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INFORMATION COMMUNICATION TECHNOLOGY (ICT) IMPLEMENTATION CONSTRAINTS: A CONSTRUCTION INDUSTRY PERSPECTIVE

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ABSTRACT

Purpose: The purpose of this paper is to report upon research undertaken on deployment of information communication technology (ICT) diffusion initiatives in the Australian construction industry. It explains how innovation implementation drivers and barriers facilitate diffusion at the organisational, group and individual levels.

Design/Methodology/Approach: Data from two web-based document management case studies and one Intranet document management system case study are used to analyse ICT diffusion dynamics within three large information technology (IT) literate Australian construction firms. The sample was purposefully limited to large IT-literate construction contracting organisations with a need to use ICT for their operational effectiveness.

Findings: Constraints at the personal level include limited budget for ICT investment, commitment from other project participants, issues of ICT standardisation, and security problems. At the organisational level, constraints include basic levels computer experience, time available to learn, and the identification of clear benefits of ICT use. Constraints at the group level include time available to share information, quality of personal contact and geographical distance.

Research limitations: The sample was purposefully limited to large IT-literate construction contracting organisations with a need to use ICT for their operational effectiveness.

Practical Implications: The driver and barrier models presented indicate that ICT innovation implementation requires intense management interventions to facilitate a supportive workplace environment that strongly links personal and organisational resource investment with demonstrated outcome benefits.

Originality/Value : This study provides rich insights of the dynamics of ICT innovation implementation. Few studies in the literature have provided such insights that link the organisational, group and individual levels.

Keywords: IT management, innovation diffusion and implementation constraints.
(6,904 words)

INTRODUCTION

Several recent studies related to information communication technology (ICT) implementation frameworks have identified key ICT implementation drivers and barriers that are useful in providing a strategic view of its success in the construction industry (CI). These studies explored barriers to ICT use and adoption at the CI level. Common highlighted barriers include low ICT literacy and investment levels (Tucker, Mohamed and Ambrose, 1999; Love, Irani, Li, Cheng and Tse, 2001).

One recent study of 134 architectural, engineering and construction professionals identified IT implementation barriers and coping strategies at the industry, organisation, and project level (Stewart, Mohamed and Marosszeky, 2004). Review of the literature however, reveals that few empirical construction studies explain ICT implementation constraints from an innovation diffusion perspective at the organisation, workgroup and individual level (Peansupap and Walker, 2005d). One recently completed study (Peansupap, 2004) differs from previous IT innovation research in two important ways. First, organisation-wide ICT diffusion (such as groupware or intranet applications) is assumed to differ from stand-alone ICT innovation (such as CAD systems or non-integrated project planning and scheduling). This is because organisation-wide ICT innovation requires a commitment from a greater number of users than does IT innovation focused upon individual stand-alone

ICT applications. Second, the research reported upon here focuses on micro level ICT innovation diffusion within an organisation. This study identifies ICT implementation constraints from the diffusion perspective to improve understanding of the importance of ICT implementation.

The paper is structured as follows. The innovation context is briefly described to clarify the focus of this paper. The research approach is then presented. Findings of factors affecting ICT diffusion have been previously published (Peansupap and Walker, 2005a; Peansupap and Walker, 2005c), however the research study revealed useful insights into the way that implementation constraints influenced ICT adoption, implementation and diffusion are inhibited. The constraint models of ICT diffusion section presents casual loop diagrams (Senge, 1990) that are used to explain these common ICT diffusion constraints. This is followed by discussion of the presented constraint models. Finally, conclusions and limitations of the research are presented.

THE INNOVATION CONTEXT

ICT innovation refers to the introduction of new ICT initiatives to an organisation. The organisational process of introducing ICT initiatives for adoption by expected users is defined as *ICT diffusion* with an *ICT diffusion constraint* being defined as resistance to change drivers occurring during ICT adoption and implementation. Resistance may occur at the organisational, group and personal level. Understanding diffusion constraints could help construction firms manage improve their ICT diffusion processes by focusing on possible ICT implementation diffusion barriers and finding ways to mitigate them. Stewart *et al* (2004) offered coping strategies to mitigate identified barriers. This paper presents a set of models that, based on three Australian case studies, graphically illustrates the constraints that affected ICT diffusion in the studied sample of construction contractors.

IT innovation may be adopted by specific groups of users within an organisation. For example, use of computer aided design (CAD) by architects or estimating software used by engineers is often implemented as a stand-alone non-system integrated initiative where only a small group of expert users participate in the initiative. A firm may independently operate small-group IT innovation such as planning and

scheduling applications whereas a groupware ICT innovation needs cooperation both within a group to share and exchange data and information as well as with external project team and supply chain members. Successful company-wide construction firm ICT initiatives, such as introducing groupware applications, needs team adoption by project managers, engineers and foremen etc. There may also be need to include organisation-external project participants such as designers, consultants and owners.

