Factors affecting ICT diffusion
A case study of three large Australian construction contractors
Vachara Peansupap and Derek Walker

Cooperative Research Centre in Construction Innovation, RMIT University, Melbourne, Australia

Abstract
Purpose – To address the critical issue of how best to adopt and diffuse information and communication technology (ICT) into organisations.

Design/methodology/approach – During April and May 2002, a survey of ICT diffusion of ICT users from three construction organisations was conducted.

Findings – Results from an earlier phase of this study indicated that 11 factors influence ICT diffusion. The aim of this paper is to report on phase 2 study results within three construction organisations based on the 11 factors found to influence ICT diffusion. Semi-structured interviews were undertaken with five to six ICT users and an implementer for each of the case study companies.

Originality/value – Three factors were found to have a weak influence on ICT diffusion, while eight have a strong influence. These influencing factors may be grouped into four interrelated categories: management, individual, technology, and work environment. Their inter-relationship should be coherently and comprehensively addressed.

Keywords Communication technologies, Technology led strategy, Innovation, Diffusion

Paper type Case study

1. Introduction
The construction industry has to cope with a highly complex, fragmented and unique combination of business relationships and processes. This is because most construction projects involve many phases such as feasibility, design, construction and maintenance. Each phase requires effective communication of underlying knowledge and coordination between many project participants such as the owner, contractor, designer, consultant, subcontractors, and suppliers. This may lead to timing and technical content communication-transfer problems – each project is unique in its construction type, location and project participants. Traditional construction management approaches have been criticised as not improving construction productivity within this turbulent environment (Latham, 1994).

Much effort has been directed toward improving construction productivity. Use of information technology (IT) is an area worth concentrating upon because it can decrease time for data processing and communicating information. Modern structural design software applications, such as 3D modelling, provide an example where designing complex structures can be achieved where previously this was almost impossible (Walker

This paper is a part of research study undertaken by Cooperative Research Centre (CRC) in Construction Innovation, Melbourne, Australia on ICT diffusion and knowledge management. We also wish to acknowledge the contribution of discussion and elements of the data gathering from other researchers on this CRC project research team, Mr Andrew Wilson and Mr Tayyab Maqsood and Mr Peter Goldsmith.
and Hampson, 2003). IT applications also aid operational improvement through communication of construction information for effective decision-making and coordination. For example, visualisation technologies can improve project information and effective communication between project participants (Liston et al., 2000). Also, reducing the processing and communicating information time for making decisions enhances the likelihood of improved construction productivity.

Information and communication technology (ICT) has been recently identified as essential in improving communication in construction processes. One benefit of ICT is to reduce information re-entry by linking information between these processes (Björk, 1999). Construction projects require a large flow of construction documentary information between project participants during both design and construction phases. Tam (1999) presents a prototype ICT system for use in construction organisations that improves communication and reduces communication costs. Other researchers have investigated the use of ICT in construction processes in design and construction (Veeramani et al., 1998), in construction cost control (Abudayyeh et al., 2001) and project management (Skibniewski and Abduh, 2000). These studies of the benefits of ICT use suggest an increasing trend of ICT use by the construction industry (Futcher and Rowlinson, 1999; O'Brien and Al-Biqami, 1999; Rivard, 2000). While potential benefits of ICT use have been clearly demonstrated, the realisation of these benefits in practice is limited. One reported problem was that ICT users resist adopted corporate ICT applications (Davis and Songer, 2002). For example, a company may invest in ICT systems but staff could still be communicating via the phone and/or on paper. As a result, potential communication benefits of ICT may not be fully realised. In particular, ICT success requires a critical mass of adopters in order to gain full communication and information exchange benefits (Markus, 1987; O'Brien, 2000). Thus, effective diffusion of ICT through organisations needs to be effectively managed to better prepare for future ICT application adoption.

In an earlier phase of this study using factor analysis on data from respondents from three Australian construction organisations, 11 ICT innovation factors were identified. The total number of respondents was 117: 35 respondents from a government construction organisation (group A); 39 respondents from a construction contractor (group B); and 43 respondents from an engineering consultant (group C). Peansupap et al. (2003) provide further details of the research methodology and results. The 11 factors are:

1. F1: professional development and technical support.
2. F2: clear benefits of use.
3. F3: supporting individual characteristics.
4. F4: supporting technology characteristics.
5. F5: supporting supervisor and organisation.
7. F7: supporting rewards.
8. F8: colleagues help.
10. F10: negative feeling towards ICT use.
This paper will concentrate on the user experience of the above 11 factors in the context of innovation diffusion and change management.

