et al., 1999), and strategic IT implementation (Stewart, Mohamed & Daet, 2002). Although there has been several research attempts to develop an implementation framework, classical technology adoption problems remain in the construction industry such as time and cost overruns and users resistance (Love et al., 2001). We believe that such problems could be resolved by these organisations having an improved understanding of the technological diffusion process.

Innovation diffusion plays an important role in theories describing information technology (IT) implementation (Rogers, 1995). Innovation diffusion 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 organisational adopters. *Micro* innovation level theory focuses on the individual adoption and *meso* innovation is classified in between these previous two and focuses more on an organisation as consisting of series of individual adoption. We believe that the *meso* innovation theory is best suited to our approach of studying innovation within organisations.

The adoption decision of technology within organisations is usually authorised by a group of senior managers, therefore the key question of ICT adoption should be focused on how to make expected users accept and use ICT in their work processes. Several concepts explain users' acceptance such as technology acceptance model (TAM) (Davis, 1989), technology planned behaviour (TPB) (Taylor & Todd, 1995), and diffusion of innovation (DOI) (Rogers, 1995). These can be considered as traditional innovation adoption models because they have been argued to explain individuals' intention behaviour in adopting technology in which the individual has independently adopted or rejected technology (Fichman, 1992). Gallivan (2001) argued that traditional innovation adoption models may not be applicable under the following circumstances:

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

As traditional adoption models rely on voluntary adoption decision by individuals, they may be less suitable in explaining complex organisational adoption decisions (Gallivan, 2001).

Success in technology adoption within organisations needs top-level implementation support and encouragement of expected users to individually adopt and use the technology. To overcome the traditional innovation adoption approach, Fichman (1992) recommended integrating DOI with other theories such as critical mass (Markus, 1987), absorptive capacity (Cohen & Levinthal, 1990), and organisational learning (Attewell, 1992). Similarly the adoption of technological innovation into organisations can be seen as a change initiation process affecting the way people work. Based on traditional DOI, the diffusion rate of technology adoption can be predicted by technological characteristics, communication channels, and social systems (Rogers, 1995).

Traditional innovation diffusion within an organisation requires change management to facilitate and encourage people to adopt ICT initiatives. Organisations 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 et al. (2003) integrated the concept of DOI (Rogers, 1995) with change management (Senge et al., 1999) and identified eleven factors influencing use and adoption of ICT. These were then clustered into management (M), individual (I) and technology (T) group factors that impact upon ICT diffusion with each of these being influenced (surrounded) 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.

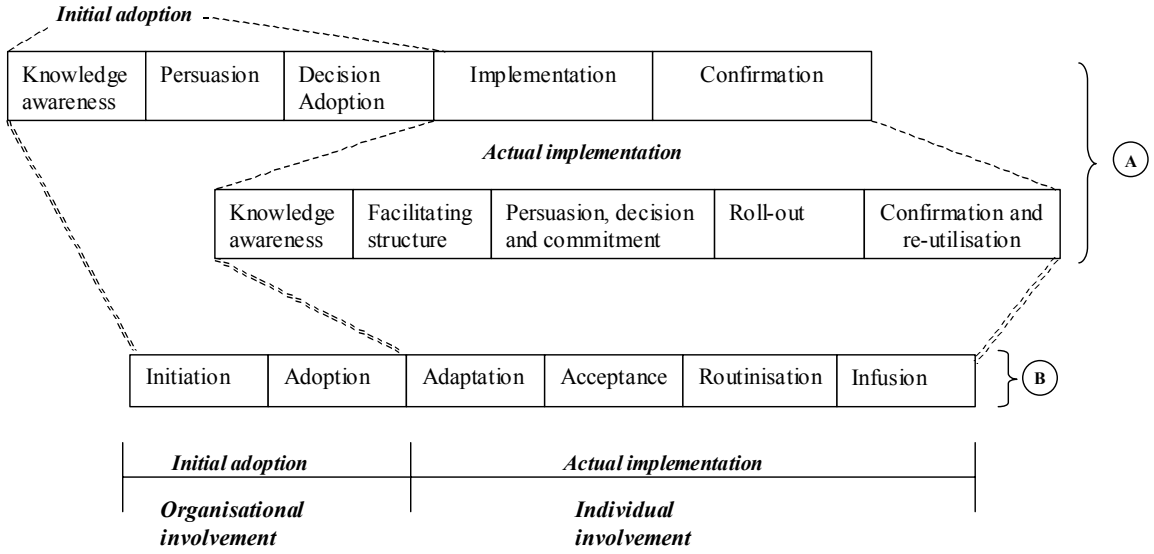

Figure 1. Stage model of technology diffusion adapted from Rogers (1995) [A], Carlopio (1998) [A] and Cooper and Zmud (1990) [B]

