An Exploratory Approach to the Diffusion of ICT in a Project Environment

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An Exploratory Approach to the Diffusion of ICT in a Project Environment

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DECLARATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

Signed:

Vachara Peansupap
November 2004

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ABSTRACT

Emerging information and communication technology (ICT) introduces opportunities for improving communication to improve many construction processes at each project phase as well as creating new business opportunities. Thus, perceived ICT benefits have motivated numerous construction organisations to adopt and invest in this technology. However, many have found that the ICT investment has failed to meet their expectations. One significant problem is a lack of understanding of how to actually implement ICT into a construction organisation. This may lead to ICT implementation failure or retardation by all users within a construction organisation. In addition, a lack of focus on actual ICT implementation may explain why ICT implementation problems still occur.

This research attempts to fill ICT implementation gaps by focusing on ICT diffusion at the actual implementation stage. The primary objective is to understand the nature of ICT diffusion within a construction organisation. The second objective is to explore and explain the factors influencing ICT diffusion process within an organisation. The third objective is to examine how ICT has been adopted and diffused into leading construction organisations, and to explore current ICT diffusion processes practices from both a strategic and actual implementation viewpoint.

This research adopted both quantitative and qualitative research approaches that were designed into two phases. Phase 1 focused on gaining quantitative data to investigate the extent of users' experience of variables influencing ICT diffusion at the actual implementation stage. A list of 46 essential variables was developed from integration of three main theories: innovation diffusion, change management, and knowledge management. These variables were used to develop a questionnaire to identify these key factors. The survey data were obtained from experienced users of ICT within three leading Australian construction organisations. By using the factor analysis technique, 46 variables were grouped into eleven factors that influence ICT diffusion at the actual implementation stage.

In Phase 2, qualitative research focuses on how ICT has been adopted and diffused into three selected leading Australian construction organisations. Both structured and semi-structured interview approaches were used to gather case study data from the three large construction contractors. Interview questions were developed from identified Phase 1 factors. Analysis of the case studies revealed four main findings. First, cross-case analysis confirmed the eleven

factors identified through the Phase 1 survey. The three case studies shared similar experiences with factors that influenced ICT diffusion at the actual implementation stage. The second finding revealed three types of community of practices (COP): an institutional COP, an implementer or technical support COP, and a project manger, engineer network and collegial support COP. These COPs were shown to play a main role in ICT diffusion. The third finding indicated two types of strategic adoption, proactive and reactive strategic adoption, that were suited to different ICT diffusion types and purposes. Finally, the findings highlighted that current ICT diffusion practice within leading construction contractors can be categorised by phase—initial adoption and actual implementation. Furthermore, the findings underscored the importance of a collegial and knowledge sharing environment factor to facilitate effective ICT diffusion.

This research contributed to the body of knowledge in at least four areas. The first contribution concerns the study of ICT diffusion at the actual implementation stage. It helps to understand the nature and extent of intra-organisational factors influencing ICT diffusion within large construction organisations. The second contribution was to knowledge management practice by illustrating how ICT knowledge has been diffused within construction organisations through users. It focused on explaining the roles of communities of practice to support ICT innovation diffusion within construction organisations. The third contribution is to IT management in construction by explaining the ICT diffusion processes that occurs at the actual implementation stage. It helps us understand the difference between planning and implementing initial ICT adoption and actual implementation. The last contribution is the development of supportive and constraints models that describe factors influencing ICT diffusion during the actual implementation phase and these help us understand the drivers and barriers that may occur during actual ICT implementation.

However, this research has some limitations that need to be acknowledged. First, quantitative data in Phase 1 was collected from experienced ICT users from only three leading construction organisation. Second, the qualitative data in Phase 2 was gathered from only three large construction contractors—even though it can be argued that these firms are representative of sophisticated first tier constriction contractors that are experienced ICT users. Thus, the study is limited to examples of technology used by these participating organisations at the time of this study. In addition, the case study was limited to study ICT diffusion of an electronic document management system.

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- Peansupap, V, Walker, D.H.T., Goldsmith, P.W. & Wilson, A. 2003 'Factors influencing information communication technology diffusion: an Australian study', Proceedings of the Joint International Symposium of CIB Working Commissions W55, W65 and W107 Knowledge Construction, Singapore, 22-24 October.

- Walker D. H. T. and V. Peansupap. (2003). 'Innovation diffusion through strategy and a COP approach – an Australian construction case study', Proceedings of the 17th ANZAM Conference, 2-5 December, Perth WA.

- Peansupap, V, Walker, D.H.T., Goldsmith, P.W. & Wilson, A. 2003 'Developing within-company information and communication technologies (ICT) innovation diffusion networks: a study of three Australian major contractors', Proceedings of the 19th ARCOM Conference, Brighton, UK., 3-5 September.

- Peansupap, V. and Walker, D.H.T. (2004) 'Understanding the ICT innovation diffusion process of large Australian construction contractors', Proceedings of the First SCRI International Research Symposium, Salford, UK, 30-31 March.

- Peansupap, V. and Walker, D.H.T. (2004) 'Strategic adoption of information and communication technology (ICT): case studies of construction contractors', Proceedings of the 20th ARCOM Conference, Sept 1-3, Edinburgh, Scotland.

- Peansupap, V. and Walker, D.H.T. (2004) 'Constraints on the ICT diffusion within large Australian construction firms'. Proceedings of the CIB-W107 the Globalization and Construction Symposium, AIT, Bangkok, Thailand, 17-19 November.

- Peansupap, V. and Walker, D.H.T. 2005 'Diffusion of Information and communication technology: A community of practice perspective'. Knowledge Management in the Construction Industry: A Socio-Technical Perspective. Kazi A.S. Hesinki, Finland, Idea Group Publishing.

- Peansupap.V and Walker D.H.T., (2005), 'Factors affecting ICT Diffusion: a case Study of Three Large Australian Construction Contractors', Engineering Construction and Architectural Management, Vol. 12, No. 1, pp. 21-37.

GLOSSARY OF TERMS

2D = Two Dimension

3D = Three Dimension

4D = Four Dimension

ABS = Australian Bureau of Statistics

ACIF = Australian Communications Industry Forum

ADSL =Asymmetric Digital Subscriber Line

AHP = Analytic Hierarchy Process

ANOVA = Analysis of Variance

ASP = Active Server Page

BSC = Balance Scorecard

BUs = Business Units

CAD = Computer Aided Design

CIB = International Council for Research and Innovation in Building Research

CIC = Computer Integrated Construction

CGI = Common Gateway Interface

CM = Change Management

COP = Communities of Practice

CPM = Critical Path Method

CSIRO = Commonwealth Science & Industrial Research Organisation

DoI = Diffusion of Innovation

EDI = Electronic Data Interchange

EDMS = Electronic Document Management System

ERP = Enterprise Research Planning

FA = Factor Analysis

FTP = File Transfer Protocol

HTTP= Hypertext Transfer Protocol

ICT = Information and Communication Technology

ID = Innovation Diffusion

IFCs = Industrial Foundation Class

ISDN = Internet service digital network

ISP = Internet Service Provider

IT = Information Technology

Kbps = Kilo byte per second

KM = Knowledge Management

KMO = Kaiser-Meyer-Olkin

LAN = Local Area Network

MAUT = Multi-Attribute Utility Theory

NIST = National Institute of Standards and Technology

ORCM = Online Remote Construction Management

OHS = Occupational Health and Safety

PC = Personal Computer

PDA = Personal Digital Assistant

PERT = Program Evaluation and Review Technique

PHP = Hypertext Preprocessor Programming

PM = Project Management

PMS = Project Management System

RFI = Requests for Information

SISP = Strategic Information System Planning

SMEs = Small and Medium Enterprises

STEP = Standard for the Exchange of Product Model Data

TAM = Technology Acceptance Model

TQM = Total Quality Management

VR = Virtual Reality

VRML = Virtual Reality Modelling Language

WAN = Wide area network

WWW = World Wide Web

XML = eXtensible Markup Language

Chapter 1
Introduction

This research is exploratory and descriptive in nature. It studies the nature of information and communication technology (ICT) diffusion within Australian construction organisations. It investigates ICT diffusion from the perspective of the ICT adoption strategy and its actual implementation within an organisation. The main research objective is to understand the nature of ICT diffusion at the intra-organisational level by identifying key factors influencing diffusion at the actual implementation phase. To this end it explores key ICT diffusion processes within leading Australian construction organisations. It uses both quantitative and qualitative research approaches. It begins with a quantitative investigation of the influence of users' experience of management, individual and/or personal, technology, and workplace environment on ICT diffusion. This part of the research generates an understanding of what key factors affect the surveyed group's perception of key factors that influences ICT diffusion. The qualitative research contribution to this work focuses on how ICT has been adopted and diffused into selected leading Australian construction organisations. It helps to develop the understanding of main essential processes that facilitate ICT diffusion during actual implementation.

The aim of the research is to assist construction senior managers to better understand, plan and monitor ICT diffusion issues during actual ICT implementation. The outcome of the research is a framework that helps to improve our understanding of ICT diffusion during actual implementation and to develop improved models of how ICT knowledge is transferred and ICT initiatives are implemented. As the results are based on case studies of large Australian construction organisations, they may require some modification before being applied to other construction organisations.

This chapter provides an overview and outlines the scope of the thesis. It starts with a discussion of how the researcher conducted the investigation of the research topic. It explains the research background, the rationale for the research, the research problem statement, research questions, research propositions, research scope, objectives and aims, research methods, theoretical framework and limitations of the current research.

1.1 Research background—The relevance of ICT to the construction industry

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

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

Another aspect of ICT benefits focuses on applications that support improving construction processes. Tam (1999) for example developed a prototype ICT system to help construction organisations improve communication and reduces costs. Other researchers have investigated the application of ICT in improving construction processes during design and construction (Veeramani, Tserng & Russell 1998), construction cost control (Abudayyeh *et al.* 2001), and project management (Skibniewski & Abduh 2000) see Chapter 2 sections 2.2.1 for further details on these applications. Other examples of IT/ICT product or system prototype development include development of web-based ICT systems to support e-commerce in construction such as providing product catalogues and facilitating material procurement (Kong *et al.* 2004, Kong, Li & Love 2001, Kong, Li & Shen 2001) .

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

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

A recent study of the International Council for Research and Innovation in Building Research (CIB) W78 conference papers claimed that management of information technology, especially adoption and implementation, has been identified as one of the three main conference themes (Amor *et al.* 2002). Similarly, the technology innovation implementation stage has also been judged as the most critical phase to concentrate upon to ensure successful technological innovation (Attaran 2000, Goodman & Griffith 1991, Leonard-Barton 1988, Tornatzky & Fleisher 1990). While the *development* of IT innovation is controlled by a relatively predictable environment (such as in a laboratory within a research and development (R&D) unit or IT department) *actual implementation* of IT is far more difficult to control because it involves the complex interaction of people in their workplace dealing with the technology. Also as an innovation is introduced, users are required to learn how to use an innovation as well as changing the way they usually work. People tend to resist change due to their habits acquired over time. This is a constraint on ICT diffusion. Such problems are compounded if the innovation concerned is unsuited to their conventional work practices (Goodhue & Thompson 1995, Mathieson & Keil 1998). For example, a project manager or an engineer may be more familiar with communicating with sub-contractors (and vice versa) via phone and fax instead of using email.

From a research perspective, most research previously undertaken in this area has focused on the primary adoption phase of ICT innovation. For example, several studies have been conducted at an industrial level to explore barriers to ICT adoption and use in construction organisations. These results tend to agree that the most common barrier of primary adoption is the high cost of investment (Love *et al.* 2001, Marsh & Finch 1998, Marsh & Flanagan 2000, Songer, Young & Davis 2001, Stephenson & Blaza 2001). In addition, several research studies indicate that ICT investment benefits are difficult to measure and this creates difficulties in making an adoption decision. Other studies argue that diffusion barriers are not limited to just the organisation's ICT adoption decision but extends to the actual implementation approach (Griffith, Zammuto & Aiman-Smith 1999, Regan & O'Connor 2000). For example, most of IT project outcomes do not meet management expectations due to management's lack of understanding of a method to best implement the ICT innovation and/or how to best measure and evaluate results and benefits derived from ICT use.

However, in the literature there is evidence of recent interest that begins to focus on the ICT adoption and implementation phase of ICT diffusion. Recently, for example, an ICT strategic implementation framework was developed to help plan ICT implementation in construction organisations (Jung & Gibson 1999, Peña-Mora & Tanaka 2002, Peña-Mora *et al.* 1999, Stewart, Mohamed & Daet 2002). Several studies have focused on what triggers an innovation adoption decision from a strategic planning and decision-making perspective (Mitropoulos & Tatum 1999, 2000). Few studies however, have been focused on the nature of ICT diffusion and its actual implementation. To fill this gap, this research project attempts to extend our understanding of ICT implementation by applying innovation diffusion, change management, and knowledge sharing concepts to explain intra-organisational ICT diffusion during actual ICT implementation in selected construction organisations. The integration of these three concepts can help to explain how people learn and exchange knowledge necessary for innovation diffusion and how people cope with the necessary changes in work and management practices that result from fully adopting an innovation.

1.2 Rationale for the research

Many practitioners and academics are beginning to realise the importance of implementing IT and ICT throughout construction organisations. Recently, interesting frameworks for strategic IT implementation were developed to provide a strategic view of IT success in construction (Jung & Gibson 1999, Peña-Mora & Tanaka 2002, Peña-Mora *et al.* 1999, Stewart, Mohamed & Daet 2002). In addition, many studies seek to identify key drivers and barriers of IT implementation during initial adoption rather than during implementation (Laage-Hellman & Gadde 1996, Marosszeky *et al.* 2000, Songer, Young & Davis 2001). These research studies have adopted slightly differing approaches. Some explore barriers to IT use and adoption at the construction industry level (Love *et al.* 2001, Stewart & Mohamed 2002, Tucker, Mohamed & Ambrose 1999). These studies agree that common barriers include low levels of IT skills and lack of IT investment. Some studies identify the various factors influencing the success of strategic IT implementation in organisations (Stewart, Mohamed & Daet 2002). However, few of these empirical studies focus on factors and processes influencing ICT diffusion during the actual ICT implementation phase.

Based on the above, the current research aims to identify factors and processes that influence ICT diffusion at the actual implementation stage. It looks at three different aspects in comparison to previous research. First, the work focuses on ICT diffusion during the *actual implementation* phase and makes the assumption that ICT innovation may be different from standalone IT innovation. One reason for this is that an ICT innovation needs a number of users to commit and use it, whereas many IT innovations are for stand-alone application or involve small specialised groups of users (Markus 1987). With ICT however, the greater the number of users that adopt and implement the technology the more benefits that the ICT innovation will likely deliver. This is because benefits are best realised by universal rather than small group adoption and implementation. Thus, the organisation that expects to obtain real benefits from its investment needs to ensure that as many (if not all) users have adopted and used it. Second, ICT adoption and implementation factors are developed from three concepts: innovation diffusion, change management, and knowledge sharing and learning. The integration of these three concepts may help to explain both the static and the dynamic factors that impact on the initial motivation to adopt ICT and its continuous use during its implementation throughout organisations. Third, the aim of the research is to identify processes that occur during actual ICT implementation phases from an innovation diffusion perspective. This could help us understand how different factors influence the ICT diffusion process during the implementation period. This aspect is still largely unclear from the existing literature.

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

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

Thus, to more fully understand ICT diffusion, we need to search beyond the ICT adoption decision-making phase to more fully study what actually happens when ICT innovation is implemented. This requires us to consider not just the innovation diffusion literature but change management as well as knowledge-sharing and learning. This is the identified gap in the existing research that considers ICT diffusion from this perspective that need to be addressed. Identification of this gap justifies this research's rationale.

1.3 Research problem statement

There is an increasing trend in the number of ICT adoption and implementation studies being undertaken in construction management research. These studies offer several dimensions of understanding IT management such as the level of ICT use, measurement of ICT benefits, and development of strategic ICT planning. Other research studies also look at the implementation of ICT innovation in construction and highlight the problems of ICT implementation. Although earlier studies related to ICT adoption and implementation provide a preliminary view of ICT use, they still lack an emphasis on how to actually implement ICT into a construction organisation. This lack of clarity of understanding actual ICT implementation may lead to a failure and/or an ICT diffusion slowdown by all users within a construction organisation. Furthermore, the lack of focus on actual ICT implementation may explain why ICT implementation problems still occur. Therefore, the current research problem is based on the following premise:

Current construction IT management literature does not adequately explain actual ICT implementation from an intra-organisational perspective and this may contribute to failure and/or slow diffusion of technology within construction organisations.

To examine the concept of managing an actual ICT implementation, factors and processes need to be identified. The current research will investigate the factors and processes of actual ICT implementation within large construction organisations. These factors are developed from the integration of three concepts—innovation diffusion, change management, and knowledge sharing and learning. This study aims to identify key factors that influence ICT diffusion amongst experienced ICT users who currently adopt and use ICT within large construction organisations. The study of processes is adapted from a standard innovation diffusion model and explains the main processes that are currently adopted and implemented within large construction organisations.

1.4 Research questions

To increase the understanding of ICT diffusion at actual ICT implementation stage, this research will address the following questions:

1) *What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations?*
2) *To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations?*
3) *How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations?*
4) *How has ICT knowledge been diffused by users within large Australian construction organisations?*
5) *What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?*

1.5 Research proposition

Based upon the research questions, four research propositions are developed and tested in this study, as follows:

1) *There are a small number of key factors that influence ICT diffusion within a construction organisation at the actual implementation phase.*
2) *Each factor has a specific and individual role to facilitate ICT diffusion*
3) *Effective ICT diffusion can be understood as a series of sequential processes*
4) *These process need to overcome a number of identified barriers to ICT diffusion*

1.6 Research scope and objectives

The current research will explore the present practice of ICT diffusion within a representative sample of large Australian construction organisations that already use ICT applications. In addition, the research will identify key factors and processes that influence potential adopters during actual ICT implementation.

The primary objective is to identify the nature and extent of intra-organisational variables influencing ICT diffusion within three large Australian construction organisations. It focuses on professional levels of ICT users within these organisations who are familiar with and currently use ICT applications. This survey not only helps to identify common issues that these ICT users have experienced, but also allows researchers to understand the nature and extent of the supportive environment within these organisations that could facilitate ICT use.

In addition, this survey identifies ICT knowledge sources and the way that knowledge is shared within each organisation.

The second objective is to explore the factors influencing ICT diffusion within an organisation. These factors represent clusters of interrelated variables identified by a rigorous review of the literature. Once identified, these factors can then be used as the basis for conducting interviews with individual ICT users in the second phase of the current research study to gain a richer appreciation and understanding of the nature of the workplace environment that drives and/or inhibits ICT diffusion within those ICT literate organisations. The focus of attention throughout this study is directed towards individuals who are computer literate and working in construction organisations that have a substantial history of using ICT in their work processes. These types of individuals can best illustrate how ICT diffusion operates in practice.

The third objective is to obtain in-depth information about how users experience the factors influencing ICT diffusion, and to explore the current practices of the ICT diffusion process from both a strategic and an implementation viewpoint. In addition, it aims to identify how ICT knowledge has been diffused by users within a construction organisation.

The summary of research objectives is:

1) To identify factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations
2) To explore the current ICT diffusion factors and processes that have been experienced by ICT users within large Australian construction organisations
3) To investigate how ICT diffusion factors influence the diffusion processes within large Australian construction organisations
4) To identify how ICT knowledge has been diffused by users within Australian construction organisations

1.7 Research aims

This research aims to apply existing theories of innovation diffusion, change management and knowledge-sharing and learning to the management of actual ICT implementation within large construction organisations.

The expected outcomes from this research are:

1) A better understanding of the nature of ICT diffusion within large construction organisations
2) A better theory of practice for management of actual ICT implementation
3) Conceptual models for actual ICT implementation that help explain the ICT diffusion within large construction organisations

1.8 Research methods

The selection of a research strategy is dependent on: the types research questions asked, control of the behaviour environment, and contemporary events. Based on research questions on 'what' and 'how', the current research is categorised as an exploratory and descriptive approach. The strategy for part of this research is based on a series of case studies that help to build an understanding of ICT diffusion within leading construction organisations.

However, this study uses both quantitative and qualitative data. For the quantitative data study (Phase 1), a questionnaire is selected as a tool to gather data about ICT users' experience of variables influencing ICT diffusion during actual implementation. The target respondents are experienced IT users within three leading Australian construction organisations. Findings can help identify the main drivers that influence ICT diffusion before conducting an interview case study.

Structured and semi structured interviews (Phase 2) were selected as tools to explore the current ICT diffusion processes within three leading construction contractors to explain what factors influence ICT diffusion processes. However, results from Phase 1 provided the basis for prompting clarification and further questions as well as for analysing data gathered in the qualitative data study. Structured and semi structured interviews can yield rich data by allowing respondents to elaborate on issues that they perceive to be important without interference or influence by the interviewer. In addition, the study also explores how users within each of the three cases have diffused ICT knowledge.

1.9 Theoretical framework

The research background section of this chapter concluded that there is a current lack of knowledge to explain ICT diffusion within construction organisations during the implementation phase. Therefore, the current research attempts to fill this gap by providing a conceptual guide. As described earlier, three main concepts of innovation diffusion, change management, and knowledge-sharing and learning are adopted and modified to establish the variables that may influence ICT diffusion during actual implementation. The exploration of processes during actual implementation is adapted stage model of technological innovation diffusion (Carlopio 1998, Cooper & Zmud 1990, Rogers 1995). It aims to identify the current practice of ICT diffusion within leading construction contractors. Figure 1.1 illustrates the theoretical framework in this research that is explained in depth in Chapter 2 section 2.2.3.