2. Integration of innovation diffusion theory with change management

After an organisation decides to adopt technological innovation, the next process is to encourage its adoption at an individual level throughout the organisation. Diffusion has been defined as the process in which technological innovation and managerial innovation have been introduced into work processes and adopted by a specific group or across the whole organisation (Rogers, 1995; Green and Hevner, 2000; Bresnen and Marshall, 2001). Therefore innovation diffusion theory can be applied to explain the nature of IT adoption (Mitropoulos and Tatum, 2000) and implementation (Fichman, 1992). The number of adopters increases as the technological innovation becomes more fully diffused. Understanding technological diffusion is required to ensure successful technological innovation (Green and Hevner, 2000) because the rate of effective adoption growth can be used as a proxy measure to reflect technology introduction success. The diffusion process is complex and should also be understood so that technological limitations and constraints on adopters in the organisation are well recognised (Senge et al., 1999). Figure 1 illustrates how change management and innovation diffusion affects organisational implementation of innovation initiatives. Static factors fundamentally affect initial IT diffusion whereas dynamic factors sustain IT diffusion changes. Without the dynamic factors, diffusion could not be maintained. We examined the relevant literature to better understand the two elements of dynamic and static influence.

We use the term “ICT diffusion” to define information and communication technology that has been adopted and transferred by potential users within an organisation at the implementation stage. Effective ICT diffusion success could be perceived in terms of factors that influence technology adoption and the way in which successful adoption of technology by potential users within an organisation could be maintained. Rogers’ (1995) innovation diffusion model describes its elements as comprising: technological characteristics; communication channels; social systems; and the diffusion rate. The innovation diffusion rate depends upon the first three factors. However, IT innovation diffusion within an organisation also requires a change management process that encourages people to adopt and use it as well as
motivating people, providing appropriate training and technical support, supervisor support and open discussion to solve problems and resolve issues (Senge et al., 1999).

As the national Internet infrastructure expands and ICT operating costs decrease (e.g. Internet service cost, hardware, and software costs), the numbers of ICT users in construction firms may increase over the coming years. Research outcomes reported upon in this paper could help development of a road map to be used by construction organisations to better diffuse ICT. For example, company directors from 20 Australian small-medium construction companies revealed several problematic ICT implementation issues. These include:

- lack of an IT infrastructure;
- lack of IT staff; investment cost;
- lack of ICT business requirements;
- unclear benefits of ICT use; and
- behavioural barriers (Love et al., 2001).

Therefore, these issues should be studied in more detail through identifying drivers and inhibitors of ICT innovation to fully understand how ICT technology is transferred into organisations. This is particularly relevant to the successful expansion and/or deployment of an inter-intranet infrastructure.

Results from the Peansupap et al. (2003) ICT diffusion survey indicate that users had very supportive personal characteristics and a high level of understanding of using ICT applications. Users from that study’s three groups felt that their organisations have high ICT diffusion influence through having:

- an open-discussion environment;
- support from colleagues; and
- support from supervisors.

However, professional development and technical support were recognised as only having a medium influence upon ICT diffusion. Respondents generally believed that any intrinsic rewards system has a low influence on their ICT application use. These 11 factors were used as the key factors to develop a semi-structured in-depth interview involving three construction contractors to validate the results of this survey.

### 3. Research methodology

This study of ICT diffusion within large construction organisations consisted of two phases: gathering quantitative data and qualitative data. This paper relates to the second phase and aims to both verify the identification of the 11 factors earlier identified by Peansupap et al. (2003) as influencing ICT diffusion and to explore how these factors affect ICT diffusion. In order to understand ICT diffusion within construction organisations, a case study methodology was adopted. The reason for choosing this methodology was to provide qualitative data that can help us better understand how ICT is initiated within the construction organisations and to expose factors that supported ICT diffusion. In addition, case studies help us understand the details of the cases from the participant’s viewpoint by using multiple sources of data (Yin, 1994). According to Neuman (1997), three research approaches can be used:
3.1 Case study criteria
The case study focused upon an ICT groupware application that assisted communication and coordination between staff and between project participants. In addition, the study was restricted to ICT diffusion within large construction organisations that had a turnover of more than AU$1 billion (Australian dollars). The study of ICT implementation in small and medium Australian construction organisations showed that they are less likely to adopt ICT (Love et al., 2001). This finding was also confirmed by the ABS (2001) that showed that the majority of ICT use is centred in large businesses. Therefore, this study focused on large construction companies with ICT implementation experience.