According to Cooper and Zmud (1990), the model of organisational adoption and its implementation consists of six stages: initiation; adoption; adaptation; acceptance; routinisation; and infusion (Figure 1, part B). This stage model has been used for measuring technology adoption maturity based on the characteristics of each stage (Damsgaard & Scheepers, 2000). We argue that the model is applicable to ICT diffusion using the same management processes.

Figure 1 shows the traditional innovation diffusion stage model. This model can be divided into two stages: initial adoption and actual implementation. The first stage, initial adoption, focuses on diffusion of the innovation at the organisational 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 the diffusion at individual/group level should follow a similar process to that of the organisation level with feedback to the organisational level. He adapted the Roger's 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-utilisation. Although the innovation stage model can help explain the nature of technology to be adoption, little work has been undertaken to link factors influencing innovation diffusion the stages indicated in Figure 1. We address this later in this paper.

Our research 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 construction organisations, it helped us to better understand factors influencing ICT adoption and diffusion through the whole ICT adoption and diffusion process. This model may also assist construction organisations to plan and monitor their ICT diffusion initiatives—feedback from participants and in seminars on the proposed model indicates that this model may also be applicably (extended) to any emerging technology.

3. RESEARCH METHODOLOGY

We used quatitative research to identify factors influencing ICT diffusion within construction organisations and explain how they influence the ICT diffusion processes. Case study qualitative research can be grouped into three broad categories: exploratory, descriptive, and explanatory (Neuman, 1997). We chose a descriptive case study approach to obtain rich information from the participant's viewpoint using multiple sources of data that helped us understand what was happening as well as how and why it followed a particular trajectory (Yin, 1994).

Data collection started with discussions with senior IT managers to understand the strategic adoption of ICT applications at the organisational level. We followed that with interviews conducted with the ICT implementer or ICT manager involve in rolling out the ICT application at the group or individual level. The research aims to explore the processes of ICT adoption and how diffusion has been undertaken through the organisation at both group and individual level. In addition, experienced users in each case were requested to discuss their experience of factors influencing their adoption and use of ICT application. Our analysis followed the organisational adoption (initial adoption) and individual adoption (actual implementation) experience. Finally, we conducted seminars to feed back and validate our analysis and to stimulation further debate.

4. CASE STUDY RESEARCH FINDINGS

Our report of the 3 ICT diffusion case studies within construction contractors is organised into two main sections: the initial adoption of ICT application and the actual implementation. Initial adoption is focused on how ICT application was decided upon and adopted into an organisation by senior management whereas actual implementation is focused on how expected users were introduced and encouraged to accept and use ICT tools for their normal work activities.

4.1 The Current Initial Adoption of ICT Application

Generally, the three cases drawn from AUD$1billion+ annual turnover first tier contractors, show similar main objectives for ICT initial adoption. These objectives are to gain competitive advantage from using ICT to improve quality control by integrating construction document management and to improve communication and coordination. These organisations invested in ICT groupware communication applications such as that used for communication and coordination—processing requests for information (RFI), and sending drawings and letters. The ICT application software in which users can access, exchange and search information from anywhere processed all correspondences and pieces of information.

Both demand-pull and technology-push forces trigger adoption of ICT. Users may seek solutions to particular problems (demand pulling supply) or ICT suppliers may sell a technology to solve a generic problem (technology pushing demand). Objectives for ICT adoption in all three cases were similar but their adoption processes were quite different. Case study organisation A's (CSA) quality assurance improvement policy in early 1990 initially drove its ICT adoption when Internet technology was in a nascent development stage. CSA decided to develop its own ICT application because off-the-shelf software packages did not fulfil or support its organisational needs. Therefore, CSA could be classified as following a proactive ICT adoption strategy because it invested early in developing ICT applications rather than waiting to later adopt suitable off-the-shelf software packages. However, CSA also used a proprietary ICT document management system. Regional senior managers and quality managers supported the adoption decision with the IT department—we classify the ICT adoption direction as 'top-down'.