Innovation diffusion can be described in either technology transfer or intra-organisational innovation adoption terms. The technology transfer perspective can involve transferring innovation information from a research and development (R&D) unit to a targeted consumer unit—individual or organisational (Scheirer, 1983). Thus, innovation diffusion usually begins before any adoption decision is made. It requires delivering positive information about an innovation to expected adopters to hasten their innovation adoption. The more persuasive the information delivered to expected adopters, the higher will be the adoption rate. ‘Innovation diffusion’ from the intra-organisational innovation adoption perspective usually occurs when top management and/or a champion (top-down approach) or expert groups within the organisation (bottom-up approach) decide to adopt an innovation and encourage other users to adopt the innovation (Yetton, Johnston and Craig, 1994). The three organisations studied in the research reported upon in this paper focused their innovation diffusion on both the initial adoption and actual implementation stages.

As diffusion of innovation deals with numerous variables, both of a technological and social nature, it is essential that organisations should provide adequate management support and monitoring of diffusion innovation (Livari, 1993; Rogers, 2003). Songer, Young and Davis (2001) argue that corporate culture is mainly responsible for poor implementation of information technology (IT) systems rather than technology issues. Implementation needs to be managed and structured because it is a critical process in successful ICT innovation diffusion (Griffith, Zammuto and Aiman-Smith, 1999). Carlopio (1998) proposes a workplace environment innovation diffusion framework by adopting the Rogers (1995) diffusion innovation concept and extending this beyond the organisational level to individual and group levels.

RESEARCH APPROACH

The present study was part of a broader one that included quantitative research involving a survey of 113 participants. Detailed discussion of this work is beyond the scope of this paper and interested readers may refer elsewhere (Peansupap and Walker, 2005c; Peansupap and Walker, 2005b). Whereas quantitative research is useful for indicating what may be happening, and may provide statistical evidence that supports developing or validating theories of causality, it does not provide the rich contextual data that helps us develop a deeper understanding of a studied phenomenon (Burton and Steane, 2004). Case study research enables the researcher to more effectively discover the context of a situation and therefore gain a deeper understanding of the studied phenomenon (Yin, 1994). The quantitative survey provided a useful guide for raising questions of case study participants to identify factors influencing ICT diffusion within their construction organisations and for these participants to explain how these factors influenced the ICT diffusion process.

Case study qualitative research can be grouped into three broad categories: exploratory, descriptive, and explanatory (Neuman and Kreuger, 2003). A descriptive case study approach was chosen to obtain rich information from the participant's viewpoint using multiple sources of data but the scope of it moved beyond that through interaction of the quantitative study results and detailed study of the literature to provide explanatory data. The research aim was to develop a model that helped us to better understand the dynamics of the constraints of what was happening to inhibit ICT diffusion as well as how and why it followed a particular trajectory (Yin, 1994). The literature provide some guidance on how causal loops could be derived (Senge, Kleiner, Roberts, Roth and Smith, 1999) from the data gathered that was in turn rooted in the results from the quantitative study (Peansupap and Walker, 2005c; Peansupap and Walker, 2005b).

Many studies have identified various factors influencing ICT implementation but few can adequately explain how these ICT diffusion constraints operate within construction firms. Also, many case studies fail to adequately describe innovation attributes (such as the type of innovation, characteristics of the units of analysis etc)

that allows comparison between studies (Wolfe, 1994, p406). Characteristics of the research are summarised in Table 1.

INSERT TABLE 1 ABOUT HERE

Two of the case studies focused upon a web-based document management system and one case study focused on an Intranet document management system. Each organisation had experience with diffusing IT and general-purpose office management software tools. While users were not immediately familiar with the ICT applications being diffused, they had IT experience. These ICT innovations were mandated by the organisations for use and they became embedded as part of the normal work processes often replacing outdated manual paper-based processes. Innovations were operationally central, of low complexity and packaged within administration routines. The unit of analysis was focussed upon experienced ICT application users and their implementation experiences. Open-ended questions were prompted when needed but topics raised with participants were grounded in theory.

Wolfe (1994, p407) states that diffusion of innovation (DOI) research addresses patterns of how innovation spread throughout a studied group of adopters while organisational innovativeness (OI) addresses the determinants of how innovation occurs—focussed upon the organization. Process theory (PT) addresses the process of innovation and how and why adopters carry out innovation. The innovation process moves through a series of stages classified in various ways. Wolfe (1994, p410) also notes 10 stages: Idea conception, awareness, matching, appraisal, persuasion, adoption decision, implementation, confirmation, routinisation and infusion. Roger (2003, p199) offers 5 stages; knowledge, persuasion, decision, implementation, and confirmation. Another way of viewing this is as two phases. Phase 1 is the initial adoption phase comprising knowledge, persuasion and decision-making. Phase 2 is concerned with the actual implementation of the adopted innovation. The present study was specifically focussed upon PT for the actual implementation stage of the ICT application's deployment.