A representative participant target group of expected ICT users and an implementer within each of three organisations were identified to help us understand the ICT diffusion process within each construction organisations. There are approximately ten such organisations operating in Melbourne. Most of the interviewees were based in Victoria, Australia, where the researchers are also based and where the selected companies had a significant regional presence. While each top tier construction company was contacted, only three organisations agreed to participate but these are representative of the group of contractors with AU$1 billion plus annual workload.

3.2 Data collection
The case study interviews were conducted from October 2002 to May 2003. Phase 1 of the research comprised one contractor, one consulting engineering organisation and a government department. In phase 2, three large main construction contractors were interested in participating in this research, including the contractor from phase 1. All had used ICT systems that supported communication and document management within their construction projects. The aim of phase 2 was to focus on the construction contracting companies to better understand how ICT diffusion took place.

The research team conducted semi-structured interviews. To receive the view from cross-organisations, data were collected from the ICT application implementer/facilitator and five to six ICT professional users including project managers, engineers, and foremen. Each was asked to discuss their perception of factors influencing ICT diffusion in their organisation. Each interview took approximately 30-35 min. Most of the interviews were taped and transcribed by the researcher and salient points of content sent back to the users for validation.

4. Case study findings
The findings from the case studies confirmed the 11 factors influencing ICT diffusion within construction organisations derived from phase 1 (see Table I). However, three of these were found to have a weak influence on ICT diffusion. Before discussing these factors, the findings of each case study are described below. These include the
<table>
<thead>
<tr>
<th>Factors</th>
<th>Interview finding case study A (CsA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1: professional development and technical support</td>
<td>Participants received internal training from people in the IT department. The training provides the basics and the concept of using this application. The training session took approximately three to four hours. Most participants were satisfied with the training; however, some mentioned that the content of the training should be more specific and updated if the application was upgraded to the new version. Two principal methods used to contact help desk people were phone calls or electronic e-mails to the help system. Participants were moderately satisfied with the help desk facility because responses to their problems needed time to process, depending on the priority and the problems.</td>
</tr>
<tr>
<td>F2: clear benefits of use</td>
<td>Most participants understood the benefits of using this application. By using it, they found that it assisted communication and coordination within their project. In addition, they also recognised that this application provided a benefit in terms of developing a knowledge repository. These helped them for future decision making.</td>
</tr>
<tr>
<td>F3: supporting individual characteristics</td>
<td>Participants demonstrated adequate personal characteristics such as basic computer skills, enjoyment of learning, self-confidence and commitment to the use of IT. Basic computer skill and self-confidence were considered as the fundamental criteria for individual use. Furthermore, some mentioned that they enjoy learning and commitment to its use provided the essential momentum for their individual use.</td>
</tr>
<tr>
<td>F4: supporting technology characteristics</td>
<td>This application consisted of several modules to assist construction processes such as correspondence, site instruction, tenders, and site diary. The application was considered a good tool to help their work processes. Participants mentioned that the function of the application was compatible with their internal work processes. However, there was a need to improve in low-level areas such as user interface and functions. The application was classified as an intranet platform because it was designed to be used only by people within their organisation. Therefore, users needed to connect with the organisation network. There were two methods for connection: (1) local intranet network and (2) dial-up network. Within the organisational network, there was a main server at head office that was linked to the sub-servers in many construction sites and regional offices. The speed of this application was dependent on the network connection because all information was transferred from an individual computer to the main server in the head office. In the case of connecting through the local intranet network, its speed was faster than connecting via dial-up networking in which the speed was limited to 56 Kbps. Although there were several modules in ICT, users believed the concept of using them is quite simple. Participants mentioned that the use of ICT is by a reliable connection. In addition, all information was backed up through the main server at the head office. Thus it is very hard to lose the information on ICT.</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Factors</th>
<th>Interview finding case study A (CsA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F5: supporting supervisor and organisation</strong></td>
<td>It was mentioned that the supervisor was a positive influence in the use of the application. Most supervisors encouraged their subordinates to use it as they play an unofficial role in helping their subordinates. In addition to supervisor support, the organisation also supported the use of the application by providing enough software, hardware, and training. They provided a computer notebook for people who use the ICT.</td>
</tr>
<tr>
<td><strong>F6: supporting open discussion environment</strong></td>
<td>There is an open discussion environment regarding the use of ICT application; however, not everybody can dedicate the time for discussion because they have their own responsibilities. This organisation also created a virtual discussion environment by allowing the user to discuss and make suggestions about the problems of using this application through the electronic whiteboard system. Some participants mentioned that they were involved in suggesting use of the application. When they found problems or had suggestions, they would discuss them with IT people. However, one participant claimed that not all people in the organisation have sufficient concept of the application to the level that they can discuss issues of improvement in detail.</td>
</tr>
<tr>
<td><strong>F7: supporting rewards</strong></td>
<td>In terms of using this application, suggesting a reward is not an imperative for implementation of the ICT. A tangible reward did not seem to be the key factor for use of the system because the use of ICT application is simply the tools they use for assisting them in their work. Therefore there was no need to provide a tangible reward to users of the application. However, some participants felt that intangible rewards to use it, such as professional standing and pride, are moderately important for them.</td>
</tr>
<tr>
<td><strong>F8: colleagues help</strong></td>
<td>Under this contractor-type organisation, most of the respondents mentioned that they helped and supported one another in any problems that they face. This strong culture helped to underpin the use and the diffusion of this application throughout this organisation. Currently colleagues help one another on an unofficial basis. Although some participants have a limited knowledge of ICT use, they will find out the way to assist or suggest ideas or expert persons who can help solve the problems.</td>
</tr>
<tr>
<td><strong>F9: positive feeling towards ICT use</strong></td>
<td>Strong positive perception on the use of the application. Participants felt that it assisted communication and coordination within their project teams. They believed that the application was compatible with their traditional work processes and assisted their communication.</td>
</tr>
<tr>
<td><strong>F10: negative feeling towards ICT use</strong></td>
<td>There were low levels of negative perception relating to the use of ICT application.</td>
</tr>
<tr>
<td><strong>F11: frustration with ICT use</strong></td>
<td>Frustration may occur in the case of people who may not have adequate computer skills. In addition, the low speed of connection also produced frustration, as they needed to upload and download attachment files from ICT.</td>
</tr>
</tbody>
</table>

