CONSTRAINTS ON THE ICT DIFFUSION WITHIN LARGE AUSTRALIAN CONSTRUCTION FIRMS

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ABSTRACT

Many practitioners and academics realise the importance of implementing information and communication technology (ICT) in construction organisations and identify various success factors influencing ICT implementation. However, few of them can adequately explain the barriers that may occur during from initial adoption to actual implementation stages. To fill the above gap, this paper adopts innovation diffusion concept and highlights the constraints of ICT diffusion within large Australian construction firms. Two case studies of web-based document management and one case study of Intranet document management systems are used to support our explanation. Our research results indicate that at the organisational level, these constraints are: a limited ICT investment budget; organisational adoption gaps; and business results gaps. The scope of this paper precludes us from discussing personal level and group level constraints that we have identified. However an understanding of the organisational level constraints may help us become more aware of possible ICT implementation delays at that level and solutions for these constraints are proposed in this paper.

Keywords: IT Implementation, technology diffusion and implementation barriers

INTRODUCTION

Recently, strategic ICT implementation frameworks have been developed to provide a strategic view of its success in the construction industry and several studies identify key drivers and barriers of successful ICT implementation. Previous research studies explore barriers to ICT use and adoption at the construction industrial level. These highlight common barriers such as low levels of ICT literacy and lack of ICT investment [Love et al. (2001); Tucker et al. (1999)]. Some studies have also identified factors influencing the success of strategic ICT implementation at the organisation level [Stewart *et al.* (2002)]. However, few empirical studies explain ICT implementation constraints from an innovation diffusion perspective at the construction company level.

The research reported upon here differs from previous IT innovation research in two ways. First, we make the assumption that organisation-wide ICT diffusion (such as groupware or intranet applications) may differ from stand-alone ICT innovation (such as CAD systems or non-integrated project planning and scheduling). One reason for this is that organisation-wide ICT innovation requires a commitment from a greater number of

users than IT innovation focused in individual stand-alone ICT applications—the greater the number of users the greater the potential benefits of ICT innovation. Thus, the organisation that expects to obtain realisable benefits from its ICT investment needs to ensure that users adopt and use ICT applications. Second, the research focuses on ICT implementation from the ICT innovation diffusion perspective at the micro level of ICT implementation within an organisation.

Before going into details, it is essential to answer why innovation diffusion is useful in explaining ICT implementation. ICT implementation is a complex rather than simple task involving both technical and social issues. Many practitioners believed that ICT failures occur because of technical issues rather than social issues. However, [Songer et al. (2001)] argues that corporate culture is one the main implementation barriers to information technology systems rather than technology issues. This supports general innovation diffusion theory where it is held that the major reason for innovation failure is poor implementation. It has also been argued that implementation needs to be managed and structured because it is the critical process in successful ICT innovation diffusion [Green & Hevner (2000)]. Thus, overlooking the importance of ICT initiative implementation may cause ICT failure.

Even though several studies argue that the main cause of ICT implementation failure relates to social issues, many practitioners still neglect the important of social issues in regard to ICT implementation. [Griffith *et al.* (1999)] provide evidence in their study of ten technology projects from a Fortune 300 manufacturing organisation. They found that project managers tend to overlook social issues when developing their innovation initiative project budgets. For example, in five out of ten cases there was no budget allocation for social issues and in another four cases the budget allocation for social issues was only 1%-2%. [Griffith et al. (1999)] also showed that MIS students and MBA students hold different views of allocating ICT budgets. They found that MIS students allocated a larger budget for people development than MBA students who allocated greater amounts for technical development. They reasoned that both replacement of technology and people movement may cause ICT implementation budget allocation problems because people can choose to leave a firm whereas a technology investment remains on its books, thus people investment can be potentially ineffective. People-related ICT implementation support is an internal activity that will often have a lower budget priority compared to investment in technology systems [Griffith *et al.* (1999)]. Thus, an unclear understanding of the implementation process can cause ineffective ICT implementation that may eventually lead to implementation failure.

This paper identifies ICT implementation constraints from the diffusion perspective to improve understanding of the importance of ICT implementation. We define constraints and diffusion terms and then discuss adoption, implementation and diffusion aspects. We then use a casual loop diagram [Senge, P. et al. (1999); Senge, P. M. (1992)] tool to explain common ICT diffusion constraints to highlight interesting issues from the an organisational perspective.