In case study 'B' (CSB), the ICT adoption initiative also attempted to gain competitive advantage from adopting ICT applications. During mid 1990, a lot of Internet applications such as email and file transfer were being developed to help basic business communication. CSB perceived these Internet applications to have limited applicability to their construction business because it is a project-based organisation dependent on an extensive less ICT-literate supply chain. The IT manager (who is interested in ICT benefits) supported investment in a web-based document management system, however, CSB decided to develop its own ICT system because off-the-shelf software packages did not provide functions that supported its organisational needs. It could be also be interpreted that CSB shows a proactive strategy on ICT adoption. Furthermore, the type of ICT adoption may also be classified as both demand-pull and technology-push. ICT was used to improve document management quality, communication and coordination. It focused on ICT use by both internal staff and other project teams. All project teams exchange correspondence information such as drawings, staff contact details, site diary etc. An e-business group supports investment and makes adoption of this tool as 'compulsory' for construction projects—the adoption of ICT for CSB should be classified as top-down.

Case study organisation 'C' (CSC) has a reactive ICT adoption strategy because it chose to adopt a web-based document management host service instead of developing its own system. The main reasons are ICT immaturity (for this application) and fear of risks associated with being an early adopter though, CSC previously tried to adopt a similar ICT platform on two pilot projects, the rationale being that a simple ICT application is more likely to be successfully adopted to a complex ICT one. This could be interpreted that complex ICT applications may present CSC with an unacceptably high risk of adoption. In addition, CSC plans to adopt a current web-based ICT host service for a pilot project to prepare the organisation to adopt an emerging ICT platform standard in the near future. An e-business unit that consists of business

representatives and IT people supports ICT adoption. This group has the essential role of exploring and initiating ICT adoption. In this case, the IT person was allocated to facilitate the adoption and diffusion of this ICT initiative. Adoption could be interpreted here as both top-down and bottom-up. The e-business unit encourages the support of ICT adoption by suggesting and analysing suitable ICT application for project use whereas the decision to adopt is decentralised, being made by project managers. In addition, the degree of adoption is influenced by technology-push rather than demand-pull. CSC provides two reasons for its later adoption decision. First, it believes that current ICT is not mature (at the time of this study). Second, CSC plans to pilot a commercial ICT application (a simple one) to create and build staff competency.

From the case studies, we can summarise our findings of ICT adoption as follows:

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

4.2 The Current Actual Implementation of ICT Application

Although the nature of ICT adoption in the 3 cases are quite different in proactive and reactive strategic adoptions, the implementation of ICT application is quite similar in term of supporting management, technology, and supporting individual users. While most participants of three cases 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 organisational implementation.

In CSA, the actual implementation focussed on: IT people providing training and technical support; technology fit; and senior management support. Most respondents received 3-4 hours training and had strong support from a help-desk. Also, CSA top management were interested in developing suitable ICT application for enhancing work-processes. One quality manager said that ICT functionality and simplicity were key essential factors required for encouraging users' acceptance. Finally, senior project managers also supported the diffusion of ICT by encouraging users, trying to help them solve problems of ICT use and feeding comments to the ICT developer for improvement. Participants in CSA had strong computer skills, clear ideas of the benefits of using ICT applications, and self-confidence in using them. Most of them adopted and used ICT for their daily work. There was also a sharing and learning environment in CSA that supported the diffusion of ICT for its users. For example, a senior manager often shared and exchanged his technical experience with IT people. This sharing environment helps both ICT supporters and

users to understand and continuously improve any ICT initiatives. Another project manager set up regular morning meetings to create a learning environment within his team to help users learn how to use ICT applications for specific tasks and support cross-team learning.