| Factors affecting ICT diffusion | 27 |
company background, the ICT diffusion and perceived present factors influencing ICT diffusion.

4.1 Case study A (CsA)
4.1.1 Company background. Case study A (CsA) is one of Australia’s large construction contractors. The company has experience in various types of construction projects such as building, civil, infrastructure and telecommunication projects. The head office is located in Victoria, Australia, with several other regional offices geographically dispersed across Australia. Thus it was difficult to transfer and exchange useful construction project information and knowledge between group members from regional offices. To overcome this, the company sought to improve its internal groupware application. This application was required not only to enhance communication but also to improve the company’s construction processes. This improvement focused on issues such as productivity, quality, and safety. To achieve this plan the company needed a collaborative system that could communicate and integrate all construction information.

4.1.2 ICT diffusion. At the beginning, the company explored and evaluated the software products in the market. However, there was no software to suit the company’s requirement. Therefore, the company decided to develop software based on a database environment as a development tool for customising software to suit the organisation’s needs.

The company teams worked closely with people in the IT department during the development period. The purpose of this was to develop the application to suit their traditional work processes as much as possible. After the development period, the company began to promote awareness of this application. This helped team developers get feedback and suggestions about the application. In addition, the company also provided employee training.

4.2 Case study B (CsB)
4.2.1 Company background. Case study B (CsB) is another large Australian construction company and a global player. Generally, the structure of the company comprises several business units. It engages in various aspects of construction such as design engineering and construction and project management. This case study is focused on the implementation of ICT in one of its larger regional offices, based in Victoria, Australia.

Two main company policies considered in CsB are collaboration and innovation. First, collaboration is focused on both internal and external teamwork. Second, innovation in this company is focused on improving traditional work processes. One of the innovative technologies in case B is a web-based collaborative application. The main objective of this application is to communicate with and coordinate people in construction project teams. As the company has the role of main contractor, it needs to be involved with the client, the architect, and specialist consultants. Hence, the benefit of using ICT is that it can assist work productivity by quickly passing information to project participants.