INSERT TABLE 2 HERE

Data collection began with general discussions with senior IT managers from the three organisations illustrated in Table 2 to understand the strategic adoption of ICT applications at the organisational level. Follow-up interviews of about 45 minutes to one hour were conducted with the ICT implementer or ICT manager involved in the ICT application rollout at the organisation, group or personal level. Any further clarification needed was undertaken by short phone conversations and or email exchanges. Experienced ICT users were requested to discuss their impression of drivers and barriers influencing their adoption and use of ICT application. Casual loop diagrams (Senge *et al.*, 1999; Walker, 2003) were used to analyse and explain the constraints that occur at the organisational, individual and group levels. Seminar feedback validated the analysis and stimulated further debate. The researchers undertook a one-hour plus seminar with each organisation to validate the models presented in this paper. This allowed discussion and feedback with more than half of the participants. Staff changes and other unavailability issues meant that not all participants could attend but most participants were contacted for individual feedback. Further, the individual-organisation seminars included several other interested staff and the researchers also presented the findings at two industry seminars as well as presenting the findings at more than five peer-reviewed academic conferences.

Each organisation has a specific culture that causes inconsistent innovation diffusion outcomes so it is difficult to generalise from only one innovation diffusion case study. However, a general understanding can emerge from each individual case study by improving identification of patterns that eventually stabilise into a general theory. The general response from the individual organisation seminars, the industry seminars and the academic conferences indicated that the models are robust. The overwhelming nature of the feedback at one additional seminar (attended by 100+ professionals from the project management institute not connected with this research but predominately being IT project managers) was that the models could be more generally applicable. The nature of feedback could be said to anecdotally endorse the perceived more generalised applicability of the models, while generalisation is yet to be proved, the models do concur with the Senge *et al* (1999) change management models.

RESULTS: CONSTRAINT MODELS OF ICT DIFFUSION

ICT Diffusion Constraints at the Organisational Level (C1)

FIGURE 1 HERE

Figure 1 illustrates the driver and restraining forces acting upon the ICT diffusion initiative at the organisational level during the initial adoption phase. The dashed line indicates the construction organisation's boundary where ICT is adopted and diffused.

The ICT initiative initial adoption driver cycle is triggered by the firm's policy on how to grow core ICT competencies. A champion will emerge with varying degrees of enthusiasm and influence within the organisation. Key technological gatekeepers in the organisation introduce knowledge to potential ICT users. They also filter messages about their impression of the way that proposed or committed levels of ICT resources and the ICT diffusion process might influence perceived business results. An ICT initiative investment decision is then made and the actual adoption phase of the initiative proceeds. The organisation adopts and implements the initiative resulting in business results (outcomes) from that innovation's adoption.

The supportive cycle 'S1' summarises the influence driver of this model. A company's vision and policy has a direct influence on strategic ICT adoption and implementation within a construction organisation. The company's vision functions as a long-term strategic objective of ICT adoption while the company's policy enhances ICT implementation by determining the framework for employee behaviour. Top management support has a key role in the ICT adoption decision because this support is essential for development of infrastructure and people for ICT adoption within the organisation (Christensen and Walker, 2004). Top management, who commit to the ICT adoption, allocate resources. Thus, to obtain adequate funding, it is necessary to provide clear potential benefits of the ICT investment to gain senior management commitment. A technology champion will also influence ICT diffusion at the organisational level. This champion is considered as the source of ICT information to be disseminated throughout the organisation (Maidique, 1980). The firm should develop people's knowledge of how to effectively apply ICT to support their work practices because successful ICT use and adoption appears to be a key motivator.

Without effective ICT adoption by expected users, the firm cannot gain full benefit from its ICT investment. Sharing and building internal group knowledge (both of how the ICT initiative technically works and how it is applied to enhance construction practice) can facilitate ICT diffusion because it can ensure that ICT will be effectively used (Storck and Hill, 2000). The company should develop a knowledge network with professional institutions and/or university academics to be able to maintain additional channels of advice and support (Gann, 2001). This information network can be an essential part of the innovation diffusion process for the company because ICT information can be effectively transferred from the industry/professional level to the organisational level (Maqsood, Finegan and Walker, 2003).

Although the organisation attempts to encourage ICT diffusion during the initial ICT adoption phase, constraining barriers inhibit the driving cycle's momentum. These constraints can be linked to three main gaps, as indicated in the more heavily shaded ellipses in Figure 1: (a) ICT investment decision, (b) organisational adoption, and (c) business result/outcome.

The first gap is a lack of technology awareness that influences ICT investment decisions. Senior IT managers from all three cases stated that some senior managers were unaware of key potential ICT innovation benefits. Lack of technology awareness may also obscure the ICT investment opportunity. This is because knowledge about a construction process (such as estimating or cost control) may be limited to more conventional/traditional methods rather than how ICT may be used to effectively re-engineer these processes.