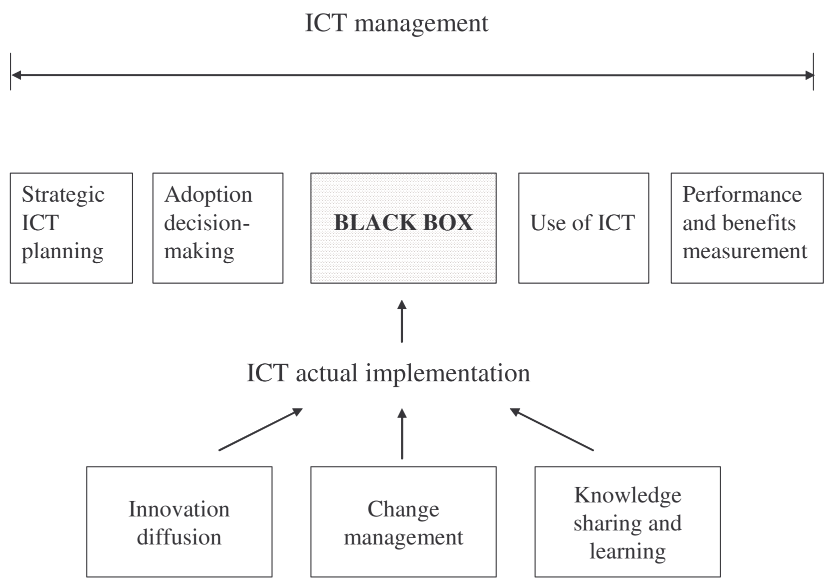

Figure 1.1 The original theoretical framework in this research

1.10 Limitations of this research

This research has some limitations that need to be acknowledged. First, data gathered for the quantitative (Phase 1) part of the study was collected only from experienced ICT users from three leading Australian construction organisations during March to May 2002. The organisations were chosen because they could source respondents that were already familiar with IT and ICT applications and so could provide valuable experience of ICT diffusion implementation initiatives in their organisation. Thus there was a deliberate policy of excluding novice ICT users and this naturally limits this research work as applying to experienced ICT users. Further, the sample of organisations chosen was drawn from available representative organisations with a strong history of ICT use. Thus, the results are only applicable to construction industry organisations experienced with ICT. Therefore one important limitation to this study is that it sought to investigate only experienced ICT users.

Qualitative data for Phase 2 of this study were gathered from October 2002 to May 2003. Thus, the study is limited to examples of ICT technologies readily available and used by participating organisations at that time. ICT advances at a great rate and so as a new wave of ICT initiatives enters the organisations to be diffused, new technical problems and issues may emerge. While the underlying results of the study may be valid and useful for the foreseeable future, we cannot be certain that radical ICT applications may not radically change this assumption.

Further, the location of the study (Australia) also may influence what is considered as contemporary ICT applications worthy of study. Australia, however, is a sophisticated technological society and so results from this study could be considered as reasonably representing a developed economy in which the Australian construction industry, and the major organisations chosen for this study, is representative of this classification of national-industrial ICT maturity level.

Finally, naturally it was not feasible to interview all employees of the selected companies and so the choice of respondents depended upon availability and willingness to participate in the study. Every effort was made to ensure that representative groups and individuals were chosen.

1.11 Structure of the thesis

This thesis comprises ten chapters. Chapter 1 introduces an overall view of this research. It addresses the research background, the rationale of research, the research problem statement, research questions, research propositions, research scope, objectives and aims, research methods, theoretical framework, limitations of this research, and thesis framework.

Chapter 2 reviews the literature related to implementation and diffusion of IT innovation within an organisation. It addresses issues related to technological innovation in the construction industry. This review explains the history, benefits and level of ICT use in construction industry. Next, the review highlights processes related to IT management. These include; strategic IT planning, IT adoption decision, management of IT implementation, and measurement of IT investment. This helps to establish the central argument of the need to study IT diffusion at the actual implementation stage. The last three sections focus on the literature related to innovation diffusion, change management, and knowledge sharing and learning—these three concepts help explain ICT diffusion at the actual implementation stage.

Chapter 3 describes the need to study ICT diffusion at the actual implementation stage from an intra-organisational perspective. To understand ICT diffusion at the actual implementation stage, Chapter 3 reviews and integrates the main variables from the main three concepts of innovation diffusion, change management, and knowledge- sharing and learning. The chapter concludes with a list of questions that identify main variables that influence ICT diffusion at the actual implementation stage.

Chapter 4 presents the research approach. This presents: the philosophical assumptions underpinning this research; the research study approach; research strategy; and the research design. The chapter then describes two main research methods: survey questionnaire and interview case study.

Chapter 5 presents the analysis and discussion of factors influencing ICT diffusion. It contains: a descriptive analysis of survey respondents; justification of the sample approach; justification of analysis data of survey questionnaires; exploration of ICT diffusion factors; and analysis of ICT knowledge sources.

Chapter 6 describes the findings of three case studies of ICT diffusion within three large Australian construction contractors. Each case describes: the case study background; the configurations of ICT systems; the use of ICT systems; ICT support groups; ICT diffusion at the organisational level; ICT diffusion at the individual and group level; users' experience of factors influencing ICT diffusion; and description of ICT diffusion process.

Chapter 7 analyses and discusses the three ICT diffusion case studies findings within the three large Australian construction contractors. The chapter presents: analysis of factors influencing ICT diffusion; ICT knowledge diffusion through users; analysis of strategic ICT adoption; and analysis of the ICT diffusion process at both the initial adoption and actual implementation stages.

Chapter 8 develops conceptual models that help us understand ICT diffusion within large Australian construction organisations. The conceptual models consist of supportive ICT diffusion models and three constraints on ICT diffusion models.

Chapter 9 summarises research findings that related to the research questions. The chapter then discusses the research contribution made by this work and presents recommendation for further research and practice. It concludes with suggestions of future research some that needs to be explored.

1.12 Summary of chapter

This chapter provides an introduction to this research study. The main argument for this research is that current construction IT management literature does not adequately explain actual ICT implementation from an intra-organisation perspective. The chapter begins by arguing that many construction organisations are facing an ICT benefits paradox, that is that ICT investment fails to meet their expectations and that users consequently resist ICT adoption and use.

The main cause of this paradox is management's lack of understanding of methods to best implement ICT innovation. The chapter then argues that many studies seek to identify key drivers and barriers of IT implementation at the initial adoption stage rather than at the actual implementation stage. These provide a rationale for this research to identify factors and processes that influence ICT diffusion at the actual ICT implementation stage. Next, the chapter identifies a series of research questions and highlights the scope of this research that focuses on experienced ICT users within the selected large Australian construction organisations that had implemented ICT. The chapter then describes the quantitative and qualitative research approaches that will be used in this research. The chapter then details the original theoretical framework that was developed for this thesis. Finally an outline of the thesis structure is given.

Chapter 2
Literature review

The purpose of this chapter is to review the previous relevant research studies regarding implementation and diffusion of IT innovation within an organisation. Specifically, it aims to provide basic knowledge on how innovation diffusion theory could assist to explain ICT innovation implementation at an intra-organisational level. To achieve this purpose, the structure of the chapter is organised into five sections. First, the review begins with issues related to construction industry technological innovation. Second, it reviews construction ICT innovation benefits, level of ICT use, barriers of ICT use, and ICT adoption. These two sections provide a broad view of construction technological innovation and ICT innovation. The following sections provide focus on within-organisation IT implementation theories. The third section focuses on issues related to the management of IT in construction organisations. It highlights key processes relating to IT management consisting of strategic IT planning, IT adoption decisions, management of IT implementation, and measurement of IT investment benefits. The last three sections will focus on three concepts related to IT implementation from an intra-organisational perspective. These concepts are innovation diffusion, change management, and knowledge-sharing and learning. The review of these concepts provides background knowledge that helps to fill construction research knowledge gaps relating to ICT implementation within construction organisations.

The literature review presented in this chapter leads to and links with Chapter 3. Figure 2.1 illustrates the general areas of literature to be explored. Innovation diffusion, knowledge management (more specifically learning and sharing knowledge), and change management concepts are reviewed. Through analysis of what the intersection of these bodies of knowledge provides, gaps in current knowledge about ICT diffusion in the construction industry can be identified. In Chapter 3 a theoretical integrated model of ICT diffusion at the implementation phase is developed and presented. This model informs the research questions and research propositions.

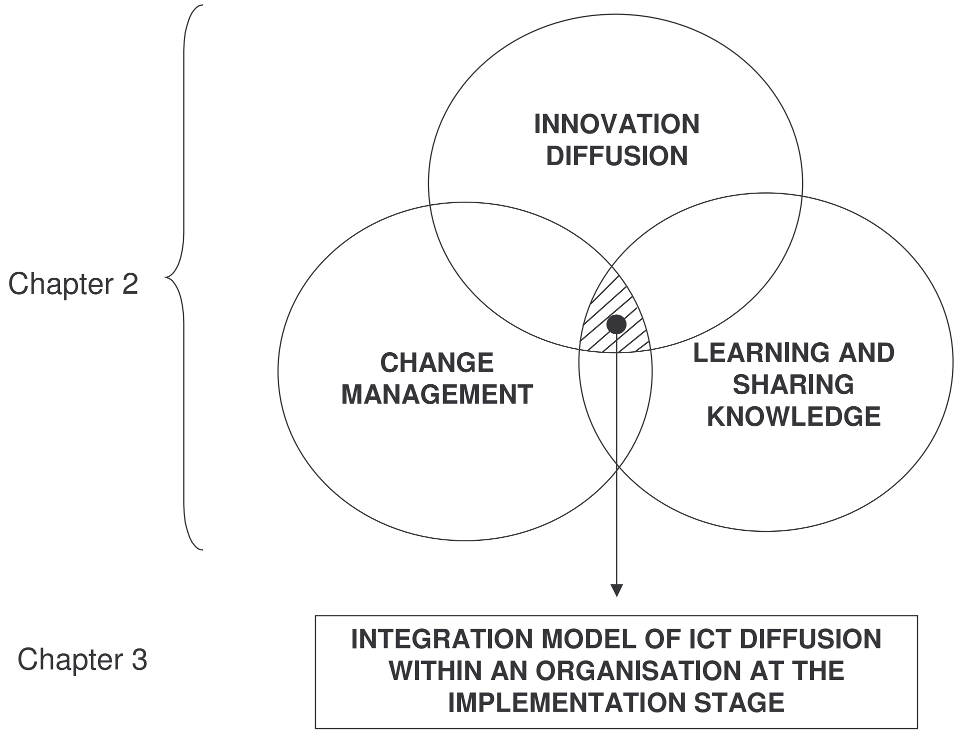

Figure 2.1 The links between background Chapter 2 supporting ICT diffusion within an organisation at implementation stage

2.1 Construction industry and technological innovation

The construction industry has unique and distinct characteristics compared to many other industries. It is therefore necessary to provide background knowledge on the nature of the construction industry and its specific need for technological innovation. In particular, this section will deal with the nature of the Australian construction industry. The discussion will centre on the primary forces and characteristics that influence technological innovation transfer within that industry. The aim of this study is to first identify basic construction innovation categories. Next, the focus will shift to IT innovations in the construction industry and then to review the history and impact of IT construction innovations on that industry.

2.1.1 *The nature of the construction industry*

The construction industry makes a significant business contribution to many national economies. For example, the Australian Bureau of Statistics, ABS[1] (2002) reports that the construction industry sector contributed 5.5% of Australia's GDP for 1999-2000 and employed 709,300 people in 2000. The Bureau of Economic Analysis (BEA) in the U.S. stated that the construction industry contributed approximately $US 425-490 billion or 4.7-

[1] ABS Cat. 8731.0 accessed, Sept. 2003

4.8% of GDP, and the U.S. Bureau of Labour Statistics (BLA)[2] estimated that the construction industry employed around 6.7 million wages and salaried employees in 2002. Similarly, a Canadian construction industry[3] (2003) report indicates that its revenues were around $US 54.9 billion, which accounts for about 5.4 % of Canada's GDP and that it employed more than 820,000 people.

Due to the significance of the construction industry's economic contribution, many studies have been undertaken on ways to improve construction management methods and techniques that could increase industry productivity (Hampson & Tatum 1997, Hampson & Tatum 1994, Lenard & Bowen-James 1996, Tatum 1988). However, the nature of construction industry practice is in itself a barrier to improving its productivity (Latham 1994).

The construction industry has been characterised as being complex, fragmented and unique (Egan 1998, Howard *et al.* 1989, Latham 1994). This claim is made for a variety of reasons. First, most construction projects involve many phases such as feasibility, design, construction and maintenance. Second, each phase involves communication and coordination among many project participants such as the owner, contractor, designer, consultant, subcontractors, and suppliers. This may lead to basic problems of communication and information exchange. Each project is unique in construction type, location, and its project participants. As a result traditional management practice within this construction environment has been criticised for not being conducive to improving construction productivity (Latham 1994).

Rather than changing the nature of construction industry, Egan (1998) suggested that the construction workforce should be wary of attempts to improve construction productivity and process by blindly adopting innovation such as new management techniques, construction techniques or IT. Any adoption of innovation should be mindful of existing industry constraints to overcome barriers with a more systemic approach to change rather than undertaking isolated piecemeal change initiatives.

2.1.2 *Driving forces of technological innovation*

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[2] BLS, US. NAISC 23. http://stats.bls.gov/oco/cg/cgs003.htm, accessed Jan. 2004

[3] Strategis Canada's Business and Cusumer http://strategis.ic.gc.ca/sc_ecnmy/sio/cis11-33defe.html, accessed Jan. 2004

The need to adopt technological innovation in the construction industry was stressed in the previous section. This section identifies forces that drive the adoption of technological innovation into the construction industry. Innovation studies in the industry undertaken by Tatum (1987, 1988) indicate three main innovation driving forces: client demands, complexity of new construction facilities, and threats from foreign competitors. Mitropoulos and Tatum (2000) in a study of six technological innovation cases show that competitive advantage, process problems, technology opportunity, and institutional requirement are the main forces driving technological innovation adoption.

Other supplementary forces have been identified such as government policy (Gann 2001), external research and development units (Veshosky 1998), collaboration with university research (Gann 2001), and other project participants (Carrillo 1994, Devapriya & Ganesan 2002, Dulaimi, Ling & Bajracharya 2003). These forces tend to push technological innovation indirectly into the construction industry. Although they may be less influential compared to forces driven by competitive advantage or process problems, they could still be classified as supplementary driving forces that motivate construction industry innovation across organisations (Dulaimi, Ling & Bajracharya 2003, Gann 2001).

Technology adoption characteristics can be influenced by the dominant demand and supply dynamic (Mowery & Rosenberg 1979, Nam & Tatum 1992). IBIS (1999) also concluded that technology adoption is the interaction between 'technology supplier' and 'technology user'. The technology supplier plays the essential role of providing the innovation, while the user plays a significant role in technology adoption. IBIS (1999) argues that technology push occurs when a technology supplier dominates the technology adoption decision with the user's role being only to identify and adapt that innovation. In contrast, demand-pull occurs when a technology user controls or demands the technology from a supplier and plays a key role in identifying the technology and the technology supplier to deliver that innovation.

This occurrence of technology-push and market-pull forces is also found in construction innovation. Based on ten innovative construction projects, Nam and Tatum (1992) found that contractors and designers represented the technology-push forces by their introduction of new technology into innovative construction projects—thereby influencing the adoption of innovation in these construction projects. The final technology adoption choice (technology-push or demand-pull) may, however, depend on forces driving construction projects such as competitive advantage or the need to solve problems. In practice, the adoption of technological innovation is influenced by innovation characteristics that might present benefits to both owner and contractor. Hence, it becomes necessary to discuss and define innovation characteristics from this perspective.

2.1.3 *Innovation and its characteristics*

The term innovation has been defined in several ways, with meaning ranging from ideas to products and processes. Innovation is different from invention and creativity. Williams (1999) defined creativity as 'the root source of invention and innovation'. Invention relates to new development tools, new design and new work processes (Williams 1999, p.14). Innovation is also defined as 'the implementation of inventions—the process that results in new things being brought into use' (Williams 1999, p.14). Thus, innovation does not always mean a totally new thing or idea for the world but it can be explained as a new idea or process for an organisation.

From the industrial practice perspective, the category of innovation could be defined on the basis of 'type of initiator'- administrative and technical innovation *or* 'type of innovation'- product and process innovation (Daft 1978, Damanpour 1992). The first category is focused on the way that idea of innovation has been initiated. An initiator with a strong background and experience of the special innovation type may influence the initiation of an innovation within an organisation. Daft (1978) pointed out that an administrative innovation is usually proposed by an administrator with the necessary management knowledge background whereas a technical innovation is generally initiated by an expert worker who has long experience on the operational work processes in question and also has a vision of how to improve these processes.

The second category of innovation - product and process mainly stresses the purpose and phase of innovation (Daft 1978, Damanpour 1996, Damanpour & Evan 1984). Three aspects could distinguish the difference between product and process categories. First, the product innovation aims to produce a new idea, product or service that satisfies the customer requirement or market need. Process innovation aims to improve production processes by using or adopting materials, processes, equipment and technologies. Second, product innovation needs new ideas or services that differ from a competitor's whereas process innovation may be to adopt an idea to improve a traditional work process. Third, process innovation usually occurs at the work process phase while product innovation takes place at the output of the process.

Meyers *et al.* (1999) also argued that there are differences between a process innovation and a product innovation. A process innovation is focused on how to improve or change a traditional work process in an innovative way and this, in turn, leads to improved construction productivity. A product innovation stresses the development of a new product and/or a market responding to customers' requirements. Consequently, the categories of innovation such as product and process should help us to understand the innovation focus (its inherent nature) that impacts on either how to select a new process technology or new product in the construction industry.

2.1.4 *Classification of innovation in construction*

Innovation is one of the essential attributes that drives competitiveness in the construction industry (Alshawi & Ingirige 2003, Slaughter 1998, 2000, Tatum 1987). Many research studies have been made on innovation in the construction industry. Construction innovations could be grouped into:

- **Innovation in materials and methods:**
  - *Construction materials and equipment*: tower crane, concrete pump, robotics, high strength concrete, fibre reinforced plastic, etc.
  - *Construction methods*: prefabrication, top-down construction, etc.
- **Management innovation:**
  - *Construction management techniques*: bar chart, CPM, PERT, line of balance, alliance, project partnering, build operate transfer, etc.
- **Information technology (IT) innovation:**
  - *Computer applications and electronic equipment*: computer, notebook, tablet PC, palm, barcode, construction simulation, estimating software, project planning and control applications, etc.
  - *Network and information and communication technologies*: LAN, WAN, EDI, Internet, Intranet, VRML, wireless, groupware, ICT innovation, etc.

First, innovation in materials, equipment and methods directly impact on the construction productivity (Toole 1998). This innovation benefit includes competitive advantage and solving traditional process problems to improve productivity. Second, the management innovation category refers to techniques that assist in improved control of the construction process. Most of these types of innovation have been borrowed from operations research theory and practice such as PERT, CPM, TQM etc. (Bresnen & Marshall 2001). Third, the IT innovation category includes computer applications, electronic equipment and network technologies (Doherty 1997b, Howard 1998, Paulson 1995). The main function of IT innovation is to improve the management and processing of information during the construction process. The volume of information flows during a construction project is enormous - speeding up information processing should help reduce time and cost, and improve work quality.

Based on the innovation characteristics (product and process) discussed in the previous section, some construction innovations may be classified as both product and process innovation. For example, new materials from a construction supplier should be categorised as a product innovation. New materials adopted by a construction contractor for improving the work productivity, however, should be classed as process innovation. Adoption of IT innovation in construction organisations should be classed as a process innovation, not a product innovation, because it involves adoption of IT product to improve their management processes. Aouad *et al.* (1999) and Björk (1999) argue for the use of advanced technological innovations to improve project management during the construction processes, such as cost control, project planning, robotics, resource management, 3D modelling, and virtual reality.

In conclusion, each innovation category has a different influence on the construction industry. First, adoption of construction materials, equipment and processes aims to improve productivity at the operational level. Second, adoption of management techniques mainly focuses on construction process control. Third, information technology adoption is targeted at improving construction management processes. In particular, Aouad *et al.* (1999) provide examples of IT innovation being effectively used throughout construction project phases. Consequently, the adoption of IT innovation can be argued as being an important technological innovation that enhances organisational process improvement capability and product development. The following section provides some historical details of IT use in the construction industry before discussing ICT innovation in greater depth.

2.1.5 *History of IT innovation in the construction industry*

Much effort has been consistently applied to improve construction productivity. IT innovation is an area worth focusing on because it can increase productivity through decreasing information processing time. One design example is the use of structural design software. This can reduce calculation time for designing complex structures. IT applications can also improve operational improvement through improving the communication flow of information for effective decision-making and coordination. For example, the use of visualisation technologies can improve the effectiveness of communicating project information between project participants (Liston, Fischer & Kunz 2000). Before studying construction industry ICT issues, it is useful to discuss the history of IT innovation in the construction industry.