4.2.2 ICT diffusion. In 1997, the company started to adopt stand-alone Internet applications such as e-mail and file-transfer protocol (FTP). However there were limitations on the use of these applications. For example, when sending files via FTP
the person named (target person) could not be identified. In addition, there was limited capacity for sending large files attached to e-mails. A lot of information and documents were sent and received by, and between, project participants especially during the construction period. The company explored existing collaborative applications in the market but there were no applications to suit the company's specific needs.

In view of this, the company developed its own collaborative application in 1998. The main objective of this application was to improve development of virtual project workgroups. This application is designed to use a common web-based interface that allows all project participants access to its groupware application via a web-browser. The web-based interface runs on the web and database server. The database server has the key role of managing and storing all information and files that transfer through the application. The main function of the web server is to communicate between users and servers through the web graphical user interface. To access this application, users require an Internet connection and Web browser software. It is not necessary to install the core groupware software because all information and files will be processed and sent through a web server linked to database servers, however, plug-in third party software such as CAD or Adobe readers needed to be installed.

Currently, this application is used and implemented on most of its construction projects. It provides several modules to support construction work processes such as document management, site diary, CAD database and correspondence. Though these functions seem to provide benefits of use in construction projects, there are several problems and concerns identified by operational users that need to be addressed.

4.3 Case study C (CsC)

4.3.1 Company background. Case study C (CsC) is another top-tier Australian construction contractor and a highly innovative construction company that has received several awards relating to innovation and construction. In mid-2001, the company established a technology centre to promote construction innovation in its business units. The main objective was to improve work performance, safety, and quality by using technological innovation.

4.3.2 ICT diffusion. One of its main strategies was to improve the use of ICT on its construction projects. To meet this objective, the technology centre started to promote awareness of using ICT, and also evaluated the potential ICT initiatives that might improve communication and coordination in construction projects. The ICT facilitator noted that the company tried to implement two ICT applications. One has simple technology characteristics and the other is quite complex. Respondents reported that implementation of complex ICT had failed but users have adopted a simpler ICT application. Therefore, CsC continued to implement the simple ICT application as a basis for making users familiar with ICT technology. By using this strategy, the implemener found it helped users to adopt the more complex ICT application in the next stage. ICT application diffusion needs time to enable users to understand and appreciate its use.

4.4 Perceived factors influencing ICT diffusion

Findings of the 11 factors influencing ICT diffusion are shown in Table I together with a synthesis of findings from CsA interviewees. The 11 ICT diffusion factors were derived from phase 1 of the broader research project.
Although there are some differences between the details of the factors in all three case studies, a comparison of perceived factors present among the three cases could more clearly explain the pattern of factors influencing ICT diffusion. The comparison of the cases is shown in Table II.

For example, F1 relates to the embeddedness of professional development and technical support to facilitate effective ICT application use within the organisation. Respondents were asked to provide their general feeling about this aspect using a five point low to high scale. This generated a broad ranging discussion and we later asked them to reconfirm their rating based on a more convergent scale of high, medium and low at a series of workshops for each of the case study organisations. This was based upon the ICT user’s perceived experience of ICT use. The discussion and implications section of this paper more fully explains the perceived impact of these factors.

The pattern of factors existing in the three case studies indicated that the “supporting rewards” factor (F7) might not be an important factor influencing the diffusion of ICT. Most participants mentioned ICT use as a tool that enhances their work productivity. The “supporting rewards” factor was perceived as the intangible rewards relating to ICT use such as productivity improvement and time saving making their work simpler or more satisfying.

The adoption decision at the individual level has a positive relationship with the “clear benefits of use” factor. This is also supported by the high “clear benefits of use” factor (F2) and high “positive feeling towards ICT use” factors (F9) in CsA and CsC. Thus, unclear benefits of ICT use in CsB indicated a moderate level of negative perception of ICT and frustration with ICT use. Therefore, clear benefit of ICT use could be one of the main factors influencing ICT diffusion.

To achieve clear benefits of use, the company needs to focus on management and organisational support. CsA, CsB and CsC show a high level of organisation support, particularly for the computer hardware and software infrastructure. Senior managers have a long-term vision of ICT use in their organisations. However, implementation of ICT within CsB is limited because some project managers do not see clear benefits in using ICT in construction projects. In CsA and CsC there is strong evidence of top manager support – most project managers encourage the use of ICT.