Technology immaturity may cause investment reluctance. CC's senior IT manager believed that ICT groupware applications were undeveloped but decided to adopt one of the many available documentation sharing ICT portals instead of developing an in-house solution. He feared that development of in-house ICT applications might lead to incompatibility with a planned future system that could become an industry standard. Integrating immature technology with potentially incompatible legacy systems can be resources-hungry and could introduce significant investment risks.

The complex nature of the construction environment may influence the ICT investment decision. For example, CB's IT developer observed that the construction industry is conservative and slow to adopt most new technologies. CA's IT senior manager believed that the construction industry culture is a key ICT constraint on investment because subcontractors and smaller-scale suppliers find it hard to adapt to ICT innovation in their way of working with contractors. This needs commitment from many supply chain project participants to fully realise integrated benefits of e-commerce and extranet technologies. In addition to the people and construction culture barriers, the complex process of construction requires many different supply chain partners of different organisational size and sophistication. Each partner often uses their own documentation processing standards. ICT investment decisions could benefit from an industrial standard. However, as noted by the CC IT manager, while several ICT construction e-business applications have been recently developed there is no current standard platform for the Australian construction industry.

Both in CA and CB, the reason for adopting in-house ICT development was a lack of suitable current commercial ICT applications for their organisation. Immature technology can lead to incomplete ICT functions, thus technological benefits that do not fit with the organisation's needs have a similar negative impact. Functions or benefits that fail to adequately fit technology within construction organisations may obstruct an investment decision because ICT adoption should support construction work processes and therefore gain benefits from the investment. To function optimally, a groupware application may require high Internet bandwidth access for all sites regardless of the suitability of using this technology on small projects where the ICT infrastructure establishing costs could be uneconomical.

Senior IT managers agreed that financial considerations pose a major ICT investment decision constraint. This caused decision delays, particularly if the organisation decided to develop its own ICT technology. An ICT investment needs senior management commitment to provide the necessary budget and support, hardware, operational training, and maintenance.

The second gap is associated with a senior managers' lack of experience in ICT adoption when introducing ICT applications into an organisation. This can also lead to

user resistance. Lack of confidence in ICT implementation strategies and user resistance appears to be linked. For example, CC's IT implementer, observed that while a previous adoption of an ICT system had been unsuccessfully piloted, it had been complex and users felt uncomfortable with it. Uncertainty and complexity can also cause lack of confidence in the users' perception of the value or effectiveness of an ICT application and this perceived risk exposure could trigger user resistance.

The third gap is failing to gain expected business results. To obtain investment support from top management, the IT department or the implementer often presents an ideal preferred outcome benefit of an ICT investment (Griffith *et al.*, 1999). This evaluation may be based on a software vendor or consultant recommendation.

Unexpected business result gaps may result from information about benefits or potential barriers not being based on organisational reality. This can happen because:

1. Of a misunderstanding of the organisation's true level of ICT readiness;
2. Of not understanding the business processes that the organisation employs or the relationship between these processes; or
3. It may be a result of misrepresenting potential benefits that are unlikely to be actually realised.

Thus, evaluation of ICT benefits should be truly concerned with the organisational context. In practice, it is difficult to estimate all benefits from the ICT investment, especially if the organisation has had no prior significant ICT experience with which to draw upon (Duyshart, Mohamed, Hampson and Walker, 2003).

Trial ICT pilot projects and organisational learning provide opportunities to minimise unrealistic ICT benefit estimates. However, ICT application success on one project may not guarantee success in another (Songer *et al.*, 2001). Understanding a pilot project's characteristics will better help IT managers plan ICT investments.

An ICT application that theoretically should deliver benefit but fails to do so may be due to several causes:

1. The external business climate may change so that the ICT application becomes a competitive 'norm';
2. Technological change may overtake any likely competitive advantage prevalent in the ICT industry where rapid advances and application

redundancy quickly undermine the organisation's decision making and implementation processes; and

3. A potential competitive advantage (cost or through service differentiation) may not be effectively capitalised upon by the organisation due to mismanagement.

ICT Diffusion Constraints at the Individual Level (C2)

Figure 2 illustrates ICT diffusion drivers and constraints at the individual level. The dashed line in the diagram shows the people boundary within an organisation.

Generally, after an organisation has decided to adopt an ICT innovation, the focus of its staff members shifts from an ICT application acquisition or development decision issue to encouraging that application's use. Two processes should take place after an ICT application decision has been made. There should be an ICT implementation process for providing personal learning and both technical and organisational support should be concurrently instigated. Case study data suggests that S2, the key driving cycle at the personal level, included training, adequate technical support and senior management support.