In the 1970s, a lot of research was focused on the use of stand-alone IT applications in the construction industry to improve productivity of specific construction processes or problems. These construction IT applications were developed on computer mainframes to assist construction operations, support decision-making and prediction of outcomes of uncertain processes (Bhandari 1977, Clemmens & Willenbrock 1978, Halpin 1977). However, these computer applications were developed in research institutes and universities and they were not widely used by the construction industry during that early period.

By the 1980s, computers were introduced to large construction companies as a result of the low cost of hardware and its demonstrated efficiency in calculating and processing construction information (Lester 1984). Software applications in use at that time included administration, accounting, estimating, planning, database and simulation (Lester 1984, Wager, Scoins & Construction Industry Computing Association (Great Britain) 1984). Computer aided design (CAD) was developed and used since the mid-1980s. In the late 1980s, there was some research undertaken in robotics, automation and knowledge-based construction systems. Also, the concept of IT integration was developed, for example for integrated construction process information and integrating time planning with cost control (Suckarieh 1984).

In the 1990s, a trend evolved in which individual IT systems for designing, planning, estimating, cost control and CAD were integrated into an organisation-wide IT system (Doherty 1997b, Howard 1998, Paulson 1995). This integration also included knowledge-based systems and simulation. Innovative technologies such as barcodes, pen-based computers, portable computing and multimedia were also introduced for managing construction operations during this time. In addition, computer science research in the field of expert systems, artificial intelligence and management information systems (MIS) were applied to construction management.

Since 1995, IT related computer applications such as Virtual Reality, 2D & 3D barcodes, and 4D-CAD, handheld devices, Internet and remote access have been developed to improve efficiency in construction processes (Aouad *et al.* 1998, Aouad *et al.* 1999). From the literature review of abstracts in many journals, it is evident that IT innovations related to Internet and communication technology (ICT) have been increasingly used on construction projects over recent years (Walker & Betts 1998).

Recently, construction IT research surveys have been conducted in many regions for example in Canada (Rivard 2000); Saudi Arabia (O'Brien & Al-Biqami 1999); Hong Kong (Futcher & Rowlinson 1998, 1999); Denmark (Howard & Samuelsson 1998); Finland (Howard, Kviniemi & Samuelsson 1998); New Zealand (Doherty 1997a); and Australia (CSIRO 1996). Although these studies indicate that the ICT use is lower than general IT innovation, the findings indicate an increasing trend in the use of ICT in construction.

According to the Economist (1999), the current pace of technological innovation is described as the fifth wave of technological change. Figure 2.2 indicates that the length of the technology development cycle has reduced from 60 years for the first wave to 30 years for the fifth wave. Each technological evolution cycle takes a less time to change. This implies organisations should prepare and update their management and internal practices to cope with this pace of change, otherwise they are in danger of losing their competitive advantage (Porter 1985b, Tan 1996).

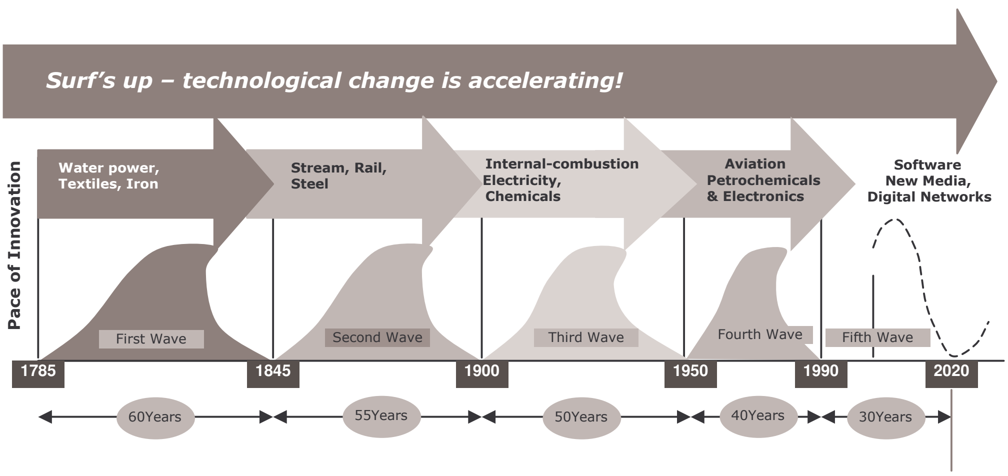


Figure 2.2 Fifth wave of technological change (adapted from the Economist, 29 February, 1999, p.8)

Figure 2.2 indicates that technological innovation changes have progressed to ICT innovation use such as software, new media, and digital networks for the early twentieth century. This trend will have a profound impact on the whole construction industry.

As ICT innovation opens greater opportunities for construction information integration, it therefore can help to obviate problems of construction fragmentation (Garcia *et al.* 1998). This is especially so because construction is a project-based activity with a locus of activity moving to a new location and group of participants after finishing each project. This constraint makes it inherently difficult to manage information and documentation. In practice, most construction information in the past was composed in traditional ways using paper-based documentation with its attendant difficulties in managing information flows (Björk 2002, Duyshart 1997, p.3). Currently, several ICT innovations have been developed to help enhance the generation and flow of construction documentation (Aouad *et al.* 1999). One of the benefits of using ICT is that all information is created and stored in electronic media formats so that it increases the capability for users to simultaneously and concurrently access and share information in different geographical areas (Hajjar & AbouRizk 2000). Benefits of ICT application use in construction are also supported by several research studies (Akinsola, Dawood & Hobbs 2000, Anumba & Duke 1997, Garcia *et al.* 1998, Opfer 1997, Orth 2000, Tam 1999, Weippert, Kajewski & Tilley 2002b)

2.2 ICT innovation in construction

As the trend of moving towards stand-alone IT innovation continues, it is necessary to match it with the trends of using ICT innovation for construction (Ahmad, Azhar & Ahmed 2002). Several emerging ICT innovations have been studied, for example Internet, Intranet and Extranet technologies and also the collaborative applications such as Electronic Data Interchange (EDI), Email, File Transfer Protocol (FTP), Electronic Document Management System (EDMS), Web-based Project Management System and Groupware System (Ahmad, Azhar & Ahmed 2002, Doherty 1997b, Skibniewski & Abduh 2000, Skibniewski & Nitithamyong 2004, Tam 1999). The following section reviews benefits and current levels of construction ICT use to help us understand the basic reasons for adopting ICT innovation.

2.2.1 *The benefits of ICT use in construction*

Many research studies have identified potential benefits to be derived from using ICT in construction processes (Abudayyeh 1998, Ahmad, Azhar & Ahmed 2002, Alshawi & Ingirige 2002, Björk 1999, 2002, Opfer 1997, Skibniewski & Abduh 2000, Skibniewski & Nitithamyong 2004, Sriprasert & Dawood 2002b, 2002c, Tam 1999). These ICT innovation benefits can be categorised from a strategy and construction operational view.
From the strategy view, ICT innovation is perceived as providing a key competitive advantage (Porter 1985a, Rackoff, Wiseman & Ullrich 1985, Tan 1996, Voordijk, Leuven & Laan 2003). Betts *et al.* (1991) argue that the construction industry should strategically plan ICT innovation. ICT innovation can impact company strategy in two ways: product or service differentiation, and cost reduction (Björnsson & Lundegård 1993). Gaining competitive advantage from using ICT in construction has been confirmed by several studies (Betts 1999, Betts *et al.* 1991, Björnsson & Lundegård 1993).

From a construction operational view, ICT can help to enhance communication and manage information construction processes (Björk 1999, 2002) and also benefit the management of construction projects (Abudayyeh *et al.* 2001, Alshawi & Ingirige 2002, Sriprasert & Dawood 2002a). For example, a study by Tam (1999) on the development of total information transfer systems for project management, demonstrates that the use of such systems can save considerable time and cost of document transfer. Second, ICT applications can help improve project planning and scheduling and cost control effectiveness (Abudayyeh *et al.* 2001, Skibniewski & Nitithamyong 2004, Sriprasert & Dawood 2002a) Third, ICT can improve data base distribution through use of a web-based electronic document management system (EDMS)—all documents can be stored in a central database and be simultaneously accessed from many locations (Björk 2002). ICT supports information integration among construction processes that helps to reduce errors from data re-entry and support real time construction project monitoring (Anumba 2000, Björk 1999). Having established the benefits of ICT use both from a strategic and operational point of view, details of how ICT innovation facilitates construction can now be further discussed.

2.2.1.1 Information integration

ICT innovation is a core technology facilitating information integration throughout the construction project life cycle from design to construction phases (Aouad *et al.* 1999). At the design phase, conceptual design information will be translated into working drawings.

Therefore if drawings are developed in a standard electronic format, then this information can be reused in subsequent construction processes such as estimation, planning, and construction management control (Koo & Fischer 2000). The advent of the computer aided design (CAD) software has had a significant impact on design document integration. Moving from a two-dimensional (2D) linear drawing to a three-dimensional (3D) object drawing provides potential for information integration. Furthermore, this object-based drawing concept further helps information integration over time to produce four-dimensional (4D) modelling (Koo & Fischer 2000, Sriprasert & Dawood 2002b, 2002c) This concept makes an object (for example a building structure) be represented over different time periods. This helps with visualising potential design clashes such as providing sufficient work space for building services and integrating structural information to build a 'fly through' visualisation of the design. Although construction information can be stored or integrated into a central database, its application could have to overcome two types of barriers. One is an *access barrier* to allow central database information to be accessed and exchanged from construction projects located in different locations. The second is an *interoperability barrier*, being able to translate and/or exchange data from one format into a compatible format used by other applications.

It is generally found that much design information is essential at the construction phase. Accurate information helps reduce data entry/modification time and errors that may occur during re-entry of design information. Several standards such as Industry Foundation Classes (IFCs) and XML have been developed to facilitate information integration. IFCs, developed by the IAI (International Alliance for Interoperability), attempt to develop a standard product model of construction objects so that software applications can integrate and share information about these objects throughout the construction project life cycle (Kosovac, Froese & Vanier 2000). For example a standard object about a door or window might hold a template of information to be transferred about not only its physical qualities, but also its cost, maintenance features etc. Another ICT standard, Extensible Markup Language (XML), was also developed to assist construction information exchange (Behrman 2002). XML is not a standard object but rather a language that uses a standard information exchange to enable different software applications to transfer and exchange information (Doherty 2004).

Although IFCs and XML have been developed from two different concepts, these standards have been developed to support construction communication that impacts upon productivity by reducing the time to re-enter data (Doherty 2004). In addition to standard communication protocols, recent virtual reality modelling language (VRML) technology has been used to enhance a web-based interface of construction to 3D models. Many research studies have argued the benefits of VRML and IFCs to integrate construction information throughout project life cycle (Anumba & Duke 1997, Deng *et al.* 2001, Mitev, Wilson & Wood-Harper 1996, Sriprasert & Dawood 2002b, 2002c). These argue that the use of VRML can provide a significant collaborative tool for project participants through visualising the construction process beforehand. These benefits are still severely under-realised because most project participants in the construction industry still have little knowledge of these technologies and how to effectively apply them.

2.2.1.2 Communication, collaboration, and project management

The construction industry is recently experiencing an emerging project procurement paradigm shift from operating as a stand-alone group of organisations, towards a more closely-knit supply chain. This promises a better coordinated and integrated activity flow between project participants. For this to be realised it is necessary to have collaboration tools to allow coordination among these teams (Anumba & Duke 1997, Deng *et al.* 2001, Mitev, Wilson & Wood-Harper 1996). ICT innovation tools such a groupware and collaboration software has been recently identified as offering an important tool for communicating, transferring and coordinating information among teams (Anumba & Duke 1997, Tam 1999). In addition, the use of such ICT innovations has been found to be an important factor for the construction project success (Poon, Potts & Cooper 2001, Walker 2003).

Vast amounts of information and documentation needs to be created and used to design and build construction projects (Duyshart 1997). During the construction phase, ICT innovation can support communication, management information, and document exchange within and among project members. Thus, ICT tools such as Electronic Document Management System (EDMS) can provide a possible solution to this challenge (Alshawi & Ingirige 2002, Björk 2002). Björk (2002) points out that the use of EDMS is an essential way to manage and enhance communication because it allows the precise delivery of documents and information to the right person in time and can reduce waiting time within any decision-making process (Rojas & Songer 1999). In addition, any EDMS document is also stored in a central database in which users can access and frequently update data and information. Based on a case study, Alshawi and Ingirige (2002) found that the use of ICT such as a web-based project management system (web-based PMS) can reduce the cost of construction reworks.

Thus, not only does ICT innovation increase the speed of information and document transfer, but it also helps in updating information and documents such as drawings, specifications, and forms that help managers make decisions based on the current information. Several researchers have attempted to develop tools for project management using a web-based platform (Abudayyeh *et al.* 2001, Sriprasert & Dawood 2002a). Other authors reviewing the current web-based project management applications in construction highlight their potential use for supporting construction management (Ahmad, Azhar & Ahmed 2002, Skibniewski & Abduh 2000). In particular, Skibniewski & Nitithamyong (2004) review current market web-based services that support project management systems (PMS). However, the use of these web-based PMS are still not widely prevalent in the construction industry (Alshawi & Ingirige 2002). A reason for this may be that most web-based PMS do not integrate the capability of project planning and control, but mainly focus on managing document and information. Skibniewski & Nitithamyong (2004) found that the barriers of using web-based PMS include password related problems, slow internet connection speed, lack of familiarity with current communication tools and immaturity of ICT use among project participants. Therefore, it is essential to explore how to best manage and diffuse an ICT application within construction organisations. To illustrate these problems and provide solutions, this research will focus on an Electronic Document Management System (EDMS) application as the ICT application that best represents the current problems of ICT use facing the construction industry.

2.2.1.3 E-procurement and e-commerce

ICT innovation can be used to enhance electronic procurement. During the invitation for bidding period, ICT innovation tools can be useful for publishing the bidding information on a website—this can as a minimum save printing and advertising costs. Second, it can provide a wider opportunity for changing the current pool of available bidders leading to better competition—this in turn, may result in a more competitive bid price (and or conditions) for the building owner. Third, as this process is performed electronically, it can save administration and travelling costs (Alshawi & Ingirige 2002). Another aspect of using ICT for supporting e-procurement is the development of a web-based construction contractor register (Ng, Palaneeswaran & Kumaraswamy 2003). The system allows contractors to submit their company information for performance evaluation through a web like pre-qualification system. This helps authorised clients to access real-time contractor's information. Table 2.1 illustrates current examples of using online-procurement in construction in Australia.

Table 2.1 List of government e-procurement websites

List of government e-procurement	Website
eTender: Department of public works in Queensland	http://www.projectservices.qld.gov.au/etender
Tenders: Department of public work in Sydney	http://www.dpws.nsw.gov.au/Tenders/Tenders.htm
eTendering: New South Wales Government	https://tenders.nsw.gov.au/
eTenders: State Government Tenders for Victoria	http://www.tenders.vic.gov.au/public/default.asp
SA Tenders & Contracts: Government of South Australia	http://www.tenders.sa.gov.au/
Contract and Procurement: Services: Northern Territory Government	http://notes.nt.gov.au/Tender.nsf
Queensland Purchasing: Queensland Government	http://www.qgm.qld.gov.au/
Tenders: State Government Tenders for Tasmania	http://www.tenders.tas.gov.au/domino/tenders.nsf
Basis: ACT Government	http://www.basis.act.gov.au/

Recently, electronic commerce (e-commerce) has been argued as an pressing benefit opportunity for the construction industry (Anumba & Ruikar 2002). This has already led private companies to develop an electronic transaction web-based portal e.g. ACONEX[4] and Optus inCITE[5]. One of the services in these portals is a tendering facility that contains details of trader members (suppliers and subcontractors). Clients, general contractors, buyers or estimators, can access information and bid and accept bids online. Skibniewski & Nitithamyong (2004) also illustrate examples of web-service sites that provide e-bidding and procurement. Another application of e-commerce is the construction material procurement system (Kong, Li & Love 2001, Kong, Li & Shen 2001). One benefit of trading online is having central information that links suppliers with buyers. A recent report by the UK centre for e-Business in Construction (CITE) [6] shows that tendering online can save information distribution costs by up to 90%. As a result, the use this type of ICT innovation can provide construction industry benefit by transforming traditional to e-commerce trading.

In conclusion, the benefits of using ICT innovation may influence construction at both strategic and operational levels. At a business strategy level, ICT could be used to establish a corporate differentiation strategy such as well as a cost reduction strategy. At an operational level, ICT can be used to help improve information exchange, communication and document sharing during the construction project life cycle. In addition, it can also enhance the process

[4] http://www.aconex.com/home.jsp, accessed July 2003
[5] http://www.optusincite.com, accessed July 2003
[6] http://www.cite.org.uk/tangiblebenefits.html, accessed July 2003

of construction procurement. These benefits should provide one of the primary drivers for ICT use and adoption in the construction industry. The next section will review current ICT use in the construction industry.

2.2.2 *Level of ICT use in construction*

The increasing trends of ICT use in the construction industry have also been found in many previous survey studies. As mentioned in the introduction, construction IT research surveys have been conducted in many regions for example in Canada (Rivard 2000); Saudi Arabia (O'Brien & Al-Biqami 1999); Hong Kong (Futcher & Rowlinson 1998, 1999); in Denmark (Howard & Samuelsson 1998); Finland (Howard, Kviniemi & Samuelsson 1998); New Zealand (Doherty 1997a); and in Australia (CSIRO 1996). Although these studies indicate that the ICT use is lower than general IT innovation, these findings indicate an increasing trend in the use of ICT in construction.

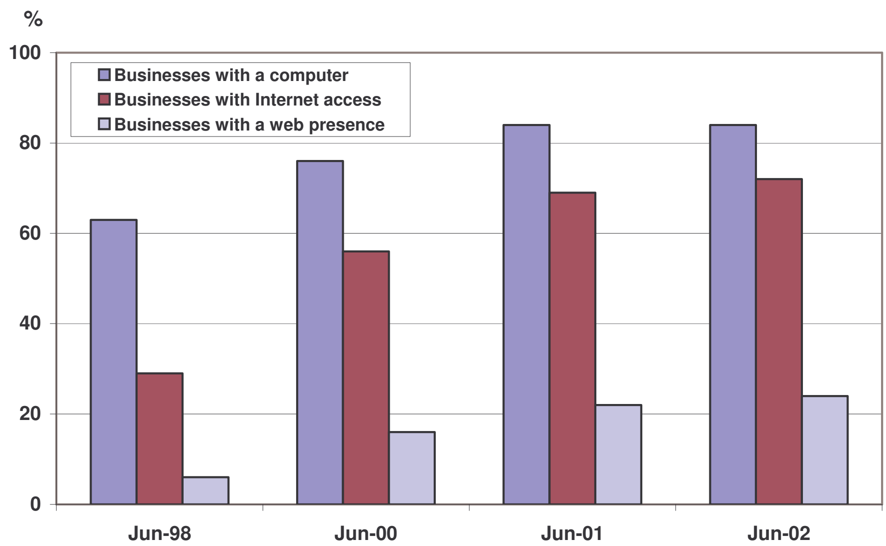


Figure 2.3 Australian business using information technology

The Australia Bureau Statistics (2003) shows that there is an increasing rate of ICT use and Internet access in all Australian businesses.

Figure 2.3 illustrates the statistical data between 1998 and 2001 showing that there was an increasing trend in businesses having Internet access and web presence. During 2001 and 2002, the businesses having Internet access increased to 72 per cent and those having web presence increased to 24 per cent.

It is now worth focusing on the Australian construction industry, to see whether it has a similar or different trend with respect to the overall trend in ICT use. Figure 2.4 summarises

ABS industry data between 1997 and 2001 and indicates that ICT use growth in Australian construction firms has been significant for the period 1998 to 2001. Internet use has increased from 17 per cent to 64 per cent, while the level of web presence by construction firms is still low, increasing from 4 per cent to only 10 per cent. Also, during 2001 and 2002 the level of Internet use and web presence remained similar.

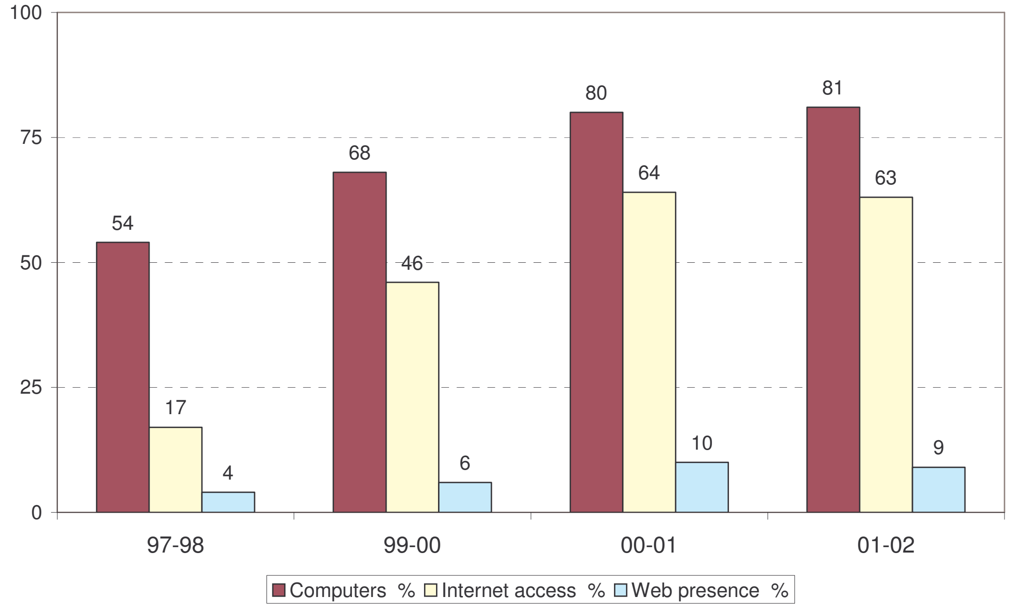


Figure 2.4 The use of ICT in Australian construction industry

Although the construction industry ICT use trend is increasing, the level of ICT use in the industry still has been low compared to other industries such as financial and insurance, property and business service and manufacturing etc. (NOIE 2001). This could indicate that the construction industry faces severe difficulties in ICT adoption and implementation.