<table>
<thead>
<tr>
<th>Factors</th>
<th>CsA</th>
<th>CsB</th>
<th>CsC</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1: professional development and technical support</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F2: clear benefits of use</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F3: supporting individual characteristics</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F4: supporting technology characteristics</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F5: supporting supervisor and organisation</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F6: supporting open discussion environment</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F7: supporting rewards</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F8: colleague helps</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F9: positive feeling towards ICT use</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F10: negative feeling towards ICT use</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>F11: frustration with ICT use</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
</tbody>
</table>

**Notes:** • Low level of perceived present factors; • • Medium level of perceived present factors; • • • High level of perceived present factors
Factors F9, F10 and F11 involve the interaction between the individual and ICT technical characteristics. However, Factor F9 has the opposite relationship to factors F10 and F11. For example, CsA and CsC show a high positive feeling towards ICT, and a low negative perception of ICT and frustration with ICT use. Therefore, these factors may be grouped together to explain a composite feeling or perception of ICT use.

The “personal development and technical support” factor (F1) was found to be essential in the adoption of ICT by the individual. Training can develop an understanding of ICT before the individual starts to use it in their work while technical support can assist ICT users during their work. In these three case studies most participants received training. The ICT implementer who was assigned by the organisation to help users during their ICT use also supported them.

It was mentioned that those people conducting training courses should be aware of the computer user’s background. Therefore, “personal characteristics” factor (F3), such as basic computer skills, commitment to ICT use, and enjoyment of learning could assist in the ICT application adoption. Also, users might need time to familiarise themselves with the ICT applications if they have no prior computer skills.

Finally, these three cases indicate a high level of “colleague help” factor (F8). Most participants sought help from their colleagues when they encountered problems while using ICT applications. However, help from colleagues may be limited by their colleagues’ computer knowledge, background and available time to assist them. This could be explained by the three case studies with a medium level of “open discussion environment” factor (F6) to improve ICT use.

5. Discussions and implications

5.1 The ICT diffusion case study

Study of ICT diffusion can be analysed at the organisational or construction project level. The first level is focused mainly on how the organisation develops an ICT initiative. The second level emphasises, via projects, the process of ICT diffusion through the organisation. It became evident that senior management and IT support staff drove the ICT initiatives at the organisational level for all three case studies. However, groups at both the organisation and construction project level shared the perception that using internet technology as a communication tool in their construction processes is of pivotal importance. In addition, the ICT initiative also depends on the combination of Internet access availability and a need for business process integration. Therefore, ICT diffusion in these case studies could be seen as demonstrating both a technology push strategy and demand pull strategy. The adoption of ICT mainly starts in larger construction organisations. Small- to medium-sized construction organisations seem risk averse regarding IT investment, due to their perceived budget constraints.

Although the development of ICT is mainly initiated from top management and IT department personnel, the final ICT adoption decision is still dependent on project managers who have the main responsibility for completing the construction projects. In some projects, project managers did not adopt ICT applications because they did not see any clear benefits in doing so. Unclear benefits of ICT use may impede a commitment to the ICT adoption decision.

After the decision was made to use ICT at the project level, the next part of the diffusion process required the support of an implementer and/or IT staff. Two of the
three case studies showed the organisations had committed an IT person to the role of promoting, training and supporting ICT use on construction sites. This person also has the role of promoting ICT use among project managers and other anticipated ICT users. The details of factors influencing ICT diffusion are discussed in the following section.

5.2 The perceived presence of factors influencing ICT diffusion

Findings from the ICT diffusion case studies within three construction organisations can be categorised into two groups of factors: intra-organisational and inter-organisational. Intra-organisational factors are focused on factors involved within the organisation such as management issues, individual issues, technical issues and workplace environment issues. Inter-organisational factors are focused on the ICT use issues of dealing with externally linked project team supply chain members – consultants, sub-contractors, and suppliers. These issues concerned ICT ownership and standards, information overload, and team commitment to ICT use.

5.2.1 Intra-organisational factors

5.2.1.1 Management issues. Three main management issues include professional/technical development support, supervisor and organisational support, and reward systems. Training and development helps ICT users understand the basics of an application to get them starting to use it. This will start diffusion through the organisation, especially for users who have low-level background knowledge in the ICT application’s use. In addition, training and development is a channel that passes ICT know-how to users throughout the organisation. Knowledge was transferred in a one-to-many mode. Therefore, we argue that training used in parallel with technical support from a help-desk or IT department resources is an effective approach for building diffusion by increasing the number of ICT users. Help desk support plays an essential part in helping ICT diffusion because it encourages ICT users to continue using an application once it has been introduced for supporting their work processes – even though they may encounter problems during its use. When users encounter ICT application problems and they cannot find help to fix they often lose motivation and eventually avoid using that application.