FIGURE 2 HERE

Learning and training content, coupled with delivery quality, may be important constraint issues. Providing only basic training provides a rudimentary understanding of ICT concepts, benefits, and know-how. This can lead to ICT trainers only focusing on the technical context (such as menus, functions, interfaces) leaving little time for users to learn how to apply the ICT innovation in their work processes. Overemphasis on an ICT application's technical aspects may result in application users getting lost in their training session, leaving them with a negative experience or poor perception of potential derived benefits. Further, the adopted training approach may provide little time for reflection and making sense of the ICT application. This can inhibit the ICT user's motivation to value the application. Management pressure for ICT users to carry out their normal work and simultaneously absorb new ways of doing it (without expectations of any temporary drop in effectiveness while new patterns of working are mastered) can inhibit ICT adoption.

Most case study construction staff experienced limited personal technology support from a technical support team. Technical support did, however, include ICT users' helping each other through one-to-one coaching as well as occasional personal support from a dedicated ICT support person. Users need an effective support system to help them solve technical problems that range from how to get hardware to work, to how to finesse their use of software applications. Without this help, personal learning gaps may develop. Eventually, as the help gap widens, users give up using the ICT application and develop a negative perceptions toward its use. Technical support constraints can also stem from poor remote access or help desk response deficiencies. As a help desk normally operates via phone or electronic mail, remote distance problems may be limited to a few cases; however, some users prefer to have 'hands on' assistance to solve any ICT application problems. Remote distance problems will probably diminish as development of effective virtual networks increases. Project managers may become too involved in their own work routines and provide little 'spare' time to mentor and encourage ICT users. Experienced project managers generally have limited ICT knowledge themselves if their experience was shaped before ICT became integral to current management practice.

Case study results indicated that some project managers perceived using ICT as an unproven project risk and did not significantly promote it. Technology investment may also be constrained by senior management's lack of confidence in real benefits being realisable, resulting in a lack of senior management support. Senior managers can impose great pressure on ICT users to 'get on with their job' and either inadvertently or deliberately make it difficult for them to finding time to help each other. However, senior managers should recognise the time lags between experimenting with a new ICT application and regaining lost productivity rates while adapting to that innovation. Case study data provided examples of this constraint, though as isolated pockets of management reaction to ICT change.

ICT investment gaps may influence users' adoption outcomes because the investment level delivered may result in technical implementation limitations. ICT hardware performance may be further limited by a bandwidth connection speed and also slowed by hardware modem limitations. ICT investment decisions should include careful

consideration of transmission speed, interoperability between versions of identical software applications, and reliability of both hardware and software.

An individual's lack of general computer skills can also present a significant limitation to ICT application use. Such lack of basic knowledge may lead to development of negative ICT use perception. Although young staff could already have basic computer skills, this knowledge may become rapidly outdated because of rapid ICT development.

Individual's lack of time to learn how to resolve potential problems can exacerbate individual frustrations with learning new ICT applications. Construction workers are usually occupied with site management work and generally have minimal professional development time to learn new skills. Case study data suggests that foremen in particular, had little time to learn ICT skills and many of them did not have the foundation computer literacy skills that many younger tertiary-educated level staff had obtained. This was a significant problem where only basic computer user training was provided to relatively IT-inexperienced staff and where ICT users were expected to learn how to use complex ICT applications by themselves with little support.

ICT Diffusion Constraints at the Group Level (C3)

Figure 3 illustrates how groups of individuals within an organisation experience barriers to ICT diffusion of groupware applications. Support cycle S3 is based on people being social animals who naturally turn to each other to get help when needed. Thus, while barriers exist as identified at the organisational and personal level, discrete ICT application diffusion barriers also exist for groups.

FIGURE 3 HERE

One group-learning barrier is lack of proximity. Learning by observation was the stated preference because it facilitates understanding and it is helpful to not only watch and learn, but also to pause, reflect, question and receive responses that link cause and effect. This strengthens ICT users' absorptive capacity (Cohen and Levinthal, 1990). Understanding cause-and-effect connections has been cited as a key element of effective knowledge transfer (Szulanski, 2003). Many users preferred the

‘show me how’ rather than a ‘tell me how’ learning approach. Physical distance may cause problems in relation to experts or colleagues sharing their experiences. Some participants who were physically close to colleagues sought help very easily and stated that they just called in or walked into the IT department (or a knowledgeable colleague) and asked for help and received it. Similarly in CC, most of the participants experienced a high level of ICT instruction from the implementation person who was allocated to the construction site. Most of them felt that physical support helped them in ICT use. Technology can deliver a partial virtual solution through online communities of practice (COPs). This approach has been reported to have effectively occurred in the UK on construction projects using a COP management system (Jewell and Walker, 2005).

Most participants request help from a confidant. Personal contact is not limited by physical distance; it may result in responses from past co-workers or others in their knowledge-network contacts.