ICT implementation in case study B (CSB) 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. The implementer also took an additional role in helping ICT use though offers of participating in help-desk support. Some users mentioned it was hard to contact the help-desk by phone and get a quick response so they generally contacted the ICT implementer. Organisations also support each user by providing users with a computer, an Internet connection, and user account. Senior management support in CSB is based on a project-by-project and job responsibility. Two construction project managers provided a role model encouragement of his team by sending information to them using ICT applications. On the other hand, a design project manger argued that ICT applications have not supported his project. In addition, expected users complained about issues related to implementation process. They were satisfied with the concept of ICT use, but some users felt that ICT application needs to be improved e.g. cost control. In addition, users complained about barriers to their use of technology "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". Although respondents in CSB were satisfied with the content of training, some had different backgrounds and skills that affected individual learning outcomes. For example, one expected user in a training session asked an implementer: "What is Netscape software". In addition, as each user may have different role on a construction project, the implementation process should define related modules that assist their job. Unclear benefits of ICT use may result in wasting time learning modules that are not essential to the user. From the CSB learning environment point of view, one construction project had a high number of experienced users in place that could influence new users' acceptance of ICT. The transfer of ICT knowledge from experience users to novices is other key ICT diffusion factors. Training provides a common understanding of an ICT use, but users need to learn and practice it for gaining benefits of use on their projects. Thus, if users have any limitation in using ICT, then effective adoption and use of ICT may depend upon support from a collegial environment.

The actual implementation in CSC was affected by training and implementer support. As ICT is quite straightforward the training took approximately one and a half hours to explain how to use the ICT application. Most participants are satisfied with having training for initial understanding of an application. The implementer uses trial projects as an exercise to help users to familiarise themselves before starting to use an application on a real project. The Implementer also had a strong influence on helping users on construction sites because he was specifically allocated to support users. Thus, users felt confident to ask for help from him. Top management supported ICT use and provided suitable infrastructure such as computer and Internet networks as well as a project manager who had an enthusiastic personal interest in ICT innovation and use. He encouraged subordinates to use the ICT system. When he had time he would sit down and help user's solving their problems. He sometimes had limited ICT knowledge but would contact the implementer to help solve any ICT problems. The characteristics of CSC's ICT systems were quite simple—the main concept was a design that supported project communication and coordination within and between project teams. Applications included daily work lists, drawing register, and correspondence. These functions provided an adequate document management system for the construction project. It was mentioned that the use of ICT was reliable and

provided a good response rate, however, participants noted that access was governed by the Internet connection speed. Participants from CSC had enough computer background and clear benefits of using ICT to feel that ICT is quite simple and provide suitable benefits for them.

CSC provided project teams with a good collegial help environment for using ICT. Not only was there a supportive implementer, but also there was assistance and other help for using ICT on construction projects. For example, a new engineer suggested how to use ICT for his job to his senior engineer who had never used it before. Most of participants felt that there was good collegial help in their workplace environment. They shared stories of their ICT use and helped each other by discussing how to improve its use. Generally, the work environment was open for people who would like to discuss how to improve ICT implementation and feeling sufficiently safe to openly ask questions and fearlessly discuss any difficulties encountered when using ICT.

We conclude from these case studies and the Peansupap *et al* quantitative study (2003) that the main process of implementation is focused on training and technical support, senior management support, characteristics of user, and characteristics of ICT. Training and technical support and characteristics of ICT were *formally* managed but support from senior management or project managers, characteristics of users, and a sharing and open discussion environment was *informally* managed.

5. FRAMEWORK OF ICT INNOVATION DIFFUSION

We have proposed a framework of ICT diffusion to help the management of technology adoption and diffusion based on three Australian construction cases and the Peansupap *et al* (2003) research. This is illustrated in Figure 2 below.