The second management issues factor is supervisor and organisational support. Our findings indicate that ICT application diffusion is strongly influenced by supervisor and organisational support behaviours. One example of this was of a traditional project manager who rarely if ever used ICT groupware and seemed to prefer to use the phone and fax rather than e-mail to communicate with his colleagues despite the organisation providing him with the necessary physical resources such as a computer and internet connection. This situation could lead to low motivation among subordinates using the ICT application because the supervisor did not provide a positive role model. We also found a few project managers who have limited basic ICT skills but they nevertheless attempted to encourage, where possible, to jointly solve problems and share knowledge with subordinates. The above examples suggest that there is a clear relationship between ICT diffusion and supervisor and organisational support through the intermediary factor of motivation to use ICT.

The third factor involving management issues is a supporting reward system. A reward system can be divided into two parts: tangible rewards and intangible rewards. Tangible rewards include material benefits that ICT users can receive if they apply the
ICT application in their work processes. Intangible rewards relate to a positive emotional experience without accompanying physical rewards for the user when they use the application. Our interview results implied that tangible rewards were believed to be unnecessary for ICT diffusion, whereas intangible rewards through self-fulfilment have a minor influence on ICT diffusion. We suspect from the interviews, that senior management consider tangible reward systems a poorly addressed issue, too complicated to tackle, because of difficulty in assessing links between achieved individual/group productivity and ICT use.

5.2.1.2 Individual issues. Individual participant behaviour is a core element of ICT diffusion because it is the individual ICT user that ultimately bears responsibility for enhancing work processes through applying ICT tools. Without users' adoption of the ICT application, diffusion within the organisation cannot occur. The conceptual model, generated in phase 1 of the research (Peansupap et al., 2003) indicates individuals influence ICT diffusion in three ways:

1. Through clear benefits of ICT use.
2. The individual's ICT knowledge characteristics.
3. Their having a positive perception of ICT.

Clear benefit of use, however, might also be dependent on an individual’s characteristics such as their ICT experience and skill. Individuals' initial experience of an ICT application is important because they may not immediately recognise benefits they are gaining from its initial use. This is why previous beneficial experiences of other ICT applications that have provided positive recognisable benefits is so important because this positive experience is likely to facilitate ICT users to more quickly understand the benefits to be derived from any new ICT applications and thus developing confidence in, and a positive perception of, ICT in general.

Individuals' characteristics include their individual skills and learning capability. One element of an individual’s skill is their capacity to apply general ICT applications to their personal work. People may have various ICT use requirements at different times in using these applications for their work. Those who are capable of applying it to their work processes may have used similar technologies and are thus computer-literate. For example the Microsoft Office suite has many common user interfaces – learning one application assists users to anticipate how to use any related applications. As a result, individual skill and learning capability could affect ICT diffusion through the way that this motivates and maintains their interest in using ICT applications.

5.2.1.3 Technological issues. The influence of technology on ICT diffusion could be addressed at three levels:

1. Individual.
2. Management.

Individuals use the technology, management allocate resources and the work environment may present enablers (if it is supportive) or barriers (if either the technology fails to deliver expected results or if people create a hostile environment for technology use). Software and hardware jointly influence ICT application characteristics. We argue that technological characteristics that should be
considered to support ICT diffusion are hardware/software functionality, simplicity, reliability, speed, and accessibility. These characteristics influence ICT diffusion in the following ways:

- functionality, if it works it helps to motivate people to use and adopt it;
- simplicity, users need to put in less effort to understand and use the ICT application;
- reliability, the application is stable during use and does what is expected of it;
- adequacy of processing data and transferring speed, this is essential because ICT is designed to deliver immediate interactive communication, therefore, transfer rates must be very fast; and
- user accessibility, this relates to ICT applications being readily available through web-based Internet access using user-friendly standard browsers or other user-interfaces.

5.2.1.4 Workplace environmental issues. The workplace environmental influences the context of ICT diffusion. The term “environment” in this study refers to the level of open discussion and collegial help in the workplace – this can be expressed by physical facilities or in virtual communities. This environment provides an important support to the novice user and also increases the diffusion of workgroups using an ICT application.