Most construction workers operate under severe time pressures and lack time to regularly or methodically share ICT experience with collegial communities. In CA, the project manager, who is ICT-experienced, stated that while he always offered the benefit of his ICT experience it was difficult for him to be constantly available to do so because he was always very busy. A project manager in CB reported that people on her construction site were often too busy to share their ICT experience even though they were motivated to do so. In all case studies, evidence supports the notion that the construction industry is particularly ‘lean’ with few slack resources provided to support COPs as recommended by Wenger, McDermott & Snyder (2002).

DISCUSSION

ICT implementation and adoption is a management intensive activity. Figure 1 supports the Griffith *et al.* proposal (1999) that managers should reframe IT implementation expectations, create small wins, and reduce any conflict of interest.

Skibniewski & Abduh (2000) proposes two strategies for adopting ICT—*in-house development* and *outsourcing*, depending upon the level of internal systems and

resources that support the main organisational functions. No matter which strategy is selected, organisations still need to implement their ICT initiatives. To understand ICT implementation, the organisation should adopt a pilot project strategy to learn from experience (Sutton and Lemay, 1999; Whyte, Bouchlaghem and Thorpe, 2002). This could help them understand real benefits and possible constraints that may occur before diffusing the ICT initiative throughout their organisation. A pilot small-scale budget strategy can help the organisation to overcome investment barriers and it help avoid any large cost impact if the ICT implementation fails. It also helps create small wins and potential best practice model to help staff understand investment benefits.

A top management decision to adopt ICT often progresses ICT implementation to the individual and group level. These people are key actors who play a significant role in how ICT diffuses throughout an organisation. The research findings indicate that ICT diffusion success at a micro level requires effective management and planning at both macro and micro levels. The individual level constraint model, Figure 2, focused on the lack of learning and training, insufficient ICT investment to meet users' needs, lack of computer skills, and lack of time to learn (C2a, C2b, C2c). Changing ICT users' way adapting to new things is difficult (Regan and O'Connor, 2000). To alleviate user resistance, organisations should provide enough training and learning time for users.

Cited barriers are attributable to the high cost of investment (Marsh and Finch, 1998; Marsh and Flanagan, 2000; Songer *et al.*, 2001; Stephenson and Blaza, 2001), however, the research reported upon here indicates that sufficient support-centred ICT investment influences users' ICT experience that could otherwise generate negative perceptions towards ICT use. O'Brien (2000) confirmed that lack of technology maturity affects investment cost and reliability and access service quality performance.

While many construction organisations attempt to gain benefits from ICT investment, they may merely obtain partial benefits if few people actually adopt and use it (Koskela and Kazi, 2003). Markus (1987) argues that successful communication technologies adoption requires a 'critical mass' of adopters. Reported research findings addressed group-level user learning and sharing barriers, such as

geographical distance and personal contact. When users adopt ICT, they may require access to help from experience person. User learning and sharing barriers can block the growth number of users and ultimately not achieved the benefit of ICT.

CONCLUSIONS AND LIMITATIONS

Figure 1 constraint loops (C1a, C1b, C1c) illustrate organisational level ICT diffusion constraints. These constraints involve a construction organisation's internal and external environment with issues that may influence the investment decision, the organisation's ICT initiative adoption and resulting business results. Research results indicate constraints at the organisational level (C2a, C2b, C2c) that are limited by the ICT investment budget, commitment from other project participants, issues of ICT standardisation, and security problems. At the personal level, Figure 2 constraints include levels of basic computer experience, time available to learn, and clear benefits of ICT use. Finally, Figure 3 constraints at the group level include time available to share information, qualities of personal contact, and geographical distance (C3a). An understanding of these constraints may help the IT project manager to become more aware of the possible delays of ICT implementation through construction firms.

This paper provides insights into what drives and inhibits effective ICT innovation diffusion at the organisational level for construction firms that already have many IT-literate key employees. While results should not necessarily be generalised to construction organisation with low level of IT or ICT experience, they do provide a useful model of potential pitfalls that may be more broadly considered in a wider context of innovative process adoption. The literature and the case study results suggest that organisations should closely manage their ICT initiative decision making and implementation using pilot studies and a reflective learning approach to maximise advantages from lessons learned. ICT application deployment is primarily about people related issues of effective change management, knowledge transfer and leadership by a champion and adoption team to sell benefits and support users.