Table 2.2 indicates that although there is an equal level of computer usage in both manufacturing and construction businesses at 81 per cent, ICT usage (e.g. Internet access and web presence) in manufacturing is higher than construction. For example, manufacturing businesses had 71 per cent of Internet access and 29 per cent of web presence while construction had 63 per cent and 9 per cent respectively. All this suggests that the construction industry should focus more on how to effectively adopt and implement ICT innovation.

Table 2.2 Business use of information technology (source: ABS 8129.0, 2003)

Industry	*Number of businesess (b) '000*	BUSINESSES WITH *Computer %*	*Internet access %*	*Web presence %*
Mining	2	89	81	30
Manufacturing	55	81	71	29
Electricity, gas and water supply	—	np	np	np
Construction	92	81	63	9
Wholesale trade	46	90	79	36
Retail trade	114	78	63	25
Accommodation, cafes and restaurants	34	72	57	31
Transport and storage	32	81	66	23
Communication services	5	83	64	22
Finance and insurance	26	90	84	25
Property and business services	150	94	87	30
Health and community services	55	89	72	15
Cultural and recreational services	19	87	80	36
Personal and other services	31	70	53	23

— nil or rounded to zero (including null cells)
np: not available for publication but included in totals where applicable, unless otherwise indicated

With the decrease of Internet cost and the growth of this technology, the adoption of information and communication technologies should be affordable. However, several barriers to ICT use and adoption are found. It would be useful to review these key barriers for ICT use in the construction industry.

2.2.3 *Barriers of ICT use and adoption in construction*

Several limiting barriers can influence ICT use and adoption. These barriers can be grouped into four main themes: the nature of the construction industry, high investment cost, technical barriers and lack of experience in ICT management.

Most of the barriers cited are attributable to the high cost of investment and the nature of the construction industry (Marsh & Finch 1998, Marsh & Flanagan 2000, Songer, Young & Davis 2001, Stephenson & Blaza 2001). Although the benefits of ICT use are well recognised, its adoption as a normal part of construction practice still faces barriers. A commonly assumed adoption barrier is the limited investment in ICT by the small and medium sized firms in general in the construction industry (Love *et al.* 2001). However, recent case studies reviews by Björk (2002) and O'Brien (2000) argue that technical problems and the cost of using ICT systems have less impact on organisational adoption of online document management systems and web-based project management systems.

The next barrier to ICT adoption is technical constraints. Problems in this area can be grouped into immaturity of technology, limited quality of technology, and non-standardisation. First, immaturity of technology can hinder the adoption decision because it may be difficult to attract organisational investment in ICT initiatives, particularly because investment costs are generally high in the early adoption stages (Love *et al.* 2001). The lack of maturity of technology affects not only investment cost but it also influences service quality performance such as reliability and speed of access (O'Brien 2000). For instance, access speed using Internet bandwidth through a traditional dialup service is slow and unreliable compared to ADSL modem technology. Another technology barrier is non-standard communication. This barrier is currently experienced with development of standard communication protocols such as STEP, IFC, and XML. The main objective of these technologies is to reuse, integrate, and exchange information between applications. Non-standardised communication solutions may have an impact on their adoption (Laage-Hellman & Gadde 1996, Underwood & Watson 2003).

The last barrier of ICT use and adoption is the lack of ICT management experience. As the ICT adoption and use involves both technical and social issues, it requires an understanding of ICT management in order to ensure that full benefit is gained from ICT investment. Recent research studies highlight ICT management barriers. For example, while many construction organisations attempt to gain benefits from ICT investment, they may merely obtain partial benefits if only a few people actually adopt and use it (Koskela & Kazi 2003). Markus (1987) argued that successful adoption of communication technologies requires a ‘critical mass’ of adopters who interact among themselves. Similar to earlier communication technologies such as phone and fax, ICT requires acceptance by a large numbers of users so that they can gain full benefits. For example, even within organisations where many users adopt ICT, they will find it difficult to communicate or transfer electronic information with colleagues who avoid using ICT. Under these circumstances, an organisation may lose any overall productivity gains while people will work with both paper and electronic data. One way to decrease these problems during ICT implementation is to ensure that users adopt and accept ICT as quickly as possible. Problems of ICT have been presented in terms of barriers relating to the nature of the construction industry, high cost of investment, technical barriers, and implementation barriers. The next section will focus on ICT management research literature.

2.3 Management of IT implementation within organisations

To understand issues related to ICT implementation management, it is necessary to review the literature on IT management studies undertaken within organisations. IT management within organisations refers to the way in which organisations plan and implement IT/IS initiatives to achieve their business objectives and results. IT management within organisations is critical and consists of three processes that predict the realisation of IT benefits (Andresen *et al.* 2000):

1. Strategic IT planning to support business strategy and opportunities (Ward & Griffiths 1996, p.96);
2. IT adoption and implementation decision-making to facilitate IT transformation within an organisation and to ensure ongoing use and adoption of IT (Eason 1988, p.157); and
3. Measurement of an IT investment and its benefits (Ho & Liu 2003, Love *et al.* 2000, Marsh & Flanagan 2000).

Many researchers argue that strategic information systems planning (SISP) is one of the most important topics of concerns to IS managers (Earl 1993, Hartono *et al.* 2003, Lederer & Sethi 1996, Wilson 1989). The purpose of SISP is to link business IS strategy, the IS/IT management strategy, and the IT strategy which in turn facilitates selection of the appropriate IT applications to meet business needs (Ward & Peppard 2002, p.41, 341). After the SISP has been developed the next process is IT implementation. According to Eason (1988, p.157), IT implementation is defined as the process that supports the transformation of IT into organisations and ensures that the organisation obtains expected benefits from IT investment by focusing on the actual use and adoption of an expected group of users in the organisation. Finally, the measurement of IT investment should be assessed to obtain feedback for continuously modifying the plan (Ho & Liu 2003, Love *et al.* 2000, Marsh & Flanagan 2000). Therefore, the key issues facing management of IT within an organisation can be categorised into four areas: (1) how to develop a successful IT plan, (2) how to decide on IT adoption, (3) how to manage the success of the IT transformation, and (4) how to measure actual IT investment benefits. The first two themes focus more on the strategic IT planning for corporate and business needs and IT adoption decision. The third theme specifically focuses on the *process* of how to adopt and implement IT for expected users within an organisation, and how to ensure their effective use and adoption of IT. The fourth theme involves the measurement of IT benefits from its investment.

2.3.1 *Strategic IT planning*

Strategic IT planning has been recognised as one of the primary areas that influence the success of IT implementation. Several terms have been proposed to guide the development of IT planning such as information systems planning, strategic information systems planning (SISP), information systems strategy planning, and business systems planning. These terms can be broadly categorised as strategic IT planning (Ward & Peppard 2002, p.119). Strategic IT planning is different from strategic IT thinking because it includes learning from previous experience and data, and then synthesising these data with innovative ideas to develop new vision and strategy (Mintzberg 1994). The main purpose of strategic IT planning is to examine an opportunity and to select the investment IT option that enhances a business need. Strategic IT planning helps to reduce problems of IT investment loss and to avoid investing in IT initiatives that provides less value-added benefits to the business than that planned for. Most studies on strategic IT planning focus on the techniques (Ward & Peppard 2002, p.86-111) and methods (Earl 1993) that help managers to analyse and prioritise IT initiatives and to also decide upon which aspects most benefit a business IS strategy. Earl (1993) argues that although there are many techniques and methods for developing an IT strategic plan, these objectives could be grouped into five common areas: (1) aligning IS with business goals, (2) search for a competitive advantage through IT, (3) drawing commitment from top management, (4) estimation of the appropriate resource needs, and (5) development of technology policy and future planing.

Many researchers have investigated predictive factors that ensure success of IT planning (Gottschalk 1999, Hartono *et al.* 2003). Factors that predict success of SISP focus on key variables that impact upon a successful IT plan and help to minimise IT plan failures to ensure that IT investments meet business requirements (Gottschalk 1999). Many argue that merely establishing an IT strategy plan is not enough to obtain IT adoption success (Earl 1993, Ward & Griffiths 1996, p.97, Wilson 1989).

While many researchers propose techniques and methods to help develop the SISP, they note that some barriers to successful plan realisation occur during the SISP implementation phase. Based on a study 186 organisations claimed to have an IT strategy, 73 per cent gave different rankings to the 11 barriers of IT plans ‘being set up’ and ‘implemented’. The results highlight key problems such as measuring benefits, nature of business, and difficulty in recruiting suitable staff (Wilson 1989). Earl (1993) argues that the success of SISP requires both planning and implementation. Earl (1993) interviewed three key persons in each of 21 leading UK companies on both benefits and barriers of SISP. The results identify the main barriers of IT planning as resource constraints, lack of implementation, lack of top management acceptance, length of time involved, and poor users-IS relationships (Earl 1993). Ward & Griffiths (1996, p.97) confirm that most organisations which claim to develop IT strategies actually face many problems during implementation.

In construction research, strategic IT planning has been suggested as useful for investigating IT applications that benefit the construction business objectives, prioritising available options, and decision-making on these. For example, Sarshar, Ridgway & Betts (1999) describe strategic IT planning techniques such as soft system methodology (SSM), information engineering (IE), and process innovation (PI). They found that an IE methodology provides for formal planning for measuring business objectives, critical factors, performance outcomes, priorities of IT application and information needs while SSM and PI use a less structured approach to obtaining information about business strategies.

Peña-Mora *et al.* (1999) developed a specific framework of information technology planning for a large scale A/E/C project. The framework consists of four main processes, namely environmental scanning, internal scrutiny, IT diffusion analysis, and IT investment modelling. Environmental scanning focuses on business objectives, relationships of IT programs and business objectives, and also on project participants who are involved in the IT project. The second emphasis is on understanding the stages of IT diffusion of both the internal organisation and external project participants. Next, the internal scrutiny emphasis aims to analyse processes in detail in an A/E/C project that can be deployed using an IT capability. Finally, the investment model helps to evaluate costs and benefits of IT investment. By using this framework, Peña-Mora & Tanaka (2002) developed a strategic IT planning framework for a major contractor. As a result, this framework helped the constructor to examine the external environment, internal process, stage of IT investment, and then to develop a map of benefits and costs for the IT investment.

Another framework was proposed by Jung & Gibson (1999). They developed a method framework for Computer Integrated Construction (CIC) planning. The framework links the relationships of IS concerns, business functions, and project life cycle. The evaluation and assessment of IT applications is not undertaken by an IT department alone, but also requires a business executive's view to share the company's strategy and senior managerial perspective on business functions (Jung & Gibson 1999). The analysis of CIC planning evaluates the value-added versus incremental investment score. The value-added score is measured by the integration of four main scores of corporate strategy, management, computer systems and information technology measurements. The incremental investment score is calculated from the estimation of IS investment requirement in each business function. By comparing the value-added and IS investment scores, the company would be able to prioritise the IS investment that provides a high added-value score that requires less IS investment.

Stewart, Mohamed & Daet (2002) developed a framework of strategic IT/IS implementation by integrating Strength, Weakness, Opportunity, and Treat (SWOT) analysis with Analytical Hierarchy Process (AHP) to prioritise the SWOT factors influencing IT/IS project. The main focus of this research aims to ensure the success of IT/IS implementation success by prioritising the issues such as enough resources allocation, user involvement, analysis of the organisation, and expected changes in the external environment, information technology to be implemented and so on.

From the above literature review, it is clear that strategic IT planning involves tools and methods that aim to help an IS manger formulate an IT plan that facilitates a business strategy. In addition, strategic IT planning assists in prioritising and selecting an IT investment as well as in assessing potential benefits. This should help managers to make a decision on what IT initiative should be invested in to gain the desired business result in a way optimises synergies the interaction between people, technology and organisational structure (Stewart, Mohamed & Daet 2002). Although strategic IT provides a comprehensive strategic plan to ensure IT success, it is not enough. It is essential that project managers and IT managers understand the decision-making adoption, drivers and enablers of IT implementation, and how these key processes drive IT innovation at the operational or end-users level.

2.3.2 *The IT adoption decision process*

Not only does successful IT management require detailed strategic IT planning but it also needs a matching IT adoption strategy. An IT adoption strategy is the decision making adoption approach within an organisation that implements an IT strategy. The first stage is awareness when an organisation searches for an IT solution to meet its strategy. One potential problem that is likely to occur that inhabits an organisation from moving beyond awareness is that the organisation becomes reluctant to adopt and invest in the required IT initiative. Early innovation adopters may fear that they are taking an unacceptable risk due to adoption uncertainties (Mitropoulos & Tatum 1999) while late adopters may fear losing competitive advantage benefits through offering novel services after others have offered those benefits (Love *et al.* 2001).

Many IT adoption studies have focused upon the adoption decision making stage of the technological innovation diffusion process. For example, Mitropoulos and Tatum (1999, 2000) explored criteria that forced organisations to adopt new IT such as 3D-CAD and EDMS. They concluded that these criteria are: a perceived need for competitive advantage; external requirements; technological opportunity; and finding solutions to process problems. They noted that organisations that tend to be early adopters are driven by competitive advantage or internal problem-solving processes. They also discovered that an external requirement such as a client's needs does not significantly influence their early adoption of innovations. Technological opportunity, therefore, appears to have a low impact on early adoption due to the high cost of technology and lack of required skills. Thus, the early adoption decision may be most significantly influenced by competitive advantage or need to solve process problems.

Few recent studies have focused on strategic adoption of IT innovation by construction firms. For example, a recent study of web-based project management implementation by Skibniewski & Abduh (2000) found that there are two strategies for adopting web-based project management. These strategic adoptions are *in-house development* and *outsourcing,* depending upon the level of internal systems and resources that support the main organisational functions. The former strategic adoption is suitable when there are sufficient resources to implement the initiative, and the latter is suitable when there are relatively fewer technical resources for development and maintenance.

Whyte & Bouchlaghem (2002) studied the top 20 house-building companies in the UK and found that there was only one company that was an early adopter of virtual reality (VR) systems. They reviewed the strategic adoption of VR systems and categorised its implementation approach as being either 'strategic' or 'ad hoc'. The 'strategic' approach considers software introduction based on long-term corporate strategy. The development of software involves top management support, user involvement, and a software developer. On the other hand, the 'ad hoc' approach was developed on a sub-strategy that depended on a special department's needs and short-term benefits. Under this approach, introduction of software needs the resource and policy support from a middle manager rather than from top management. Thus, although strategic adoption can be viewed as 'early adoption', an organisation may still choose an 'ad hoc' innovation adoption approach.

Mitropoulos & Tatum (2000) argued that strategic IT adoption behaviour may depend upon general organisational innovativeness. Like Rogers (1995), they argue that organisational innovativeness relies on variables such as leader characteristics, and characteristics of both the internal and external organisational structure. Although these characteristics can influence an organisational adoption decision, it can be argued that these variables are hard to change and thus can only be used to measure organisational innovativeness (Ginzberg 1981b). Thus, it would be of value that research should focus upon how innovation adoption strategy facilitates greater understanding of the nature of early and late adoption of innovation.

Organisational innovativeness and slack resources may significantly influence an adoption decision strategy. For example, Mitropoulos & Tatum (2000) found that contractors who have low innovative or technological capability will display a reactive attitude to IT adoption. After an organisation has made a decision to adopt IT, it should focus on developing a successful IT implementation process. This aspect is discussed in the next section.

2.3.3 *The IT implementation process*

Eason (1988) argues that an organisation attempts to transform its current IT practice by adapting it to its environment and then continues to maintain it through an IT implementation process. Bikson (1987) defines implementation as 'the translation of any tool or technique, process or method of doing, from knowledge to practice'. Tornatzky & Fleisher (1990, p.29) argue that implementation is a sub-process of innovation that occurs after the adoption decision. According to Griffith, Zammuto & Aiman-Smith (1999), implementation includes 'any process undertaken to institutionalise a new technology as a stable part of an organisation'. Thus, IT implementation implies management of its adoption and adaptation into the workplace in response to business objectives.

IT implementation management should play an essential role in creating a proper fit between organisational needs and user requirements (Korunka, Weiss & Zauchner 1997). In fact, IT implementation has been recognised as the one of the most difficult tasks and with several problems. Johnson (1995) found that 53 per cent of 3,682 IT projects in 365 companies were faced with costs-and-budgets overrun problems and 31% were cancelled. Korunka, Weiss & Zauchner (1997) found that inadequacy in managing IT implementation led to project cost overrun. Griffith, Zammuto & Aiman-Smith (1999) assert the root cause of IT failure is the 'invisibility problem' of implementation such as overestimation of a new IT initiative's value or lack of concern for people-related issues. They suggested that project managers should focus on implementation-related issues such as funding, support, and realistically estimating an initiative's technology benefits.

Two main approaches can be pursued to understand IT implementation: (1) a factor approach and (2) a process approach (Fichman 1992). A factor approach is focused on understanding the factors, variables or criteria that influence successful IT implementation. The aim of this approach is to predict and measure likely IT implementation success. A process approach focuses upon understanding key activities or stages of IT implementation so that the way in which the IT implementation can be understood and optimised depends on the nature of the prevailing circumstances. Both approaches can be used to better manage the development of IT maturity in an organisation. The details of two approaches will be discussed in the Section 2.4.3 .

2.3.4 *Measurement of IT benefit/performance*

Measurement of IT performance needs to be made to identify any gaps between expected and actual results. This helps us to monitor any IT implementation problems and improve our IT strategy. A measurement of expected results refers to the evaluation of expected IT benefits before IT implementation. This requires evidence of the IT impact on an organisation's operation and so it also depends upon a system of measuring impact that can be supported by evidence.

Baldwin *et al.* (1999), categorise IT innovation benefits as efficiency, effectiveness, and performance. Their study provides a guideline of IT benefits related to business but did not include measurement scales for these categories. Later, Marsh & Flanagan (2000) applied cost/benefit concepts to the evaluation of barcode systems by integrating the automation effects, informational effects, and transformation effects. Irani, Ezingeard & Grieve (1998) and Irani (1999) proposed that cost of IT/IS consists of direct cost factors, indirect human factors, and indirect organisational cost factors. Furthermore, Love *et al.* (2000) extend the Irani's concepts and proposed an IT/IS evaluation framework of costs/benefits by establishing a taxonomy of IT/IS benefits—strategic, tactical, and operational levels with an integrated taxonomy of indirect human costs and indirect organisational costs.

IT performance refers to measurement of actual results. Li (1996) and Irani, Ezingeard & Grieve (1997) argued that measurement tools such as financial ratios lack measurement of intangible benefits and they assert that IT performance measurement should include unquantifiable benefits such as user satisfaction, system flexibility, and system quality. Li (1996) suggests six performance indicators: information value, information quality, user satisfaction, information accessibility, management redundancy, and module compatibility to measure IT performance. A Balance Scorecard (BSC) approach was used for IT performance measurement by Stewart & Mohammed (2001). They applied the BSC with an analytic hierarchy process (AHP) and multi-attribute utility theory (MAUT) to measure construction IT/IS performance from five perspectives: operational, benefits, technology/system, strategic competitiveness, and user orientation. They broke down the measurement into four levels to measure each perspective:

1. Business objectives;
2. IT/IS performance perspective;
3. IT/IS performance indicators; and
4. IT/IS performance measures.

The calculation of performance begins at level 4 by applying utility function and weight to transfer the data into utility value that can be measured and compared.

Andresen *et al.* (2000) categorise IT benefits into efficiency benefits (quantifiable and valuable), effectiveness benefits (quantifiable but non-valuable) and business performance benefits (non-quantifiable and non-valuable). Under their framework, they measure both expected benefits and actual benefits. Empirical research conducted by National Institute of Standards and Technology (NIST) studies the relationships between IT use and project outcome (Thomas 1999). This study reveals that overall project performances have a positive relationship with the increase use of 3D, CAD, and EDI. The performance benefits via increasing IT use are mainly presented in forms of schedule compression, operating cost-saving, and decreased amount of rework. A review of the above studies stresses the key concept of IT performance measurement as being the identification of key performance indicators that provide a holistic measure of success, and then translating these indicators into measurable factors to provide quantifiable data for monitoring the level of success. In this way expected benefits are clear and unambiguous and there is a mechanism in place to determine the degree of success so as to allow corrective action to realign implementation plans.

The summary of the IT management literature illustrates four main processes crucial for successful IT/IS innovation management: strategic planning, the adoption decision, actual implementation, and measurement of benefits/performance. The IT implementation process is central to influencing the way that expected benefits are converted to the actual outcomes of IT investment. Therefore, this research will focus on management of IT implementation process.

2.4 Diffusion of innovation (DoI) in IT

It is widely accepted that IT implementation is a complex process, and related problems to it still continue to occur (Griffith, Zammuto & Aiman-Smith 1999), therefore an understanding of the IT implementation process could help minimise associated risks (Brancheau & Wetherbe 1990). This section explores the diffusion of innovation (DoI) to enhance the management of IT implementation. DoI theory helps explain the IT implementation within construction organisations. The following discussion explores: (1) relationships between adoption unit and its behaviour; (2) IT implementation from a DoI viewpoint; (3) the research approach related to IT diffusion; and (4) a critique of traditional IT diffusion theory.