DEFINITION OF TERMS

In this paper, we use the term ICT diffusion *constraint* to refer to *resistance* to drivers of change that occurs in organisations during ICT adoption and implementation. We define ICT *diffusion* as a process where organisations introduce ICT initiatives for adoption by expected users. Resistance may occur at organisational, group and/or personal levels. Therefore, an understanding of constraints could help construction firms manage ICT diffusion by focusing on possible ICT implementation diffusion barriers and finding ways to militate against these problems.

We refer to *innovation* in this paper as the introduction of new ICT initiatives to an organisation. Thus, it is necessary to describe differences between ICT and traditional IT innovation. In general, IT innovation may be adopted by specific groups of users within an organisation. For example, the use of computer aided design (CAD) by architects or estimating software by engineers is often implemented as a stand-alone or non-system integrated initiative whereby a small group of expert users participate in the initiative. On the other hand the success of company-wide ICT innovation initiatives such as groupware applications needs adoption from multiple groups of staff such as project managers, engineers and foremen within a construction organisation. In addition, the adoption of ICT may include organisation-external project participants such as designers, consultants and owners. A firm may operate small-group IT innovation such as planning and scheduling applications independently whereas groupware ICT innovation needs cooperation both within a group to share and exchange data and information to help in managing the construction project as well as with external project team and supply chain members.

Innovation diffusion can be described in either technology transfer or intra-organisational innovation adoption terms. Firstly '*Innovation diffusion*' can be defined from the technology transfer perspective as 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 because it requires delivering positive information about an innovation to expected adopters to hasten the targeted users to adopt the innovation. Thus, the more persuasive the information that is delivered to expected adopters, the higher will be the adoption rate. Secondly, '*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 *et al.* (1994)]. In this research, innovation diffusion focuses on both initial adoption and actual implementation of the innovation.

Different organisations have their own specific process and culture, which in turn causes an inconsistent outcome of innovation diffusion so that it is difficult to generalise any case studies of innovation diffusion with certainty. However, a general understanding can emerge from individual case studies and so the more case studies that can be undertaken, the greater is the chance of patterns being identified that stabilise into something approaching a general theory.

As diffusion of innovation deals with numerous variables, both of a technological and social nature, it could be argued that it is essential that an organisation should provide adequate management support and monitoring of diffusion innovation within the organisation. (Carlopio 1998) proposed an innovation diffusion framework in the workplace environment by adoption of the Rogers diffusion of innovation concept to extend the model to an individual/group level. His framework indicates that the diffusion of innovation may occur at both organisational and individual/group level. While our research analyses innovation diffusion constraints at the organisational, individual, and group levels, we are limited by the scope of this paper to report only upon the organisational level.

RESEARCH METHODOLOGY AND ANALYSIS

This paper focuses on the qualitative data analysis on constraints that occurs during ICT diffusion within three contractors' organisations from the top ten Australian construction contractors with an annual turnover in excess of one billion Australian dollars. These companies are experienced ICT users with a history of decades of ICT initiative deployment ranging from accounting and planning information technology (IT) applications during the 1980s to groupware applications today such as email and intranets. Further details about the contractors can be found elsewhere (Peansupap et al 2003) as the space limit in this paper does not permit us to provide this information. 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)]. Case study qualitative research can be grouped into three broad categories: exploratory, descriptive, and explanatory [Neuman (1997)]. We used quatitative research to identify factors influencing ICT diffusion within construction organisations and explain how they influence the ICT diffusion processes.

Data collection started with discussions with senior IT managers from the three organisations Case study contractor A, B and C to understand the strategic adoption of ICT applications at the organisational level. We followed that up with interviews conducted with the ICT implementer or ICT manager involve in rolling out the ICT application at the organisation, group or individual level. Experienced ICT users were requested to discuss their impression of drivers and barriers influencing their adoption and use of ICT application. Our analysis followed casual loop diagram [Senge, P. et al. (1999); Senge, P. M. (1992)] to explain the constraints that occur at the: organisational level, individual and group levels. Finally, we conducted seminars to feed back and validate our analysis and to stimulation further debate.

ORGANISATIONAL LEVEL ICT DIFFUSION CONSTRAINTS

Many studies have identified various factors influencing ICT implementation but few can adequately explain the ICT diffusion constraints for construction firms. Results from two case studies of web-based document management and one case study of an Intranet document management system are used to support our explanation. These are illustrated in Figure 1 and show that the influencing forces comprise one driving (positive impact)

cycle of organisational support at the organisational level and three barriers (negative impact) that constraint the ICT diffusion initiative.