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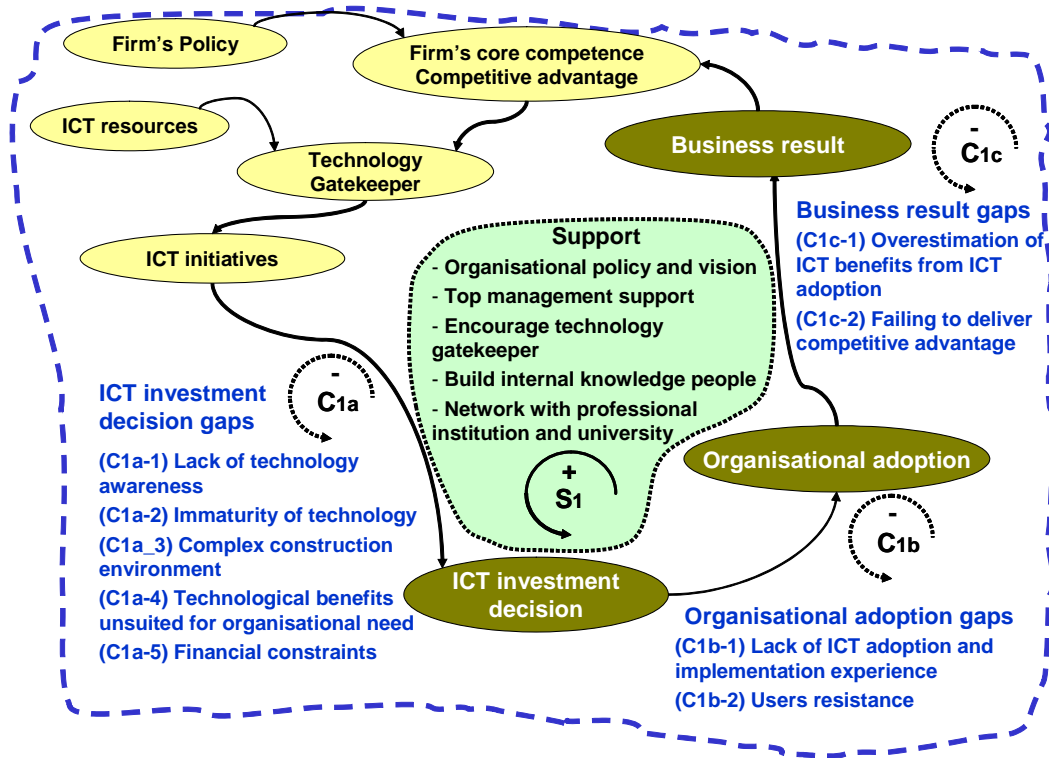


Figure 1- Constraints of ICT diffusion within a construction organisation (organisational loop, C1a, C1b, C1c)