2.4.1 *Relationships between adoption unit and its behaviour*

One of the essential features of innovation diffusion research is the focus upon the unit of innovation adoption. In general, the adopter can be considered as the person who accepts or rejects innovation. In fact, the unit of adoption may be focussed on either the individual or the organisation. Individual adoption refers to people who make their own decision about innovation adoption while organisational adoption refers to senior managers who make a decision for innovation adoption on behalf of an organisation (Agarwal, Tanniru & Wilemon

1997, Fichman 1992, Gallivan 2001). These differences in adoption emphasis may lead to further concern on the actual progression of diffusion in real situations found in organisations. Fichman (1992) argues that classical diffusion theory only explains the influence of individuals who play an independent role in the adoption decision, while it lacks an ability to explain the influence of organisational adoption.

In addition, the nature of the adoption decisions may be influenced by the innovation diffusion characteristics such as *independent* or *compulsory* adoption (Fichman 1992, Gallivan 2001, Prescott & Conger 1995). An *independent* adoption decision refers to a situation where the persons have autonomy to make an innovation judgment; whereas a *compulsory* adoption decision implies that the person has a limited choice on an adoption decision due the decision having been already made by the organisation. In addition, the unit of adoption such as individual, intra-organisational or inter-organisational, also has an impact upon the boundary of the IT diffusion decision-making process. Fichman (1992) provides a useful framework to analyse IT adoption and diffusion. This framework has been adapted below to explain the nature of IT diffusion.

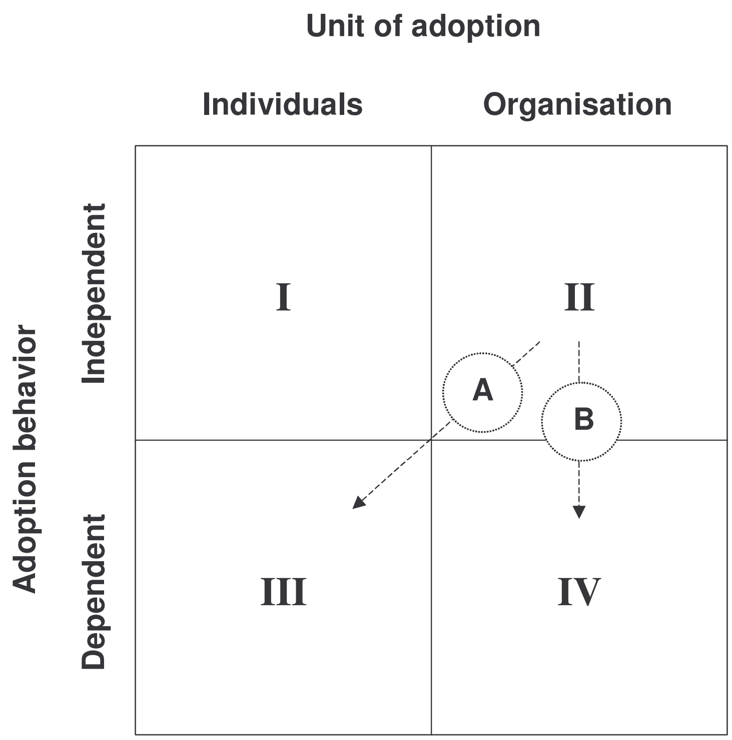


Figure 2.5 Framework of behaviour on innovation diffusion adapted from Fichman (1992)

Figure 2.5 illustrates the relationship between unit of adoption (x-axis) and nature of adoption decision or adoption behaviour (y-axis) and presents four possible different types of innovation diffusion characteristics. The framework illustrates the innovation diffusion adoption behaviour under four quadrants: namely individual adoption (I), organisational adoption (II), intra-organisational adoption (III), and inter-organisational adoption (IV). Quadrant I illustrates the situation where the unit of adoption is an individual with autonomous decision-making power to either adopt or reject the innovation. Most individuals usually make their adoption decision based on: their attitudes and characteristics (Coffin & MacIntyre 1999, Davis, Bagozzi & Warshaw 1989, Fishbein & Ajzen 1975), their previous experience (Igbaria, Iivari & Maragahh 1995) and available information from peers, a vendor or the mass media (Rogers 1983). Rogers (1983) argues that users will accept an innovation based on their general perceptions of the innovation. Type I innovation diffusion decisions depend upon communication channels through which information of the benefits of adopting the innovation is conveyed to individuals (Nilakanta & Scamell 1990a, Rogers 1983). Moreover, this type of innovation diffusion may support marketing research in the area of selling or predicting product adoption by expected customers (Mahajan & Muller 1979, 1990).

Quadrant II illustrates the situation where the unit of adoption is an organisation and the adoption decision is primarily made by senior managers (Regan & O'Connor 2000). Senior managers have an independent and significant role as the representative of the organisation. Therefore the senior managers' vision would influence the adoption decision. Additional research highlights that characteristics of managers may not be the only criteria for the adoption decision (Harrison, Mykytyn Jr. & Riemenschneider 1997). Type II innovation diffusion decision is depend upon organisational variables such as structure, size, and innovativeness (Lai 1997, Leonard-Barton 1988, Mitropoulos & Tatum 1999, 2000). The adoption decision is therefore influenced by organisational variables and is still categorised as an independent behaviour, as the management decision to adopt is not forced by other organisations. Such innovation adoption decisions are mainly influenced by competitive advantage and problem-solving forces (Mitropoulos & Tatum 1999, 2000). However, good strategic IT planning requires threats and opportunity forces in the external environment to be taken into consideration when making this type of decision (Stewart, Mohamed & Daet 2002).

Quadrant III illustrates the situation where an organisation primarily adopts innovation and encourages users of the innovation throughout the organisation to adopt it. Individual adoption is therefore dependent on organisational adoption (Gallivan 2001). Other research studies defined two terms related to behaviour in this quadrant: infusion and assimilation (Cooper & Zmud 1990, Fichman & Kemerer 1999). Agarwal, Tanniru & Wilemon (1997) define assimilation as a combination of adoption and diffusion, but in this current research diffusion is defined as the initial adoption and actual implementation process. Under this quadrant behaviour circumstance, an individual adoption decision may result in a different outcome from the organisational expectation (Griffith, Zammuto & Aiman-Smith 1999)—this conflict may lead to a situation called an '*assimilation gap*' (Fichman & Kemerer 1999). To minimise such problems, the organisation should plan for innovation adoption and diffusion (Regan & O'Connor 2000). Gallivan (2001) and Fichman (1992) argued that classical DoI may require modification to explain diffusion because it involves adoption from both a primary adopter (organisation) and an individual adopter. This can be found as the mix of factors in this research, present in both quadrants I and II.

From the above discussion, diffusion behaviour in quadrant III is more complicated because it involves several factors, which are needed to be managed properly. For example, Armstrong & Sambamurthy (1999) suggest that senior management should play an active role by interacting with business mangers to ensure that IT supports business objectives. This interaction between senior management and business managers can help IT assimilation into the organisation because the interaction leads to an interchange of knowledge from both points of view. In addition they argue that supporting infrastructure is a key IT assimilation driver. However, an empirical study by Cooper & Zmud (1990) found that technology compatibility seems to be a less important factor after infusion, which may be influenced by political and learning issues. While management and technology influenced the IT diffusion, Kappelman (1995) asserts that both user and participant involvement may influence IT diffusion success. This explains why the user participant (behaviour engagement) can develop a positive attitude to engagement or user involvement. Attewell (1992) found that management should not overlook the importance of learning required by users when adopting an IT innovation. As a result, it appears that diffusion behaviour is highly complex and requires further research.

Quadrant IV illustrates the situation of mutually dependent adoption decisions (Prescott & Conger 1995). Prescott & Conger (1995) reviewed 70 published papers related to DoI, and classified the differences among units of adoptions. They grouped the nature of diffusion into intra and inter-organisational adoptions and explained that success of an inter-organisational adoption is required for either subsequent organisational adoptions to occur or for the initial adoption to be influenced by external environments. This type of research examines how relationships influence adoption behaviours. One example is the adoption of electronic data interchange (EDI), in which the adoption and diffusion is dependent upon organisational trading members (Ramamurthy & Premkumar 1995). Their survey of senior managers in 83 firms supports the theory that the success of EDI diffusion among members requires the commitment and adoption coordination from all participants in a supply chain using EDI. This type of research involves interaction among participating organisations that would ultimately lead to the adoption decision. In addition, Prescott & Conger (1995) found that inter-organisational innovation adoption can be explained by critical mass and economic theory rather than DoI.

This framework places innovation adoption research in quadrants I and II, whereas research in quadrants III and IV may be classified as both innovation adoption and diffusion. Although the research foci of quadrants III and IV are different from the research foci in quadrants I and II, it could be argued that quadrants III and IV are an extension of adoption from independent organisational adoption. This is represented in quadrant II as the arrows A and B (Figure 2.5). The research to be undertaken in this thesis is focused on quadrant III (dependent individual adoption and diffusion) where the unit of study of adoption and diffusion is individual staff within a specific organisation. Rather than examine the extent of innovation diffusion in construction organisations, this research aims to understand the nature of innovation (particularly of information and communication technology (ICT) diffusion within an experienced construction organisation. The study of experienced construction organisations could help us to learn from early adopters and explore the essential variables and processes that generally occur as a normal practice in that type of organisation.

Another interesting framework of IT adoption and diffusion is proposed by Agarwal, Tanniru & Wilemon (1997). Their framework focuses more specifically on the diffusion of IT innovation within the organisation. Based on the relationships between adoption and diffusion behaviour, they established four main scenarios of IT diffusion that occur within organisations. These are illustrated in Figure 2.6 as:

1. Individual adoption and individual diffusion;
2. Individual adoption and organisation diffusion;
3. Organisational adoption and individual diffusion; and
4. Organisational adoption and organisational diffusion.

		Diffusion	
		Individual	*Organisational*
Adoption	*Individual*	Cell 1 Individual adoption + Individual diffusion	Cell 2 Individual adoption + Organisational diffusion
	Organisational	Cell 3 Organisational adoption + Individual diffusion	Cell 4 Organisational adoption + Organisational diffusion

Figure 2.6 Framework of intra-organisational diffusion adapted from Agarwal, Tanniru & Wilemon (1997)

From the synthesis of the above two IT diffusion frameworks, the review illustrates that IT diffusion in a generic case can vary from individual adoption to organisational adoption. However, the nature of IT diffusion within an organisation may be a combination of individual adoption and organisational adoption. The different nature of IT diffusion within an organisation can be influenced by the type and complexity of IT innovation that the organisation intends to adopt. At the same time, the different natures of IT diffusion may be dependent upon the number of adopters. Based on these two frameworks, this research is focused on intra-organisational adoption Type III in Figure 2.5 and more specifically it focuses upon the adoption at both individual and organisational levels (cell 3 and cell 4 in Figure 2.6).

2.4.2 *IT implementation from DoI viewpoint*

This section explains the link between diffusion of innovation (DoI) theory and IT implementation. It focuses on the research idea of how DoI theory can be used to explain IT implementation. Based on many empirical diffusion research studies by Rogers (1983), diffusion of innovation is defined as *'the process by which an innovation is communicated through certain channels over time among the members of a social system'*. This definition of IT implementation appears highly relevant to discussion on the barriers to IT use identified in section 2.2.3. This is because the DoI process involves the introduction of innovation to expected users in an organisation and encouragement of their IT use. Thus, the nature of individual IT implementation and group adoption can be seen as a DoI concept in which an innovation has been introduced and adopted by potential users within a social setting (Rogers 1983).

Research on intra-organisational diffusion of IT innovation is different from classical diffusion theory. This is because intra-organisational diffusion of IT innovation is introduced by top management or opinion leaders and then members throughout the organisation are encouraged to adopt the IT innovation. Classical diffusion theory is focused on the independent adoption decision made by users (Carlopio 1998, Fichman 1992). In addition, Wolfe (1994) points out that traditional DoI research focuses on how innovation is communicated to members in a social setting to explain why an innovation is independently adopted or rejected. Traditional DoI, however, fails to explain why so many adopted innovations have failed during the implementation phase or why they sometimes cause negative perceptions of IT use among adopters. Therefore, it is essential to modify classical diffusion theory to explain how IT innovation diffusion is undertaken within an organisational context (Fichman 1992, Gallivan 2001).

2.4.3 *Research approach related to IT diffusion*

To understand the nature of IT diffusion, it is essential to review the research approach related to IT adoption and diffusion. Kwon & Zmud (1987) categorise IT implementation research into a factor research approach, a process research approach, and a political research approach. However, the political research approach could be better categorised as a subset of the factor approach because it concerns factors that hinder IT diffusion. Fichman (1992) also suggested that IT diffusion can be studied from a factor and process approach. This PhD research focuses on both the factors and processes that affect IT diffusion within an organisation. Further details of the research are explained in Chapter 3 and 4.

2.4.3.1 Factor research approach in IT diffusion

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

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

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

Some factors seem to have a different impact when they occur at different stages. For example, Cooper & Zmud (1990) determined that the managerial interactions influenced an inventory control system throughout diffusion stages. However, such interactions only influenced the introduction rather than actual implementation of that particular innovation. Kwon (1990) identified separate prior and post-implementation DoI stages. Infusion is defined as the final stage of IT implementation whereas adoption is defined as the introduction stage. Kwon (1990) also found that interpersonal communication and innovation maturity are two key factors influencing technology infusion. This thesis will explore the factors that influence the diffusion of ICT at the actual implementation stage within construction organisations and examine how these factors influence ICT diffusion process.

2.4.3.2 Process research approach in IT diffusion

This section discusses technology transfer aspects and intra-organisational innovation diffusion aspect. Scheirer (1983) defined the technology transfer aspect of innovation diffusion as an approach in which information of innovation is transferred from a research and development (R&D) unit to targeted consumers, either individuals or organisational units.

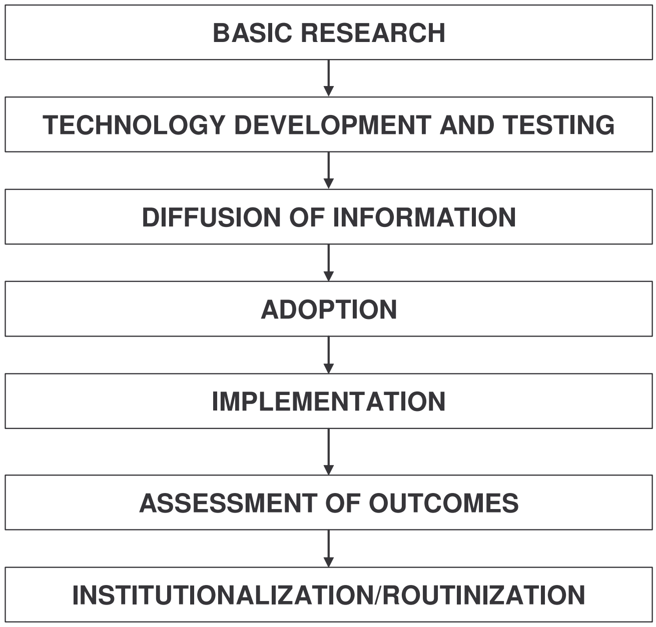


Figure 2.7 Framework of innovation transfer (Scheirer 1983)

Scheirer (1983) explored technology transfer processes that explained how technology has been developed and transferred into organisation in a model of innovation diffusion. Figure 2.7 illustrates this sequence. It begins with basic research that is subsequently developed and tested. After that process, it is essential for diffusion of information to expected adopters emphasising the positive aspects and benefits of the innovation. The more effective the information delivery process is to expected adopters, the greater will be the expected adoption rate. Then, the organisation or the adopter will be better prepared to decide whether to adopt the innovation and begin its implementation. This DoI phase is therefore focused on delivery innovation to support or improve work processes. After the implementation occurs, it is essential to measure and evaluate the outcome of innovation investment to decide whether to use the innovation as part of a normal routine (routinisation) or to reject using it.

From an intra-organisational innovation diffusion aspect, it can be argued that different organisations have their own specific processes and culture, which in turn, cause inconsistent outcome of innovation implementation. As the implementation of innovation deals with several technological and social variables, it could be argued that simple management of IT implementation may not be enough. It is essential that the organisation should provide intensive management support and to monitor the organisational innovation diffusion. This aspect of innovation diffusion within the organisation is supported by Carlopio (1998). He proposed a framework of innovation diffusion in workplace environments. He adopted Rogers' DoI model and extends the use of this model at the individual/group level. His framework indicates that the diffusion of innovation may occur at both organisational and individual/group levels as later indicated in 'Part A' of Figure 2.9.

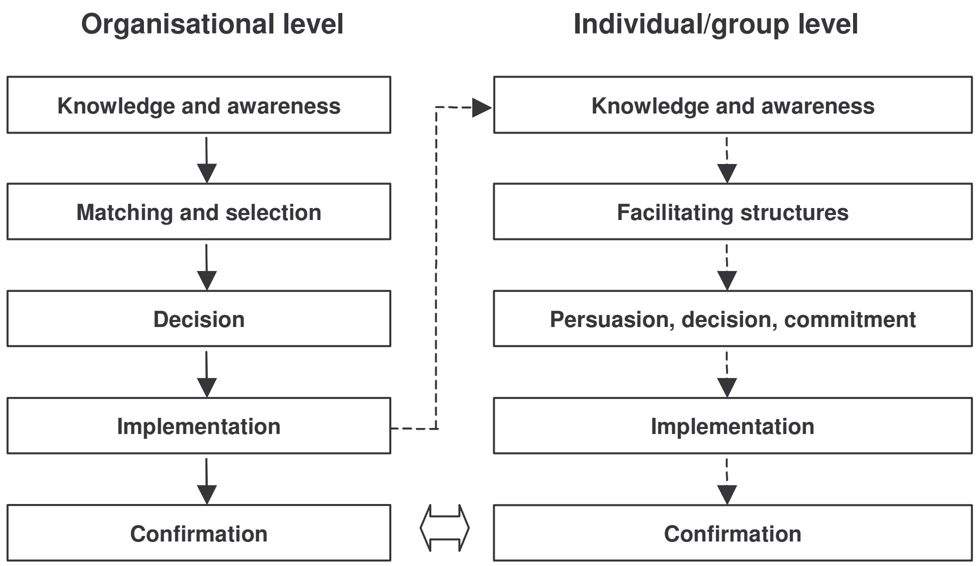


Figure 2.8 The levels of implementation process of innovation diffusion, adapted from Carlopio (1998)

Figure 2.8 illustrates the organisational innovation diffusion process as a cyclical loop beginning with knowledge awareness then moving through matching and selection, decision, implementation, and confirmation. In addition, the implementation at the organisation level consists of replicated sequences of innovation diffusion, but with innovation diffusion occurring at individual/group levels. At the individual/group level, innovation diffusion is focused on members who are expected to adopt it. This is similar to identified different behaviours between dependent and independent adoption aspects discussed in the previous section.

Innovation diffusion plays an important role in theories describing information technology (IT) implementation (Rogers 1995). Innovation diffusion can be studied using both factor and process approaches (Fichman 1992). The former approach focuses on the *'what'*-key factors influencing adoption and diffusion- whereas the process approach focus relates to *'how'* of adoption and diffusion. In addition, the unit of technological innovation adoption could be grouped into *macro*, *meso*, and *micro* levels (Iivari 1993). *Macro* level innovation theory focuses on organisational adopters. *Micro* innovation level theory focuses on the individual adopters and *meso* innovation is classified as being in between these previous two and focuses more on an organisation as consisting of series of individual adopters. The *meso* innovation theory is identified as being best suited to study innovation within organisations.

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

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

As traditional adoption models rely on voluntary adoption decision by individuals, they may be less suitable in explaining complex organisational adoption decisions (Gallivan 2001). Success in technology adoption within organisations needs top-level implementation support and encouragement of expected users to individually adopt and use the technology. To overcome the traditional innovation adoption approach, Fichman (1992) recommended integrating DoI with other theories such as critical mass (Markus 1987), absorptive capacity (Cohen & Levinthal 1990), and organisational learning (Attewell 1992). Similarly the adoption of technological innovation into organisations can be seen as a change initiation process affecting the way people work. Based on traditional DoI, the rate of technology diffusion adoption can be predicted by technological characteristics, communication channels, and social systems (Rogers 1995).

In addition, traditional innovation diffusion within an organisation requires change management to facilitate and encourage people to adopt ICT initiatives. Organisations can do this through: motivating staff; providing appropriate training and technical support; and ensuring supervisor support for an open-discussion sharing environment (Senge *et al.* 1999)

According to Cooper and Zmud (1990), the model of organisational adoption and its implementation consist of six stages: initiation; adoption; adaptation; acceptance; routinisation; and infusion (Figure 2.9, part B). This stage model has been used for measuring technology adoption maturity based on the characteristics of each stage (Damsgaard & Scheepers 2000) and this model can be argued as applicable to ICT diffusion using the same management processes. The development of such a model will be addressed later in chapter 9 in which this research is adapted to the innovation diffusion stage models and extends the model by integrating the factors and processes with innovation stages.