It is important to differentiate between an open discussion environment and a helping environment. Generally, an open discussion environment will encourage the user to openly discuss their problems that is free from recrimination. This allows the user to ask for an opinion on how to use or improve the use of the ICT application and for a dialogue to take place between colleagues to jointly solve problems – a willingness to help. User working in a closed discussion environment would be reluctant to discuss ICT application problems and this could create hidden ICT diffusion barriers. Unresolved hidden problems may develop negative feelings in users towards ICT applications. In a helping environment there is a capability to help – not just being able to, but also having time, space and freedom from work pressures to do so.

5.2.2 Inter-organisational factors

5.2.2.1 Ownership and standard of ICT. From the supply chain’s viewpoint, the issue of ICT application ownership may influence ICT diffusion into an organisation. Introduction of ICT at the project level may introduce problems created by different project participants having incompatible ICT applications. This is because it may necessitate entering data and information into multiple ICT systems resulting in a waste of time. Therefore, the development of ICT should be based on an information exchange standard such as STEP, IFC, and XML). A standard will help different ICT systems communicate and exchange information between organisations giving each organisation the independence to develop their own internal ICT system to suit their own business requirement whilst also communicating and transferring information among other ICT systems.

5.2.2.2 Information overload. Of the many documents that flow during the construction project life cycle, information may be sent to persons who may not be
involved with or partially interested in the issues. Our data suggests that criticism of
information overload was based upon problems for users in managing and searching
for information. The establishment of a communication chart (similar to an
organisation chart) may help to reduce information overload. This chart could help
users contact only the appropriate person involved in specific issues. Another method
for solving this problem is to design an ICT application that can control the level of
information involvement such as direct message (To:) or copy carbon message (Cc).
This can help recipients to identify or filter the relevant e-mail to them.

5.2.2.3 Commitment to using ICT. Conceptually, ICT was designed to help
communication and coordination within and between project teams. The effective use
of ICT needs commitment from all project participants, otherwise, organisations that
communicate electronically through ICT would need to send the documents in a paper
format to those organisation that did not use ICT. The data suggests that long-term
relationships between principal and subcontract organisations might affect the use of
ICT. A qualified subcontractor with prior ICT history may get preferential
consideration by the principal contractor. In one case study, the architectural
company adopted the principal contractor’s ICT in order to foster a long-term
relationship despite having their own ICT.

6. Conclusion
Phase 2 research results of the study relating to the diffusion of ICT within three main
construction contractors supports the validity of 11 key factors developed in the survey
undertaken in phase 1. These factors comprised people, management, individual and
technology groupings. The three case studies shared very similar experiences with the
driving forces and barriers to ICT diffusion and this study revealed a rich vein of
comment and feedback on how identified drivers and inhibitors of ICT diffusion
operate in practice.

These issues are particular and specific to those interviewed from the companies,
yet it can be reasonably assumed that these issues and concerns are generalisable.
Many of those highlighted in this study relate to workplace culture and a supportive
management that ensures that adequate technical resources are made available.

The extensive discussion and implications section of this paper highlights the
centrality of human relations. It is clear that people diffuse ICT innovation and they
must feel motivated to do so. This introduces the importance of support mechanisms
that include not only technical solutions such as superior hardware and software
operational features, but also software support that is championed by supervisors who
behave as role models. An important insight, uncovered by the research was the
importance of an open discussion environment and organisational culture. This was
important because it highlights the value of encouraging experimentation and learning
from difficulties and mistakes, people feeling safe to ask for help and their colleagues
being inclined to respond by helping. Fostering a supportive workplace environment is
highlighted as an important lesson to be learned from results reported upon in this
paper.

7. Further research
This paper focuses on factors affecting the ICT diffusion within three large Australian
construction contractors. From the case study, we found that the 11 influencing ICT
diffusion factors are dynamically inter-related, however, we were unable to explore this aspect more fully. While this issue is both interesting and relevant, it was considered beyond the scope of this paper. It is, however, addressed in one of the author’s (uncompleted) PhD work. While the study concentrated upon ICT diffusion among a representative group of major construction organisations in Australia, similar studies could be undertaken as a longitudinal study of the next tier of construction companies that are just beginning to grapple with ICT to see if these organisations follow similar experiences. Also, the whole issue ICT diffusion through the supply chain provides fertile ground for further research.

Note
1. An equipment malfunction inhibited recording all interviews but copious notes were also taken for reference and analysis.

References