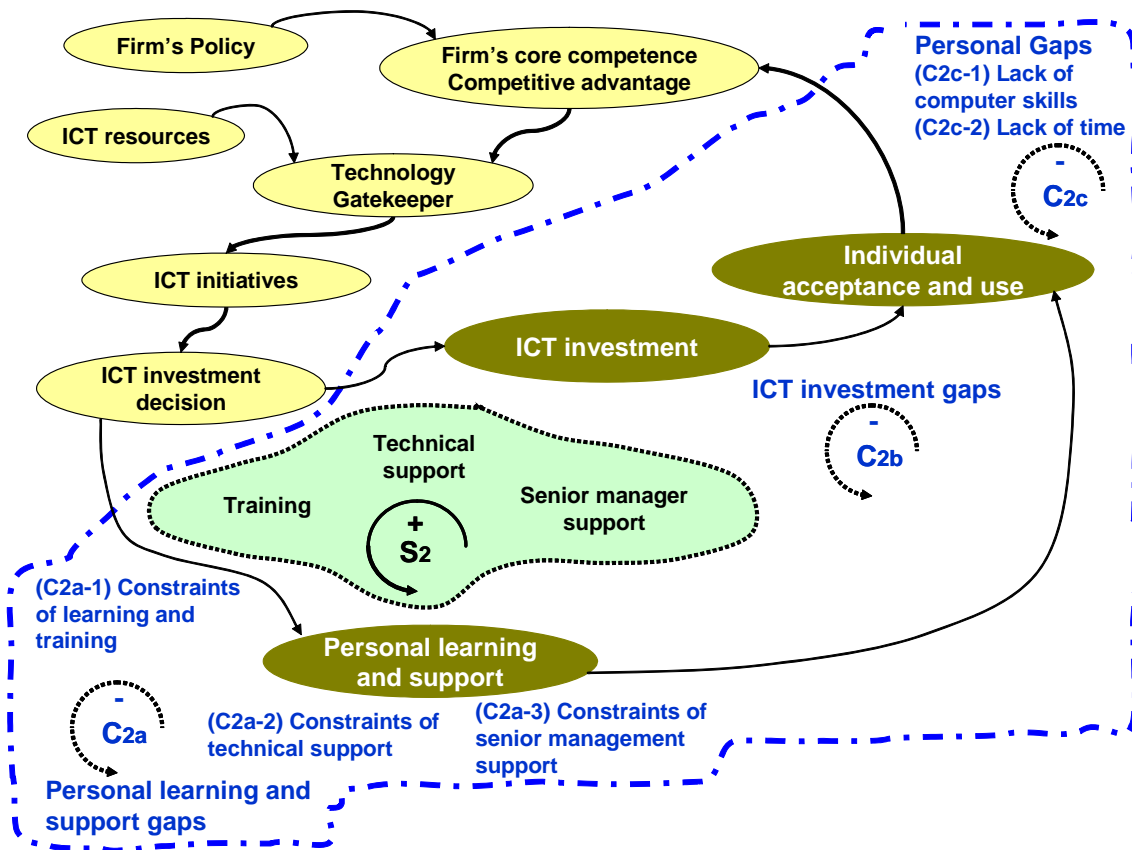


Figure 2 Constraints of ICT diffusion within a construction organisation (individual loop, C2a, C2b, C2c)

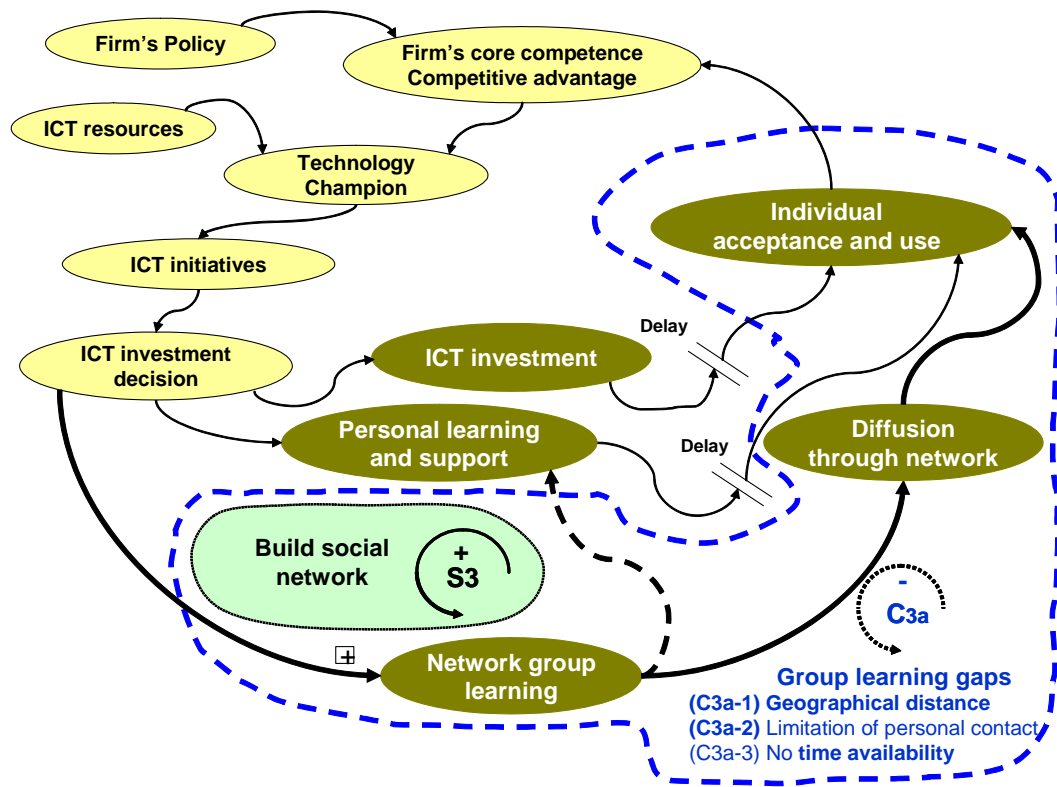


Figure 3 Constraints of ICT diffusion within a construction organisation (network loop, C3a)

Table 1: Summary of three case study Characteristics

Characteristic	Comments
Organisation type	Three of the largest 10 internationally operating Australian construction contractors with an annual turnover of more than A\$500 million.
Innovation type	Introduction of a new process requiring the use and adoption of ICT groupware communications software that changed the way that individuals and groups may communicate with each other and interact in problem solving.
Innovation characteristics	Operationally central, low complexity and packaged within administration routines
Phase of innovation studied	Actual implementation
Unit of analysis	Experienced IT users adapting to a software system that is new to them.
Research type	Case studies using open-ended questions, observation and structured feedback from at least one individual feedback workshop with the majority of participants.
Other validation	Cross-reference to the literature, presentation of findings at two industry forums with a range of Australian construction and generalist project management professionals with feedback on more general findings, 5+ academic conference presentations with subsequent feedback and discussion.

Table 2: Categories of interviewee in the three case studies

Interviewee	Case study		
	CA	CB	CC
It Strategist	1	1	1
Implementer (L1)	1	1	1
Project/Engineering manager (L2)	4	1	1
Site engineer (L3)	1	3	2
Foreman (L4)	1	1	1
Total	8	7	6