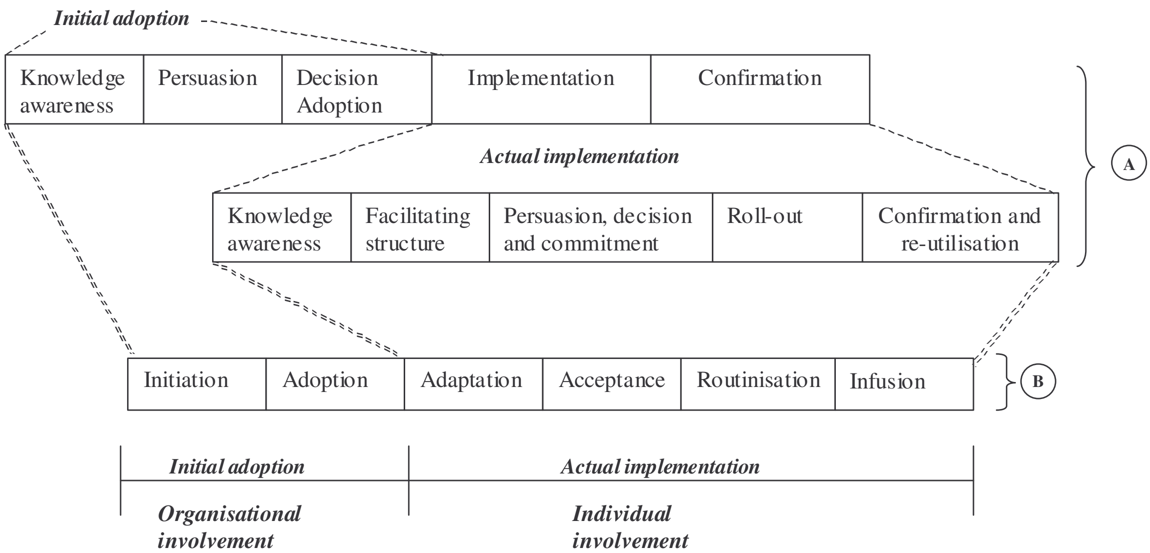


Figure 2.9 Stage model of technology diffusion adapted from Rogers (1995) [A], Carlopio (1998) [A] and Cooper and Zmud (1990) [B]

2.4.4 *Critique of traditional DoI theory*

IT innovation diffusion research studies have been applied to independent inter-organisational adoption that occurs within project-based organisations. They focus on the inter-relationships between organisations that influence the use of technology within industry. However, few of these studies have been focused on understanding how to diffuse ICT within a construction organisation at the actual implementation stage (Regan & O'Connor 2000, Whyte & Bouchlaghem 2001).

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

2.5 Management of change

The previous section provides the concept of innovation diffusion as a theory that can be applied to understand IT implementation. This section complements identified DoI theory gaps with concepts drawn from change management, and consists of three main subsections. First, it begins with the view of change management in relation to IT implementation and discusses how change management assists in understanding IT implementation. Next, it highlights the concept of change management. Then, it will describe the support roles that are involved in IT transformational change. Finally, it concludes with the variables related to the management of IT change.

2.5.1 *IT implementation problems related to change management*

Many IT innovations have been developed to effectively enhance work processes. The problem of putting these innovations into practice, however, remains (Leonard-Barton & Kraus 1985). Scott Morton (1991, p.12) points out that IT has been focused on the development of a *'physical product and standard'* but it is less concerned with how to exploit IT into work practices. When an organisation invests in an IT innovation and implements it to facilitate users' capability in their work, users should ideally accept the introduction of the IT innovation. But the introduction of IT in practice does not always follow a managerial plan, especially when it is implemented into a workplace (Orlikowski & Hofman 1997, Regan & O'Connor 2000, p.361). In addition, this problem can be seen as a perception gap between the proposed value articulated by an IT developer (or the organisation's champion of that initiative) and the actual benefits experienced by IT innovation users (Griffith, Zammuto & Aiman-Smith 1999). One explanation of this problem is that IT implementation is not static and simple but rather it involves a change process in which an organisation introduces IT and encourages its use. Wolek (1975, p. 38) also stated that *'part of the problem of implementation is that the difficulty is directly related to the extent of change in management behaviour that is required'*. Also, IT implementation problems can be described in terms of changing IT end-users' behaviour (Regan & O'Connor 2000, p.360). Consequently, critical issues encountered during IT implementation should include change related issues because of the users' need to adapt their behaviour to fit new tools and work practices relating to the IT innovation's use.

2.5.2 *Change constraints related to IT implementation*

IT implementation related problems were viewed as change management issues that relate to changing organisational behaviour and processes and/or users' behaviour. This section further explores change constraints related to IT implementation and highlights reasons behind the change. These constraints focus upon change related to IT implementation; some of these may overlap with IT implementation problems. However, such problems will be described in the context of change management constraints.

Change constraints occur because IT management often only focuses on technical problems rather than organisational problems (Humphrey 1989). Markus, and Benjamin (1997) claim that the failure of IT change derives from the traditional belief of managers and IT experts that technology is a *'magic bullet'* and so they neglect the essential role of people in any change management task. Nevertheless, this claim does not intend to place less importance on technical issues. In fact, solving technical issues can minimise barriers from users' resistance to technological innovation. (Martinko, Henry & Zmud 1996) argue that IT implementation failure is more likely to occur because of *'user's resistance'*, especially as it involves the change of users' behaviour to handle new tools. Thus, IT implementation success is often realised by managers who understand the management of technological change (Mckersie & Walton 1991, Regan & O'Connor 2000, p.361). Therefore, this review needs to focus on change constraints grouped into barrier categories such as individual users, group users, and organisational, management, and technology influences.

Martinko, Henry & Zmud (1996) identify users' resistance at the individual level as a barrier to be confronted during IT implementation change. Users' resistance to change can hinder organisational productivity because they tend to stick to a proven technology that they already know can facilitate their work practices (Robbins 1998). Regan & O'Connor (2000, p.361) in particular found that implementation of IT related organisational change should focus on changing users' behaviour because the success of IT transformation cannot occur without the final commitment of those who actually use it.

In addition, others have also identified factors relating to users' resistance such as personal fear, anxiety and attitude (Anderson 1996, Igbaria & Parasuraman 1989, Sarker 2000). Personal fear of change usually occurs from users' fear of loss of their productivity and professional capability. Productivity fear of loss occurs when users feel uncomfortable with an IT innovation that they have to take time to learn how to use (Koskela & Kazi 2003). Thus, some users may resist using an IT innovation because they think it will harm their productivity, especially within organisations that focus only on measuring the productivity without considering change constraints. The second fear is the loss of professional capability because the introduction of an IT innovation sometimes harms their professional capability. Sarker (2000) gives the example of programmers who were reluctant to use new programming tools because these tools requires less skill. This is an example of technology that can create professional career insecurity.

Insufficient experience and knowledge about a computer application may lead to high anxiety. Based on a survey data of 166 managers, Igbaria, Magid & Parasuraman (1989) found education and training to have a negative influence on computer anxiety and positive influence on their attitude toward computers. Martocchio (1994) also argues that the reduction of computer anxiety may be managed by providing training to create personal self-efficacy in people before they are forced to use IT. Also, Igbaria, Magid & Parasuraman (1989) found that anxiety itself has a strong negative influence on manager's attitude toward computer technology. Barriers related to user groups could occur in different ways such as ICT interfering in their normal routine, coping with differences to their conventional systems, and an ICT intervention being unsuited to their norms and group cultures.

First, the introduction of IT can be seen as a routine organisational intervention, however can interrupt the *'status quo'* or normal routine of people's work (Regan & O'Connor 2000, p.361). This change requires people to change their work procedures and to learn how to operate with new IT and/or new systems. Thus, the more IT innovation supports personal work processes, the more users will intend to use it (Yetton, Johnston & Craig 1994). The second barrier IT related to group users is their having to cope with different IT applications. This can occur by user groups having to contribute to a common process using different IT applications or through their using the same application but with different versions. A typical example of this is several work groups (project participant teams) using different planning and scheduling software to plan and monitor the same project or a site team using a different version that is incompatible with a head office team. Thus, the experience of using incompatible versions or conflicting ICT application products may create difficulties in transferring files or communications. These barriers are related to technical problems called *'compatibility'*. Songer, Young & Davis (2001) point out that corporate culture, rather than technology issues, can be a key barrier to IT implementation. Thus, if the IT application in use did not fit with users' norms or their group culture, the introduction of an IT application could be problematic.

At an organisational level, resistance to change can be grouped into several contexts such as investment cost, political issues, fear of change, intervention into routine, difference with conventional systems, and unsuitability to norms (McShane, Travaglione & Marshall 2003). The first two resistances could be classified as a management barrier whereas the last three variables could be classified as a group barrier. Barriers to change may also be derived from management issues such as inexperience of the IT manager, aggregation of IT benefits, political issues and/or fear of change. First, inexperience of an IT manager can lead to problems of IT change. Carlopio (1998) states inexperienced managers may incorrectly view technological change as being a static event concerned only with buying a technology without thinking through how to implement it. Lack of concern about the impact of change on culture and people may lead to IT implementation failure (Davis and Songer, 2002). A second change barrier derives from management's over-estimation of IT benefits in order to obtain IT project funding (Griffith, Zammuto & Aiman-Smith 1999). McKersie and Walton (1991, p.271) cite examples of IT managers attempting to launch projects without a clear understanding of people at the *'coal face'* expected to work with the IT applications and also their overestimation of IT outcomes. This can result in organisational change problems because outcomes rarely meet users' needs. The third barrier for change is from the management of political issues. Keen (1981) highlights that political influence may cause social inertia because managers feel that they may lose their autonomy and control over information or knowledge. Markus (1983) emphasises that the introduction of IT can increase or reduce the power of adopters. This in turn influences the IT user adoption and/or resistance. Finally, fear of change also has a direct impact. Griffith, Zammuto & Aiman-Smith (1999) found that some managers are reluctant to change because they don't want to face uncertainty in project productivity that might reflect poorly on their management performance.

In addition to barriers to change stemming from the impact of management of individuals and groups of users, the characteristics of IT also produces resistance to change. Cannon (1994) identifies that failure of IT implementation may be due to large project scope, unrealised benefits, lack of users' acceptance, lack of management support, and IT inexperience. This issue involves IT innovation system complexity. Markus (1983) argues that IT application design has an impact on the time it takes for users to learn how to operate these tools. Regan & O'Connor (2000, p.371) agree that IT application design characteristics such as users' interface and functionality can influence the use of an IT system. Similarly Markus & Keil (1994) state that *'software usability'* is a key factor impacting on unused IT systems. Songer, Young & Davis (2001) confirm that IT characteristics are of primary concern during IT implementation. Thus, research should be focused on transforming IT change within organisations to reduce technology problems (Munkvold, 1999).

In understanding how change management should support implementation, it is essential to answer two basic questions: (1) What are the differences between change management and IT implementation? and (2) How does change management assist IT implementation?

The answer to the first question is that change management must be focused on the reaction of users and their need to adapt their behaviour towards actual IT implementation. Thus, the main objectives of change management are preparation of users for change, avoidance of user resistance, and minimisation of a turbulent period. On the other hand, IT implementation is focused on how to design and develop IT to fit with users' requirements.

To answer the second question, as many researchers have pointed out, there is the need for an effective change management process. For example, Benjamin (1993) suggests that the successful IT transformation requires an IT implementation change management process. Mckersie & Walton (1991) explain that the success of IT implementation requires a change management strategy that involves people, structure, and process issues. Regan & O'Connor (2000) state that change management is important because end users are required to change their behaviour on how to use IT innovation. From the above perspectives, it could be argued that change management can complement IT implementation by ensuring that an effective environment is provided within an organisation for use and diffusion of IT.

2.5.3 *Concept of change management*

This section reviews several change models to understand the development of the change management concept in relation to IT innovation within an organisation. These models use Leavitt's system model, Lewin's force field model, MIT's strategic change, Galbraith's *'Star'* model, and Senge's model of drivers and barriers to change.

One of the change models that link the impact of IT innovation change is Leavitt's system model (Leavitt 1965). Figure 2.10 illustrates the relationship between four independent elements: technology, structure, process (task), and people. Changes in technology can influence organisations to enhance or improve the effectiveness of their current work processes. However, technology change is not enough; it is necessary to change the organisational structure, its process, and behaviour of people.

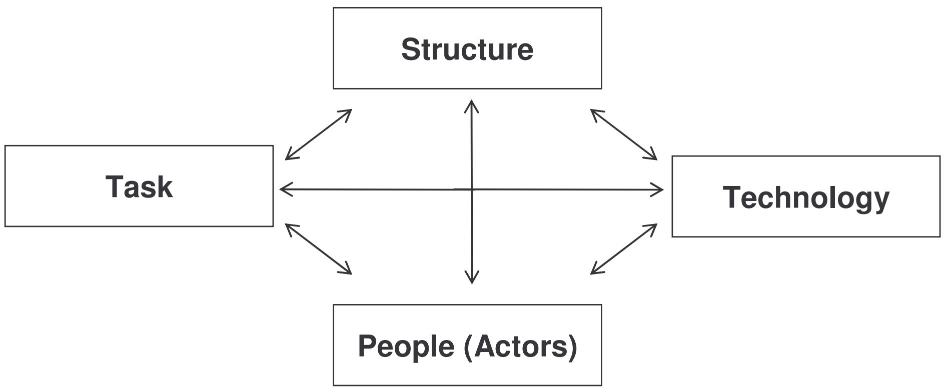


Figure 2.10 Organisational change from Leavitt's model (1965: p.1145)

Lewin's force field model (1958) describes change in terms of a balance between driving forces and restraining forces. The driving force creates the change environment in an organisation, and is called *unfreezing*. Once the driving force occurs, restraining forces resist and block the driving force that attempts to change peoples' behaviour. These forces will interact until they are in equilibrium, and this is called *refreezing*. From Lewin's force model, IT implementation can be described as a change process of reducing ICT users' resistance behaviour (Martinko, Henry & Zmud 1996).

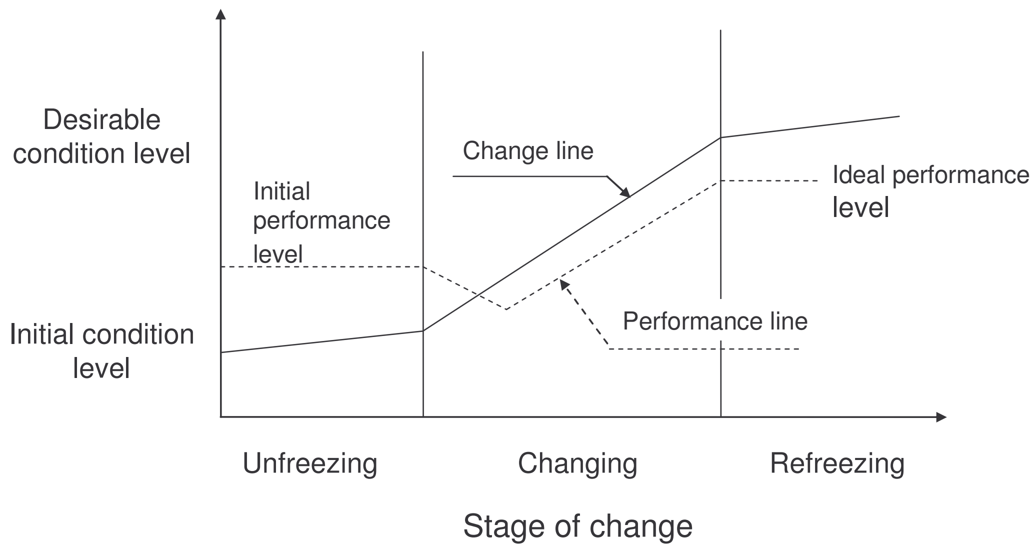


Figure 2.11 Lewin's force field model (adapted from Lewin, 1958)

In the 1990s, MIT management started a research project about the impact of IT on business strategy, organisational structure and operational management. As a result of this research, they concluded that there are five elements linking IT and organisational transformation. The five elements are strategy, structure, management processes, individual skills and roles, and technology. All elements have an effect on the others both directly and indirectly.

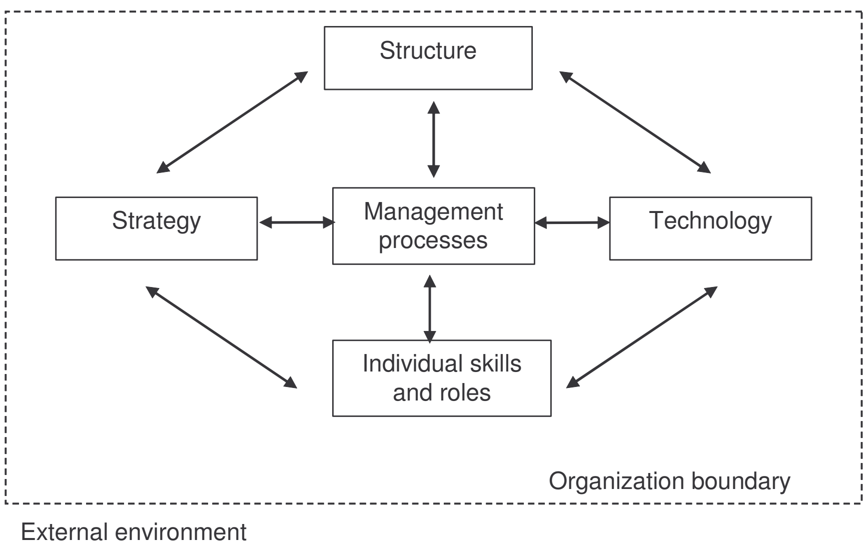


Figure 2.12 The MIT's strategic change (adapted from Scott Morton1991, p.20)

MIT's model offers useful insights into IT transformation change within organisations. It highlights the influence of factors from both internal and external environments. Based on the model, all elements are implicitly controlled in a business strategy. However Yetton, Johnston & Yetton (1994) claim that MIT's model lacks a direction on how organisations should begin their change. They extended the MIT's strategic change into three main interactions and show the path of IT strategy that occurs during the IT change transformation. Figure 2.13 and Figure 2.13 illustrate findings from a case study of computer-aided design (CAD) Two IT transformation strategies are described, using the *'conventional way'* (top-down) and a 'strategic path' (bottom up) direction.

Figure 2.13 illustrates conventional technology transformation starting at the beginning of an IT strategy by adjusting the structure and then managing processes that consist of a suitable management process, technology, individual skills and clear role definition. In this model, it can be interpreted that IT management has a strong relationship with technology, individual skill and roles.

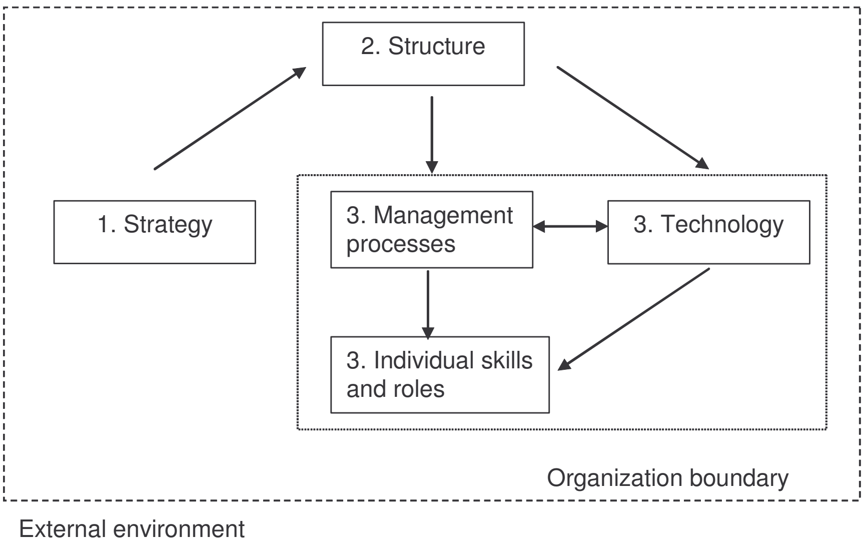


Figure 2.13 Traditional path of strategic fit (adapted from Yetton, Johnston & Craig 1994, p.62)

On the other hand, the strategic path framework illustrated in Figure 2.14 shows the influence beginning from introducing technology and then training staff to understand systems because they need to understand and be familiar with any new technology. The role of staff should be extended in order to reflect the benefit of using IT. The structure of a company should be adjusted to match the staff's skill and role; for example, architectural skill has also to be combined with CAD drafting abilities. At the same time, management and control processes should be integrated to improve computer infrastructure that supports communication and file transfer. IT can influence not only organisation processes but also company strategy.