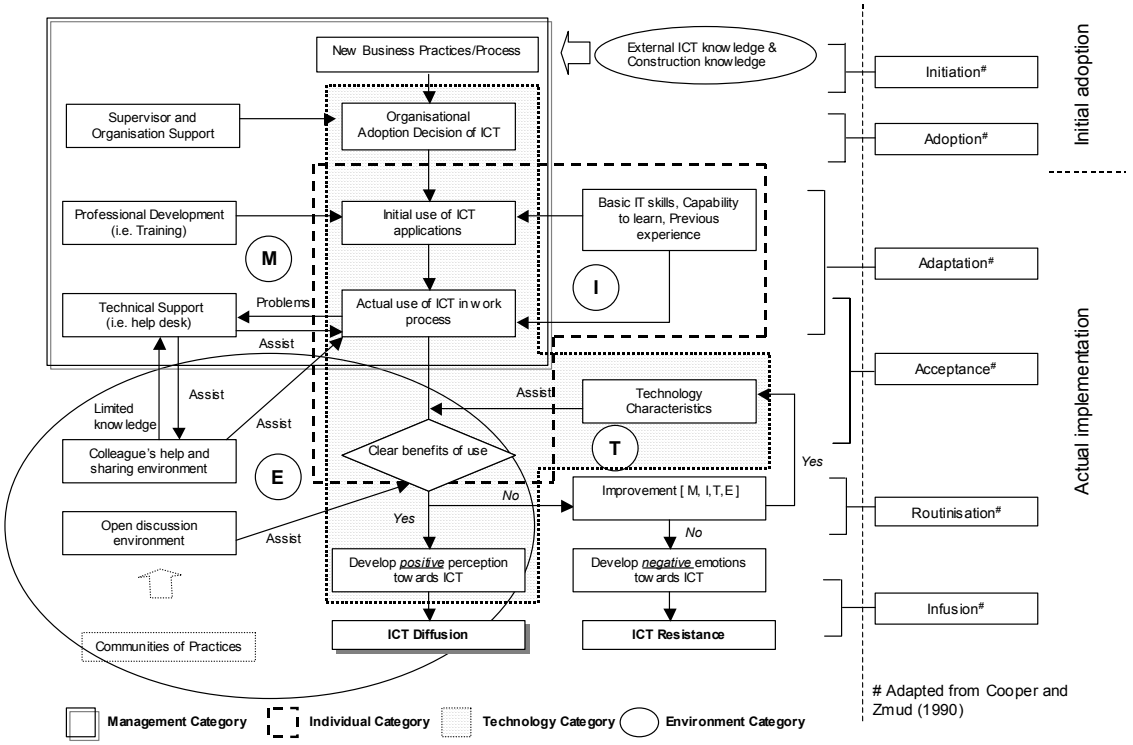

Figure 2. The framework of ICT innovation diffusion within an organisation

Figure 2 presents a framework consisting of processes and factors influencing ICT diffusion. On the right hand side, the figure shows the innovation diffusion stages whereas the detail processes of ICT diffusion within an organisation are described on the left hand side. It crystallises the preceding discussion of theory and the case study research into a model. First, the framework indicates how ICT diffusion takes place from initial adoption to actual implementation within a construction organisation. Second, it shows the relationship between key factors—management (M), individual (I), technology (T) and environment (E) that influencing the diffusion process. From Figure 2, the key processes of ICT diffusion consists of: (1) development of new business practices/processes, (2) organisational adoption decision of ICT, (3) initial use of ICT application, (4) actual use of ICT application, (5) clear benefits of use, (6) development of positive perception towards ICT and ICT diffusion throughout an organisation. We have analysed, using the 3 case studies, adoption and diffusion of ICT applications into an organisational level and a group/individual level. First, at the organisational level, there are two main stages: initiation and adoption (see Figure 1). These two stages involve IT executives, gatekeepers and ICT developer teams. Second, after the organisation decides to invest in ICT applications, the actual implementation is triggered to delivery the ICT application matching the user and business requirement with the functionality of the ICT innovation. Figure 2 illustrates the issues that ICT diffusers/implementers should consider (such as ICT application development and configuration, infrastructure support and training and technical support). We acknowledge the limitation of this paper's scope, and regret the restrictions on presenting further details of the ICT diffusion process discussed in this paper and provide more details on Figure 2, however, these details are discussed in a range of papers currently under review.

6. CONCLUSIONS

This paper aimed to explain how the ICT diffusion process takes place at different developmental stages. We argue that senior management is in a pivotal position to strongly influence support the initiation and adoption stages of ICT diffusion. After the initial organisational adoption has been decided upon and sufficient resources committed for successful diffusion, the next process is to encourage users to adopt and use these ICT initiatives in their daily job. This actual implementation stage requires a supporting management, technology, individuals and work environment infrastructure. To achieve successful innovation diffusion, the proposed framework of ICT diffusion was presented to help managers understand the nature of ICT diffusion and how the identified factors, discussed above, may affect the diffusion process. This framework has been synthesised and tested from the experience of first tier construction organisations. It is yet to be tested at second and lower tier levels in the industry, however, we present a tool to examine what factors should be brought into focus to improve ICT diffusion within other construction organisations.

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