Figure 1 illustrates the drivers and barrier forces that act upon the diffusion of this ICT initiative at the organisational level during the initial adoption phase. The dashed line indicates the construction organisation's boundary in which ICT is adopted and diffused. Factors that drive the initial adoption of the ICT initiative into the construction organisations start with the firm's policy that relates to the way in which its core ICT competencies will be grown. A champion will emerge with varying degrees of enthusiasm and influence within the organisation. Key people in the organisation will act as gatekeepers who help filter messages about their impression of the ICT diffusion initiative as well as bring additional knowledge to potential ICT users depending upon the level of resources available to them. The ICT initiative investment decision is then made and the adoption of the initiative proceeds and this results in perceptions of the business result of the ICT initiative's deployment.

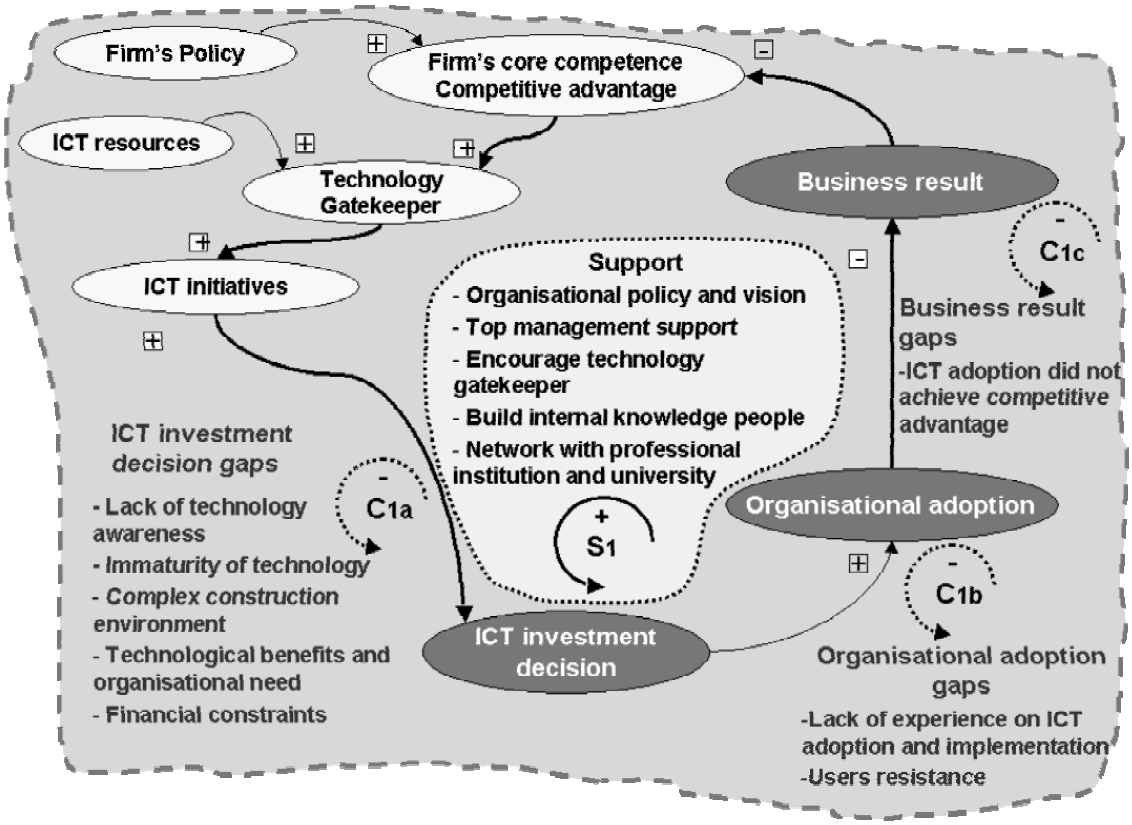

Figure 1. Constraints of ICT diffusion within construction organisation (organisational loops, C1a, C2b, C2c) at the organisational level

The supportive driver influence can be summarised as:

- An effective organisational policy and vision
- Top management support and commitment
- Encouragement of technology champion
- Development of internal knowledge groups

- Development of external networks

Each driver has its own function in influencing ICT diffusion within a construction organisation. Firstly, the company's vision and policy have 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. Secondly, support from top management 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. Without management support, ICT adoption is hard to accomplish. Top management, who commit to the ICT adoption, allocates financial expenditure. Thus, to obtain adequate funding, it is necessary to provide clear potential benefits of the ICT investment to gain commitment from senior management. Thirdly, the technology champion will also influence ICT diffusion at the organisational level as this champion is considered as the source of ICT information to be distributed to employees throughout the organisation. Fourthly, the firm should develop people's knowledge of how to effectively apply ICT to their work practices because successful use and adoption of ICT diffusion is required to support their work processes. Without effective ICT adoption by expected users, the firm cannot gain full benefit from its investment. Thus, sharing and building internal group knowledge (both of how the ICT initiative works technically and how it is applied to enhance construction practice) can facilitate ICT diffusion because it can ensure that ICT will be effectively used. Finally, 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. This networking can increase interlinking with the firm to others with ICT knowledge to feed updated ICT knowledge back into the intra-organisation supply chain network. 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.