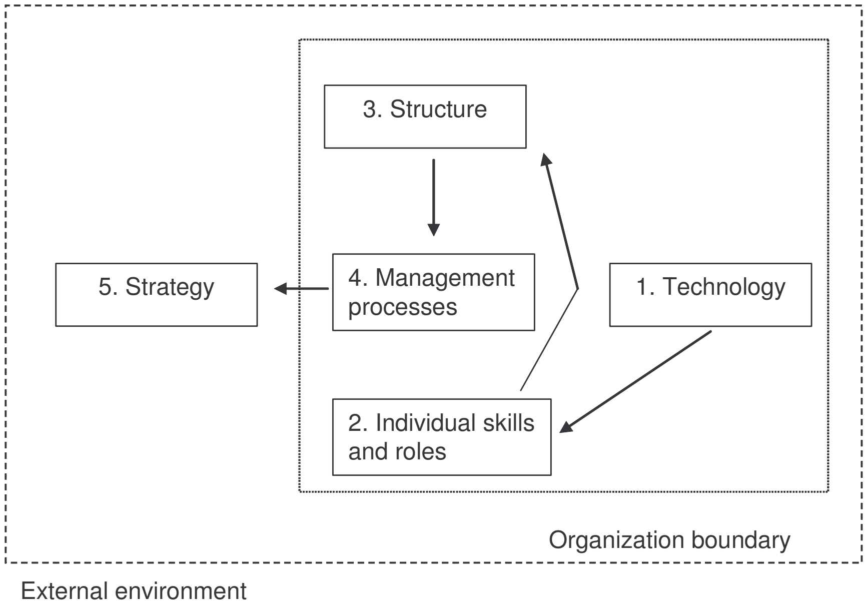


Figure 2.14 The path of strategic fit (adapted from Yetton, Johnston & Craig 1994, p.63)

These two models highlight the interaction of the main factors and have allowed for the sequence of strategic changes that may occur within an organisation.

Figure 2.15 shows the change model proposed by Galbraith (2002) with an inter-relationship among key five factors: strategy, tasks, structure, people, processes and reward. The model also provides a path of change according to hierarchical relationships. In the Star model, *Strategy* imposes the *Task* of developing a vision and objectives, which are then prioritised. Next, a *Structure* is developed that involves *People,* who implement the change using defined accountabilities, roles and responsibilities. This activity is undertaken in conjunction with the identification and implementation of the skills and developmental needs of the *People*. *Processes* are undertaken to enable the development of change processes to take place—these include protocols or rules and regulations, communication means and coordination mechanisms. *People*, with their skills and willingness, make change possible. The *Reward* system motivates people to ensure that the required action takes place.

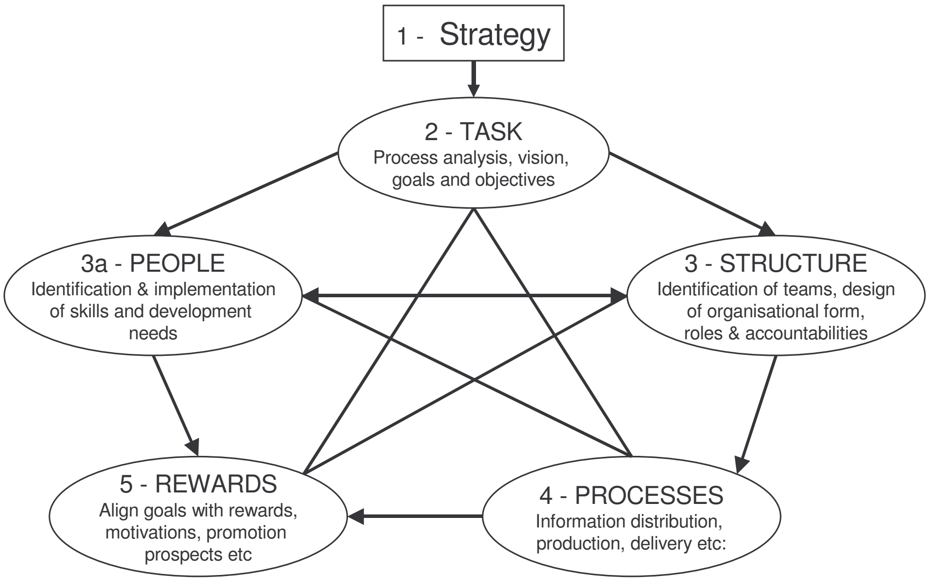


Figure 2.15 The Galbraith 'Star' model of change management (adapted from Galbraith 2002, p.10)

Not only do several models focus on factors that influence the change within an organisation, but other models also focus on barriers that hinder the transformation. Kirveennummi, Hirvo & Eriksson (1998) argue that the focus on overcoming barriers is important in successful change processes. They also extend Lewin's change stage to explain barriers to change in their Barriers Identification Framework (BIF) as illustrated in Figure 2.16. The framework shows barriers at the unfreezing, changing, and refreezing stages of change. They tested the framework with a library organisation and found that this framework is useful to identify barriers that occur during change. However, they found that some barriers might occur in particular phases and other barriers overlap several phases. Therefore, it could be concluded that barriers influence the success of IT transformation differently in particular phases.

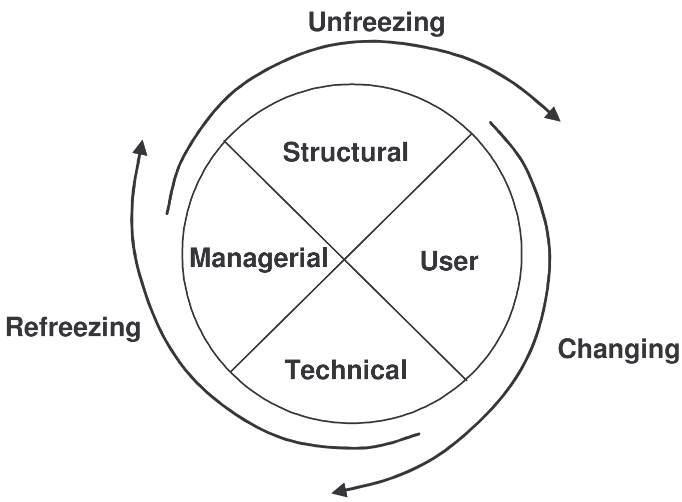


Figure 2.16 The model of BIF (Barriers identification framework) adapted from Kirveennummi, Hirvo & Eriksson (1998)

Senge *et al.* (1999) propose a useful set of models for explaining drivers and inhibitors (barriers) to change, implementing innovation or enabling the kinds of organisational cultural transformation that must be made for effective IT innovation. Figure 2.17 illustrates change management drivers defined by Senge *et al.* (1999, p.54) interpreted by Walker (2003, p.274-275) . In this model, the management of change is described by three driving cycles.

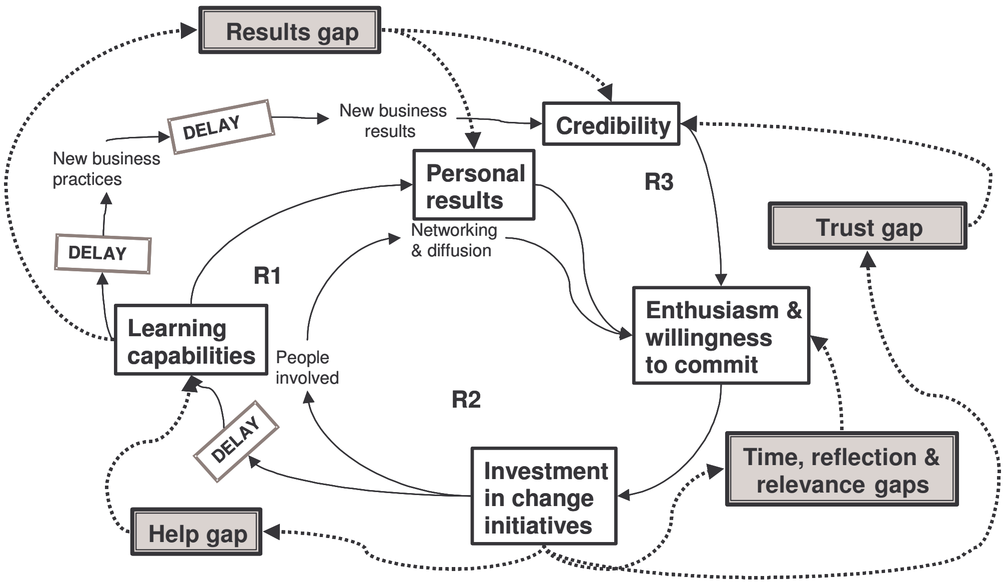


Figure 2.17 Drivers and barriers to change (Adapted from Senge, Kleiner et al. 1999, p54)

Walker (2003) explain organisational change by adapting the concept of learning development of Senge *et al.* (1999). They understand that the development of learning capabilities is similar to the change concept that occurs within an organization because when staff learn something new they intend to adapt their knowledge or change their behaviour or practices. Based on a diagram proposed by Senge *et al.* (1999, p.54), there are three reinforcing cycles of change. In cycle R1, the root of change involves the encouragement of individual/staff to have a commitment and enthusiasm to change. Senge *et al.* (1999) emphasise that the success of sustainable change is needed to make staff understand the personal benefits/results that positively influence them. To make staff clear about their benefits, it is essential to invest in change initiatives in which staff can experience and learn from a change until they realise the benefits from the change. Cycle R2 represents the interaction of group learning that involves informal networking and idea sharing among staff. The result of the staff's interaction can facilitate the diffusion of knowledge. This social interaction of tacit knowledge helps to make knowledge explicit (Nonaka, Toyama & Konno 2001, Nonaka & Takeuchi 1995b) and this further reinforces a sense of worth and value for knowledge workers. This learning and sharing knowledge can build enthusiasm and commitment throughout the staff within an organisation. Cycle R3 shows the business results for an organizational change initiative. Senge *et al.* (1999) state that the outcome of business results may take several years to achieve because it involves individual learning processes. Thus, successful business results require not only fundamental reinforcement by individual commitment and network learning, but also needed to demonstrate business results. Positive business results can build credibility that reinforces further commitment and willingness for continuous change by top managers and staff members. Walker (2003, p.274-275) argued that 'if the cycle is not subject to atrophy then success will build upon success. This would be an ideal condition that is rarely fully experienced because of restraining cycles that adversely impact upon this virtuous cycle'.

In practice, these reinforcing cycles of change may be delayed by several constraints. The impact of constraints can be represented as the gaps between expected and actual results that affect the momentum of change drivers (Griffith, Zammuto & Aiman-Smith 1999). The delays that may occur during the processes of change include: the delay of creating individual learning and learning environment, the delay of developing network sharing and trust, and the delay of developing new business practice. These delays can be explained by constraints called *gaps,* for example a help gap, a time, reflection and relevance gap, a trust gap, and a result gap. Walker (2003) explains that these gaps indicate how enthusiasm and a willingness to commit undermine a change initiative—in this case, behavioural change to deliver an effective team-working environment to support ICT diffusion.

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

2.5.4 *Support roles in IT transformation change*

The above sections discussed key variables in IT transformational change concepts. This section describes the actor's role that facilitates successful IT implementation change. As the IT change implementation involves many issues both at technical and human levels, it requires different actors to support IT change. Also, understanding an actor's role will help organisations to define and assign staff responsibility and what role that these actors should fulfil. McKersie and Walton (1991, p.262) highlight key roles for IT transformational change: top management, middle management, users, and user representatives. These key roles are essential to delivery of IT project success.

Several terms such as champion, change agent, coach, coordinator, and mediator is established to explain the key roles in facilitating the IT implementation and change processes (Mckersie & Walton 1991, p.262). Each support role has a significantly different responsibility in the organisation. Gray (1998) defined the four support key roles as:

- ***Sponsor*** - person who has a control over the resources and commits to providing resources to the IT project.
- ***Champion*** - person who initiates the IT project and is involved in the process improvement. A champion is involved in, promotes, and controls the IT implementation within the resources provided by the sponsor.
- ***Change agent*** **–** a person who brings the IT implementation project to life. A change agent may be faced with unexpected resistance and problems. The main role of a change agent includes skill improvement and dealing with operational problems. A change agent normally follows the strategic plan set by the champion and gets extra resources from sponsors via the champion.
- ***Coach*** **-** person who acts as the consultant for the change agent. When the change agent is faced with problems, the coach seeks suggestions for IT process improvement and management of IT change.

Comparing these roles to observed practice in construction organisations, support roles could be viewed as constituting an additional support department in construction organisations because the main perceived role of construction workers is centred upon construction production activities. The use of IT in construction organisations is recognised as only a tool to enhance their work processes. In addition, most construction workers have a limited knowledge of new IT innovations and their adaptation to use IT is slow. However, some construction workers may have taken their own personal interest in IT innovation. Thus, these types of construction workers can not only support IT implementation but also facilitate IT diffusion and change within their organisations.

Although the concept of change management can facilitate the success of IT implementation and transformation, Markus & Benjamin (1997) argued that IT implementation failure can still occur. They state that 'people do not see other ways to accomplish the same goals and do not take proactive, effective measures to keep change on track' (Markus & Benjamin 1997, p. 56). For example, users need to learn from whom to use IT and also understand the reasons for change. In addition, implementers and IT specialists should also understand their assigned roles and actual practices in relation to change management (Markus & Keil 1994).

2.5.5 *Need for change in IT implementation*

According to the above discussion, change management concepts should be useful for managing IT change during the implementation period. There are three reasons to support this idea. First, IT implementation involves factors such as organisational support, individual support, technology support, and work environment support (Scott Morton 1991). These factors influence the complex processes involved in the transformation of new technology, i.e. its 'institutionalisation' (Griffith, Zammuto & Aiman-Smith 1999). Thus, these factors need continuous management and control for successful IT implementation (Mckersie & Walton 1991). Second, unrealistic or unviable plans may result from an unclear understanding of an IT implementation's 'invisible' problems and this may cause difficulties with IT change management during the implementation phase. Planning assumption problems could include overestimating IT benefits, having unbalanced budget allocations between technology and people, or using biased capacity data from an IT vendor (Griffith, Zammuto & Aiman-Smith 1999). Therefore it is necessary for organisations to adapt to change and make more realistic plans. Last, IT implementation can be seen as a change process that requires appropriate time to allow change to become accepted. Munkvold (1999) argues that managers should understand all barriers that can limit effective IT transitions and so it its vital to focus upon understanding how to best achieve IT transformation within organisations. Therefore, a clear understanding of change management not only helps managers to deal with IT implementation problems but it also assists them to initially formulate realistic transformational plans.

2.6 Learning and knowledge sharing to encourage IT implementation

The third concept involving IT implementation is learning and knowledge sharing. As mentioned earlier, IT implementation needs users to learn how to operate new IT tools. Therefore, learning should be part of intra-organisational IT implementation diffusion (Attewell 1992). Learning may be categorised as self-learning, learning from an expert, and learning from a peer. Self-learning is the process in which individuals attempt to learn by themselves from written sources or through experience—trial and error. Self-learning is therefore dependent on personal characteristics and IT experience. Learning from domain experts is a viable alternative way of learning that is dependent upon knowledge, expert availability and quality of communication between experts and novices. This is traditionally provided through training, short courses, or university courses. Third, learning from peers occurs when users share their personal experiences of their IT innovation use. This usually occurs when peers have a high level of confidence in using IT or have used the IT innovation for relevant periods of time. Learning from peers is a source of IT implementation support where people have specific operational questions that require a rapid and effective response to address the specific, usually urgent, problem.

Learning and sharing knowledge can be seen as formal or informal. Formal learning occurs when organisations formally provide knowledge resources and encourage delivery of IT knowledge into and within the organisation. For example, an organisation may provide training and a technical help desk that supports IT uses. Informal learning occurs during social interaction between group members.

Communities of practice (COPs) generate knowledge networks that enhance and sustain competitive advantage and they are also used to help COP members actually use ICT tools. Etienne Wenger defines communities of practice as ‘groups of people informally bound together by shared expertise and passion for a joint enterprise’ (Wenger & Snyder 2000, p.139). This ‘chicken-or-egg’ argument about needing a COP to use the tools that are needed to effectively broaden COPs (beyond co-located groups) indicates the need to explore how best to improve the process of ICT diffusion through construction organisations—primarily using people supported by technology that improves knowledge sharing among people who need to use ICT.

At the organisational level, diffusion of innovation depends on how well organisations can absorb external sources of innovation as well as develop their internal capacity through trial and error experimentation and piloting, research and development and supporting learning systems (Cohen & Levinthal 1990). Absorptive capacity is one of the essential factors that sustain innovation and its diffusion through building up an experience and knowledge base that can be drawn upon when needed to develop or diffuse innovation. This infrastructure capacity helps to provide not only the technical and knowledge enablers of innovation and its diffusion, but also can be used to help to build an organic organisation, often unofficial, that utilises external and internal sources of knowledge to enhance the internal innovative process or product. Due to the individual features of an organisation's business processes, the adoption of external innovation needs to be modified to suit its specific business objective.

At the individual level, innovation diffusion depends upon information or knowledge gatekeepers who help transfer innovative knowledge from external and internal sources to the internal unit of organisation. These gatekeepers interpret or transform knowledge into simple language to fit the environmental context of known target groups (Rogers 1995). Diffusion could not be achieved if individuals within an organisational unit do not accept the innovation and convince others to use it.

At the group level, people naturally tend to form knowledge networks to share and re-frame knowledge that they routinely or occasionally use. History provides many such examples of learning communities. Trades and guilds of Europe are one medieval example, with more recent cases of COPs being documented in many organisations. One example from the Daimler Chrysler Corporation reports groups of people being clustered around a particular skill to form 'tech clubs' (Wenger, McDermott & Snyder 2002). The power of people forming small groups to learn from each other has triggered a great deal of interest and led to the concept of communities of practice (COP). Lave and Wenger (1991) first introduced this term when studying forms of apprenticeship and social groups and studied how these communities shared not only knowledge but also the culture of access to knowledge and its use to diffuse complex tacit knowledge. A COP shares knowledge and skills and sustains its members through obligation to exchange knowledge, providing access and accessibility to shared insights and knowledge about the practice of work (Wenger, McDermott & Snyder 2002, p4).

People helping each other by sharing knowledge can occur within the context of one-to-one relationships as either isolated or continued instances and indeed this is a normal feature of working on joint problem-solving activities. More often people are working in groups so that there are 'many-to-many', '1-to-many' or 'many-to-1' communication patterns. Groups can become teams but they are distinguishable. A team is defined as 'a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable' (Katzenbach & Smith 1993, p.45). However, as Katzenbach & Smith (1993, p.89) argue, 'a working group uses its purpose solely to delineate individual roles, tasks, and responsibilities. Those roles typically match formal organisational positions. To get their assigned tasks done, working group members, especially at senior levels, usually delegate the real work to others beyond the group.' Groups exchange information, knowledge perspectives and insights as well as act as a point of further reference, but there is unlikely to be the depth of focus that is evident in teams working toward realising a particular project.

Table 2.3 Differences between teams and COPs (adapted from Wenger et al. (2002, p.42 and Bourne (2003, p.14)

	Teams	**COPs**
Nature of formation	Selected through resourcing processes	Generally formed through voluntary and informal processes
Term	Temporary and finite: until the project is complete	It depends: the COP will remain as long as its members consider it has a purpose
Duration	Set up a specific time period for team joining Team members will be desegregated after finish the project	Don't specify time The member COPs will be finished if the members feel that it is not their interest
Structure	Each team member will have a specific role and 'place' in the team	Peers with a common purpose.
Purpose	Deliver the 'result' (building, system, change) Organisation determines a specific goal and time framework to achieve goal	Sharing of knowledge Members determine group interest and share their knowledge in natural manner
Operating principle	Command and control	Collaboration and commitment
"Legitimation" (power+authority relations)	Formal hierarchy /leadership	Informal and dynamic/ fluctuating membership Status in COPs must be earned
Essential success ingredients	Trust, shared 'vision' and purpose Commitment	Trust, shared 'vision' and purpose Commitment
Type of knowledge	Explicit knowledge and information (documentation, processes, report)	Tacit knowledge (stories practical experience, lessen- learn, tips)
Communication mode	Formal (formal meeting) Formal meeting	Informal (social activity and peer group, conference) *Ad hoc* and informal meeting

The distinction between teams and COPs is clear and relevant because there is often a different purpose for each, though there can be a designed development of integrating COPs and teams to help realise team goals and objectives. As Wenger *et al* (2002) have demonstrated, companies that creatively engage with COPs realise a significant set of knowledge assets and competencies that would otherwise be unobtainable.

Table 2.3 developed from ideas offered by Wenger, McDermott & Snyder (2002, p42) and Bourne (2003, p.14) assists us to understand the differences between teams and COPs. It highlights the difficulty in assuming that teams naturally are COPs or that they can naturally become COPs where sharing knowledge becomes the cultural foundation that distinguishes them from other associations of people solving complex problems. COPs are distinguished by being more informal and self-referential than teams as is the duration of the association. Motivation also differs between these groups as do operating principals, legitimacy and ingredients of success. The type of knowledge exchanged is generally different and the communication mode also different between teams and COPs.

This begs the question: how can organisations harness the power of COPs in engaging with teams to solve complex problems? Part of the answer lies in the levels of formality, so this stressed the importance of cultural factors and a management style that facilitates learning and professional development as well as actively supporting interaction and questioning the status quo to explore many potential solutions in an atmosphere of open and honest discussion. This can be further explained with reference to Figure 2.18.