Although the organisation attempts to encourage ICT diffusion during the initial ICT adoption phase, some constraining barriers may develop. These constraints can be categorised into three main groups: (a) ICT investment decision gaps, (b) organisational adoption gaps, and (c) business result/outcome gaps.

ICT investment decision gaps, C1a

In Figure 1, the first constraint loop (C1a) illustrates ICT investment decision gaps at the organisational level. These stem from several issues such as: lack of technology awareness; a complex construction environment; immaturity of the technology to be used; unsuited technology for organisation needs; and financial constraints.

Lack of technology awareness

Lack of technology awareness could be one constraint affecting ICT investment decisions. For example, senior information technology (IT) mangers from the three cases mentioned that some senior managers were unaware of some potential ICT innovation

benefits. Lack of technology awareness may also obscure the ICT investment opportunity because knowledge about a construction process (such as estimating or cost control) may be limited to more conventional methods rather than how ICT may be applied to more effectively re-engineer these processes.

Complex construction environment

The nature of the construction environment is complex and this may influence the ICT investment decision. For example, the IT developer in Case B mentioned that the construction industry is slow in its adoption of most new technologies. Many construction people are very conservative in their thinking. Similarly, the IT senior manager in Case A said that the construction industry culture is a key constraint on ICT investment because construction subcontractors and smaller scale suppliers find it hard to change their way of working with contractors, especially in the area of ICT innovation which needs commitment from many other project participants in a supply chain to fully realise the benefits of e-commerce and extranet technologies. In addition to the people and construction culture barriers, the process of construction is also complex requiring many different supply chain partners of different organisational size and sophistication each often using their own documentation processing standards. ICT investment decisions would benefit from an industrial standard. However as noted by the IT manager in Case C, while several ICT construction applications for e-business have been recently developed there is as yet no standard platform for the Australian construction industry. Engineering consultants who have to adopt and use several ICT platforms that are used by different main contractors also made this statement. Thus, ICT investment decisions should be made in the context of constraints that exist in the current construction environment.

Immaturity of technology

Immaturity of technology may cause reluctance to invest. For example, the IT senior manager in Case C mentioned that ICT groupware applications were immature. However, he decided to adopt one of the many available ICT portals for documentation sharing instead of developing an in-house solution that would better integrate with other organisational ICT systems. He commented that the development of in-house ICT might lead to incompatibility with a future system that may become an industry standard. Thus, immature technology may require a lot of resources including technical specialists and hardware and software development for integration with legacy systems that in turn might demand high ICT development investment. This may be the reason why many small-medium construction organisations are slow to adopt ICT innovation. Immaturity of technology, therefore, may be seen as an investment risk because of potential high costs and possible incompatibility.

Unsuitable technology for organisational needs

In both Case A and Case B the reason given for adopting in-house ICT development was that at the time there was no commercial ICT application suitable for their organisation. While immature technology can lead to incomplete ICT functions, technological benefits

that do not fit with the organisation's needs have a similar negative impact but it focuses more on the functions or benefits that fail to adequately fit technology within construction organisations. This constraint may obstruct the investment decision because fundamentally ICT adoption should support construction work processes. Thus, if ICT applications are not supported with organisational work processes, it will be hard for the company to gain benefits from its investment. For example to function optimally a groupware application may require high band width access for all sites regardless of size, this may not suit using this technology on small projects where the cost of establishing the ICT infrastructure may be uneconomical.

Financial constraint

Senior IT managers agreed that financial considerations are a major ICT investment decisions constraint. This can cause ICT investment decision delays. This is especially true if the organisation decides to develop its own ICT technology with a requirement for a lot of people and funding resources. The ICT investment needs commitment from senior management to provide the necessary budget and support. Where there are financial constraints, the investment decision of in-house ICT application should be based on a long-term ICT strategy that allows the organisation to develop ICT in several modules. Furthermore, financial constraints may result in a lack of budget for hardware, operation, training, and maintenance.

Organisational adoption gap, C1b

The second constraint loop (C1b) is the organisational level adoption gap. Lack of ICT adoption implementation experience of senior managers introducing ICT into an organisation and user resistance (possibly as a result of this) may contribute to this gap. There was evidence that there may be a link between lack of confidence and user resistance.

Lack of experience of ICT adoption and implementation

We suggest that adoption of an ICT application might not be a success because of an IT manager's inexperience in ICT adoption and implementation. Lack of experience in ICT adoption and implementation may cause several difficulties in the organisation during ICT adoption. As ICT adoption affects both people and process within the construction organisation, care needs to be taken in its adoption and implementation. The IT implementer in case C mentioned that a previous complex ICT system had been tried as a pilot study on one construction project, but its implementation was found to be unsuccessful because the ICT application had been too complex. The reasons for this complexity were unclear. Thus, inexperience in ICT adoption and implementation may lead to the development of a gap in ICT adoption. This uncertain complexity led to a lack of confidence in the application's value and user resistance.

Business result gap, C1c

The third constraint loop (C1c) at the organisational level is the business result gap. The business result means the actual tangible outcome of the ICT investment though intangible results may be recognised as of value. However, the actual result may not match expected organisation needs and be devalued as a result. The perceived value of a business result may be hindered by an overestimation of expected ICT benefits.

Overestimation of ICT benefits—Did not achieve competitive advantage

To obtain investment support from top management, the IT department or the implementer often presents an ideal preferred outcome benefit of the ICT investment [Griffith et al. (1999)]. This evaluation may be based on a software vender or a consultant recommendation. An unexpected business result gap may result from information not being based on organisational reality. This can happen because of a misunderstanding of the organisation's true level of ICT readiness or of the business processes that it employs or it may be a result of misrepresenting potential benefits unlikely to be actually realised. Thus, evaluation of ICT benefits should be truly concerned with the organisational context. In practice, it may difficult to estimate the benefits from the ICT investment especially if the organisation has had no prior significant experience with ICT. When the only source of ICT benefits may come from a software vender or an IT consultant, this information should be used only as guide for evaluation.

One way to minimise unrealistic estimates of ICT benefits, is for the organisation to trial ICT pilot projects and learn from them. However, it is natural for IT managers to select projects with enough support and resources to be successful [Songer et al. 2001)]. Thus, success of an ICT application in one project may not guarantee success in another. Therefore, an understanding of the pilot project's characteristics will help the IT manager to adjust investment plans of actual ICT investments to reflect reality.

DISCUSSION

Clearly, ICT implementation and adoption is a management intensive activity. Figure 1 illustrates organisation level driver and barrier constraints that govern the success of ICT diffusion initiatives. [Griffith et al. (1999)] propose for example, that managers should reframe expectation of IT implementation, create small wins, and reduce any conflict of interest. We found that our constraint model at the organisational level supports this suggestion because the model provides the possible organisational gaps such as an ICT investment decision gap (C1a), an organisational adoption gap (C1b), and a business result gap (C1c). Therefore, this model could help IT manager to explore the gaps and help to understand the hidden constraints that reflect the actual implementation of a proposed ICT outcome.

[Skibniewski & Abduh (2000)] found that there are 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. Our belief is that no matter which strategy is selected, organisations still need to implement their ICT initiatives. To

understand the ICT implementation, the organisation should adopt a trial, a pilot project strategy to learn from experience [Sutton & Lemay (1999); Whyte et al. (2002)]. First, this strategy could help them understand real benefits and possible constraints that may occur before diffusing the ICT initiative throughout their organisation. Second, a pilot strategy can help the organisation to overcome the investment barriers because a pilot generally requires a small-scale budget. Third, a pilot project can help avoid a large cost impact if the ICT implementation fails. The final advantage of this strategy is help to create small wins and create a best practice model, which helps staff, understand the benefits of the investment.

CONCLUSIONS AND LIMITATIONS

The constraint loops (C_{1a}, C_{1b}, C_{1c}) describe 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. Constraints at the organisational level are different from the constraints at both the individual and group levels. For example, the organisational constraints involve issues relating to an organisational decision adoption that is determined by a senior management group or IT managers whereas the individual/group constraints involve issues relating to operational users who are expected to use ICT. Thus, it is necessary to explore the constraints at both individual and group levels. While we acknowledge the limitation of this paper's scope group and individual level implications are explored in one author's PhD thesis currently under examination.

This paper, based upon research of three sophisticated large construction contracting organisations, provides insights into what drives and inhibits effective ICT innovation diffusion for this class of construction firm at the organisational level. While we do not intend that results should be generalised to other types of construction organisation, they do provide a useful checklist of potential pitfalls that may be more broadly considered in a wider context. 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. This research work formed part of a much wider study and so many of the unanswered issues are unaddressed elsewhere.

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