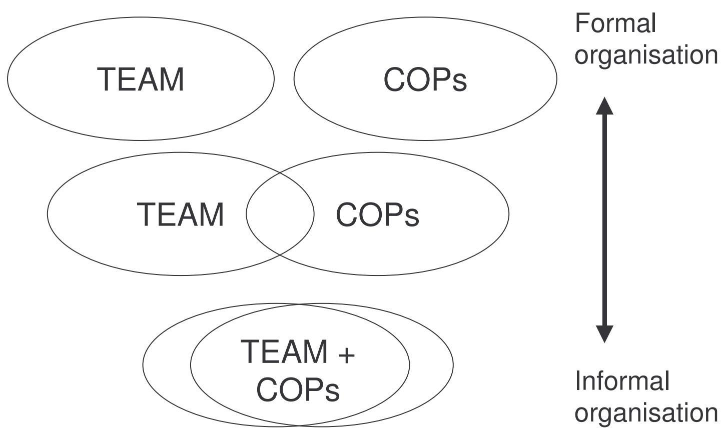


Figure 2.18 Formal/informal organisation structure for teams and COPs

This idea may help to explain the relationship between teams and COPs by the level of formal and informal structure/style of management of organisations. The two groups (teams and

COPs) in a formal organisation may be more separated than those in informal organisations. If an organisation can inject a combination of informality as well as its formal team governance arrangements then it has an opportunity to integrate the potential knowledge assets of COPs with that of any given team. The formal-informal requirement also has another interesting dimension—trust. In one sense formal team governance can engender trust because it establishes a set of rules that everyone knows should be adhered to and so there is an element of predictability and near-certainly about the way that activities take place. Also Wenger *et al.* (2002, p.51) argue that a set of guiding principles needs to be addressed when developing or nurturing COPs and they promote seven principles for cultivating a COP that is akin to a formal team working on a project. Their principles do appear to engender trust from rules and principles that apply, namely:

- Designing the community of practice for evolution;
- Having an open dialogue between inside and outside perspectives;
- Inviting different levels and intensity of participation;
- Developing both public and private community spaces;
- Having a focus on value; combining familiarity and excitement; and
- Creating a rhythm for the community, where activities fall into a natural flow that supports relationship building and knowledge exchange and where people's contribution ebbs and flows. People enter various levels of a COP, from core participants who actively participate and share knowledge through to 'lurkers' whose contribution ebbs and flows with their engagement.

An interesting case study of a project spawning a community of practice is the Xerox Transition Alliance reported by Storck & Hill (2000b). This was an example of a strategic community of practice of 50 IT specialists responsible for maintaining 70,000 workstations and 1,200 servers in which Xerox top management deliberately established the alliance to serve as a vehicle for diffusing new ICT. The interesting aspect of this case that is relevant to our discussion in this chapter is that this community of practice was designed and developed for ICT diffusion and it was judged a success that endured as a more recognisable community of practice after the project aim of ICT diffusion was achieved. It was facilitated and formally enacted and recognised many of the informal imperatives that characterise COPs, but it has been termed as a 'strategic COP'. Six principles were highlighted:

- Design an interaction format that promotes openness and allows for serendipity;

- Build upon a common organisational culture;
- Demonstrate the existence of mutual interests after initial success at resolving issues and achieving corporate goals;
- Leverage those aspects of the organisational culture that respect the value of collective learning;
- Embed knowledge-sharing practices into the work processes of the group; and
- Establish an environment in which knowledge sharing is based upon processes and cultural norms defined by the community rather than on other parts of the organisation (Storck & Hill 2000b, pp.73-74).

The implications of the theory proposed by Wenger, McDermott & Snyder (2002) and Storck & Hill (2000b) for the construction industry is that a COP approach to encouraging ICT diffusion in particular, and knowledge sharing in general, is both valid and to be encouraged.

As learning and shared knowledge influences IT implementation, it should be interesting to further explore how this concept supports the previous two theories that were outlined earlier. In fact, learning and knowledge sharing can be seen as part of the previous two concepts of innovation diffusion and change management. For example, part of innovation diffusion involves communication channels that contain both mass media and interpersonal channels (Rogers 1976). These channels can influence awareness of IT use and transfer of knowledge among ICT users. Change management also highlights the importance of development of an open discussion and sharing environment (Senge *et al.* 1999). Therefore, learning and sharing knowledge should be integrated into the model developed through this PhD thesis.

2.7 Summary of chapter

This chapter reviews six main topics: construction industry and technological innovation, ICT innovation in construction, management of IT implementation, IT innovation diffusion, and change management. The first section shows the basic nature of industry and links to the need of technology, in particularly ICT innovation. The second section reviews the current ICT use and problems facing ICT use in the construction industry. To understand the previous concepts related to ICT implementation, it was necessary to explore the concepts that apply to generic IT implementation. This allowed the following sections to focus upon IT innovation. The third section moves forward to understand the context of management of IT implementation and focused on issues of IT implementation. The fourth section extended the discussion to help understand the concept of DoI theory and focused on how DoI helps to explain IT implementation. A critique of DoI was then presented to highlight gaps in the theory. In the last two sections, the concepts of change management and knowledge management were discussed. These concepts supplement identified DoI variables that could be investigated to better understand key issues influencing IT diffusion within organisations.

IT implementation was identified as one of the critical processes of IT management. It was argued that IT implementation is difficult to manage because it involves several uncertain issues relating to technology and people. To overcome this problem, this research attempts to integrate three important concepts: diffusion of innovation (DoI), change management, and knowledge sharing.

Although DoI is a broadly applicable concept, this research applies it to explain ICT innovation within construction organisations. The DoI concept contributes variables that influence users to adopt IT innovation. The change management concept provides supplementary variables relating to sustaining IT innovation use within organisations. Similarly, knowledge sharing is also a supplementary DoI concept by enabling users' interaction through sharing knowledge. This chapter provides a background of these three concepts that links IT implementation. In the next chapter, the integration of these three concepts will be more fully applied to focus on ICT innovation within construction organisations.

Chapter 3
Development of factors influencing ICT diffusion

Chapter 2 introduced IT management, DoI theory, change management, and knowledge management/sharing and learning theory. The aim of this chapter is to further extend DoI theory by integrating it with change management and knowledge sharing theory to better explain actual ICT implementation within construction organisations. The chapter begins with an explanation of the need to understand ICT adoption strategy and actual ICT implementation within construction organisations. This is followed by the development of a conceptual model that integrates DoI, change management, and learning and sharing knowledge. The model contains five main areas related to ICT implementation. Analysis of this model focuses on variables and processes that influence IT implementation. Finally, development of the research questions for conducting and evaluating interviews about users' experience is explained.

3.1 Challenges of current ICT implementation

Section 2.2.1, identified ICT innovation as an effective facilitator for improving information integration (Anumba & Duke 1997, Björk 1999, Deng *et al.* 2001, Love, MacSporran & Tucker 2000, Mitev, Wilson & Wood-Harper 1996, Sriprasert & Dawood 2002b, 2002c), enhancing construction communication and team collaboration (Ahmad, Azhar & Ahmed 2002, Alshawi & Ingirige 2002, Anumba & Duke 1997, Björk 2002, Skibniewski & Abduh 2000, Tam 1999), and expanding e-procurement/e-commerce (Anumba & Ruikar 2002, Kong *et al.* 2004, Kong, Li & Love 2001, Kong, Li & Shen 2001, Skibniewski & Nitithamyong 2004, 1999). These research studies suggested possible ICT innovations that may be applied in the construction industry to improve service delivery and productivity. They found that Internet technology, especially web-based applications; provide benefits for information service, communications and computing management.

Although ICT benefits are recognised, the level of ICT use in the construction industry is still low. From the discussion in Section 2.2.3, most earlier research studies indicate cost and technological problems that create barriers to ICT adoption and its use in the construction industry. However, a recent study has shown that the barriers of ICT use and adoption have moved beyond technical and cost problems to ICT management problems within construction organisations. This may be because many generic ICT applications have already been developed and there has also been considerable Internet infrastructure investment, so the uncertainty associated with cost of investing in ICT applications is now considerably reduced. Management of IT/ICT, however, especially its adoption and implementation, has been identified as a major theme in International Council for Research and Innovation in Building Research (CIB) W78 conference papers (Amor *et al.* 2002).

This research trend is also supported by the nature of research in construction. It is clear from the Chapter 2 literature review that many previous construction ICT research studies could be categorised as: (1) construction industry ICT application and prototype development, (2) review of current construction ICT application use (3) evaluation of ICT benefit and performance, (4) development of strategic ICT planning, and (5) investigation of ICT implementation drivers, barriers and related issues. The first two research themes attempt to demonstrate advantages of using ICT applications and explore the extent of ICT use in the construction industry. Strategic ICT planning in the third theme focuses on tools and method that help top management to develop strategic planning while the evaluation research in the fourth theme focuses on the quantified value and benefits of ICT investment for decision-making of ICT adoption into an organisation. The final ICT implementation theme concentrates on variables that support and hinder ICT implementation. Figure 3.1 illustrates research gaps in ICT implementation. Therefore, this research will focus on the factors and processes that occur after an organisation decides to adopt ICT.

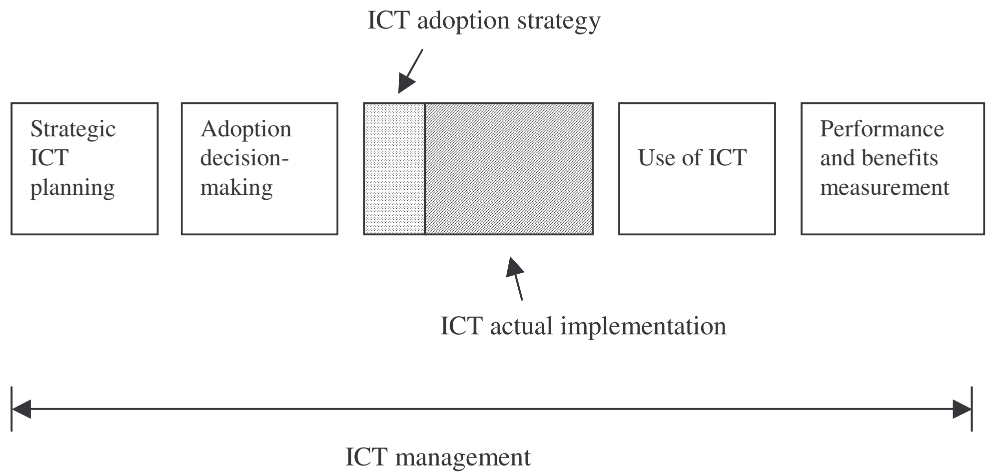


Figure 3.1 Diagram of strategic ICT adoption and actual ICT implementation

This research thesis addresses the challenge of identifying variables from theoretical concepts of innovation diffusion, change management and knowledge sharing and learning that explain the effectiveness of actual ICT implementation at the intra-organisational level. After identifying *what* factors affect ICT diffusion the challenge is then to investigate *how* these factors affect the ICT diffusion process. To identify the factors and processes influencing ICT diffusion at actual implementation stage, it should explore why ICT adoption strategy and actual ICT implementation are so important and worthy of rigorous research. Thus, the following section will focus on the ICT adoption strategy and actual ICT implementation in selected construction organisations.

3.1.1 *Need for a study of ICT adoption strategies within construction organisations*

ICT adoption strategy deficiencies may cause several problems. First, it may result in slow ICT adoption by construction organisations because they are unsure of how to begin this process (ABS 2001, ACIF 2002) and this, in turn, may result in loss of competitive advantage through ICT use. Second, unplanned ICT adoption may cause several continuing problems during the ICT implementation stage relating to organisational and individual factors. These may include a slow and ineffective diffusion rate of ICT by potential users within an organisation, experiencing technical problems, and lack of clarity of the ICT benefits (Songer, Young & Davis 2001). Finally, improper ICT adoption may result in a negative perception towards ICT use among intended users and lead them towards resistance to its adoption (Davis & Songer 2002). As a result, an organisation that lacks a coherent a strategic adoption policy may obtain little benefit from an ICT investment.

Strategic ICT planning focuses upon a long-term plan for ICT application use that supports competitive advantage through the link between core business strategy and information systems (IS) use (Björnsson & Lundegård 1993, Porter 1980, Porter & Miller 1985). For example Björnsson & Lundegård (1993) found that (based on a study of three European construction firms) there are two possible strategies of IS use to gain competitive advantage: a cost reduction strategy and a differentiate strategy. A cost reduction strategy emphasises using technology to improve productivity or process improvement as a means to reduce cost. A differentiation strategy stresses creating a new product or service that opens up new business or service delivery opportunities (Porter 1985c). Therefore, the selection of appropriate strategic ICT planning policy will help organisations to select the suitable ICT application for

supporting a business's competitive advantage. Successful ICT adoption requires both detailed strategic ICT planning and a matching ICT adoption strategy.
A strategic ICT *adoption* strategy refers to the approach within an organisation to adopt a strategic ICT plan. It comprises sub-processes in which an organisation starts to become aware of, searches for, selects, and finally decides to adopt an ICT initiative. One potential problem is that the organisation can start to become aware of ICT benefits but is reluctant to adopt and invest in it. From the organisation's viewpoint, early adopters may be taking an unacceptable risk due to adoption uncertainties (Mitropoulos & Tatum 1999) while late adopters may lose competitive advantage benefits through offering novel services because they join the many offering those benefits (Love *et al.* 2001).

A commonly assumed adoption barrier is the general limited ICT investment by the small and medium construction organisations (Love *et al.* 2001). Specifically, recent case study reviews by Björk (2002) indicate that technical problems and the cost of using ICT systems have only a limited influence in adopting online document management systems. Also, an important barrier recently identified by Love *et al.* (2001) and Songer, Young & Davis (2001) is that many construction practitioners appear to have insufficient experience in understanding organisational and social issues of strategic ICT adoption. If an ICT adoption strategy is effectively pursued, then it could counter barriers of limited funding for across-company deployment (particularly with smaller organisations) by gradually investing in ICT to fit their financial constraints. However, strategic adoption by itself may not lead to successful ICT use in organisations. What is required is continuous management attention and energy throughout the actual implementation stage.

3.1.2 *Need for a study on actual ICT implementation within construction organisations*

This section argued the need of studying actual ICT implementation by discussing their negative effects from a failure viewpoint. Unsuccessful actual ICT implementation may cause several problems: (1) cost and time overruns, (2) users resistance, (3) failure to achieve expected benefits, and (4) declining overall work performance.

3.1.2.1 Cost and time overruns

Based on an empirical survey of 69 individuals from 34 companies, Songer, Young & Davis (2001) found that unclear strategy and actual implementation process can lead to excessive technological investment costs and delay the implementation. Others support this finding and concluded that failure to manage actual implementation can lead to system cost and implementation time overruns (Regan & O'Connor 2000, Villeneuve & Fayek 2003). Also, a case study of VR implementation by Whyte, Bouchlaghem & Thorpe (2002) shows that problems at the actual implementation stage can cause business uncertainty and delays due to technical problems and learning/ramp-up time. Implementation failure could be slowing down the uptake of ICT in the construction industry, especially for early adopters of this technology (O'Brien 2000).

3.1.2.2 User resistance

During the actual implementation stage, lack of top management support or organisational commitment can lead to user resistance. Villeneuve (2003) points out that the acceptance or rejection of technological change involves human behaviour. Resistance can occur within organisations at top management or potential user level. Stephenson & Blaza (2001) found that resistance of ICT change occurs more with low-level staff than staff at management level. Voordijk *et al*. (2003) argued that limitations of ERP implementation in a case study resulted from high consultation costs, fear of leaking sensitive information, and system functionality not matching user needs. Regan & O'Connor (2000) provide the evidence of discontinued use of a calendaring and messaging system in an insurance office. They argue that users who discontinued their ICT use did so because of a lack of top management commitment and motivation. O’Brien (2000) conducted a study of project website user experience and found that the type of user can influence their adoption decision. He concluded that ‘pragmatists’ need to see benefits from using web technology before they adopt it while ‘innovators’ will experiment and commit to their web use and then only accept those with perceived potential benefits. This is important when an ICT application needs to be adopted by a range of project participants. It is therefore essential to provide organisational support and create an inter-organisational long-term relationship otherwise the implementation of ICT will most probably fail (Munkvold 1999).

3.1.2.3 Failure to achieve expected benefits

Actual ICT implementation failures can hinder the benefits that organisations are expecting. The gap between expected and actual benefits derives from two hindrances: user resistance and poor fit between technology and organisational needs. User resistance refers to avoidance of using ICT because they did not receive suitable resources and technical support—discussed in the above section—to realise personal benefit. Technology not fitting with organisational needs was studied by Gottschalk (1999). ‘Task-technology fit’ at the organisational adoption level refers to the technology fitting with the individual user’s need to perform various tasks. A technology-fit performance model developed by Goodhue & Thompson (1995) links technology task fit and utilisation of that technology. Implementation of an ICT application should continuously improve the functions that fit with organisational/users’ needs. Thus, it is essential to evaluate feedback from users who actually use the system and to fix any problems they encounter during their use. In particular, some work process may need to be modified in order to accept any new system. O'Brien (2000) concluded that as ICT applications may be difficult to design to support everybody’s system needs, any implementation strategy should accommodate the impact of application limitations and manage users’ expectation accordingly.

3.1.2.4 Declining work performance

Uncertainties during actual ICT implementation can reduce overall work performance. Researchers present many benefits of using ICT, such as reducing time and cost of information transfer, enhancing communication, and saving travel costs (Alshawi & Ingirige 2003, Deng *et al.* 2001, Murray & Mavrokefalos 2000, Rojas & Songer 1999). However, these benefits will be only be realised if technology is fully used and integrated into an organisation. The survey by Songer, Young & Davis (2001) indicates that respondents had little perception of how IT investment increases project and organisational performance.

On the basis of an empirical investigation by Thomas (1999), Koskela & Kazi (2003) argue that there was no absolute relationship between project productivity improvement and the extent of IT investment. They explain that low perceived IT benefits may be derived from neglecting to properly implement organisational change management. Some researchers agree that the introduction of IT into organisations can clause a declining in work performance because there is a learning phase where staff adapt to the new system (Eason 1988, Regan & O'Connor 2000). Performance reduction can also be explained by uncertainty during IT implementation. Eason (1988, p. 160) points out that organisational performance can be reduced during the transition of technology implementation (called ‘initial dip phenomenon’). Brynjolfsson & Hitt (1998) found that the benefits of IT investment in the long-term may increase up to 2-8 times as much as short-term benefits. However, long-term benefits were not believed to be the result of IT investment but rather a result of changed organisational business practice triggered by the IT investment. Regan & O'Connor (2000, p. 370) and Thomas (1999) argue that any short-term productivity decrease can be explained by the learning curve effect during the change phase of Lewin's change model. Thus, a focus on ICT implementation should be useful to reduce uncertainty and expedite ICT learning, which in turn can create benefits of its use. Understanding this will help managers to effectively prepare and plan ICT implementation. Therefore, the implementation of ICT should be managed and the issues related to ICT implementation clearly understood, especially in a construction environment.

3.1.2.5 Concluding remarks

There are other reasons that reinforce a need for an effective ICT adoption strategy and actual ICT implementation processes. First, ICT functions are different from many IT applications. ICT packages provide general-use communication and collaboration software for all team members whereas engineering design applications such as computer-aided design (CAD) or engineering computational software are generally used by a small group of specialists. Second, ICT is characterised as being a communication technology that connects a wide range of users rather than individuals in stand-alone IT applications for specialists. Therefore, these diverse applications need different adoption strategies based on the way that users interact and communicate. Also, Markus (1987) found that communication technology success requires a large number of adopters to feel comfortable with applications before benefits of using ICT reached a *critical mass*. Third, while there have been many IT adoption strategy and actual IT implementation studies in the computer science literature (Attewell 1992, Carlopio 1998, Fichman 1992, Gallivan 2001, Prescott & Conger 1995), only a few have been undertaken on ICT adoption strategy and actual ICT implementation in the construction industry at the organisational level. This paucity of construction industry examples means that, to better understand the adoption processes in the construction industry context, more studies of strategic ICT adoption and implementation are required. Table 3.1 presents a summary of the effects of mismanagement in strategic ICT adoption and actual ICT implementation.

Table 3.1 Effects of lack of ICT adoption strategy and implementation

Effects of mismanagement in ICT adoption strategy	**Effects of mismanagement in actual ICT implementation**
(1) Loss of competitive advantage (early adopter vs. late adopter) (2) Problems during implementation (3) Negative perception towards future adoption	(1) Cost and time overrun (2) User resistance (3) Failure to achieve expected benefits (4) Decline of overall work performance

These effects indicate the need for research on ICT adoption strategies and actual ICT implementation within construction organisations. In addition, the current lack of research in this area may be one reason why such implementation problems remain. A literature review that traces the study of strategic ICT adoption and ICT implementation within construction organisations will now be discussed.

3.2 ICT strategic adoption and actual implementation research

This section reviews previous research related to ICT adoption and implementation within a construction industry context. Based on the review in Section 2.4.3, research in ICT adoption and implementation can be grouped into factor and process research approaches. The factor research approach focuses on the criteria/ barriers that influence ICT adoption and implementation while the process research approach focuses on the processes that influence ICT implementation within construction organisations. Table 3.2 shows the summary of research studies related to ICT adoption strategies and actual ICT implementation in construction organisations.

From a factor research approach, earlier research studies identify and evaluate a range of variables on the success of initial adoption and actual ICT implementation. These studies mainly focus on barriers and drivers from the initial adoption view. For example, Laage-Hellman & Gadde (1996) identify EDI implementation barriers in the Swedish construction industry. Marsh & Finch (1998) and Marsh & Flanagan (2000) investigate drivers and barriers of Auto-ID adoption from both industry and organisational views. Marosszeky *et al.* (2000) investigate the causes of low levels of adopting ICT that show risk factors related to adoption and implementation of ICT. Whyte & Bouchlaghem (2001) study the issues and process that influence VR implementation. Songer, Young & Davis (2001) focus on social barriers to IT innovation (such as 3D, data warehouse, engineering applications, web, data management) across organisations. Stephenson & Blaza (2001) concentrate on organisational change that influences the success of IT implementation. Table 3.2 presents an historical summary of case studies reported from 1996 to 2004 of drivers of and barriers to IT adoption and implementation at *industrial and organisational* views grouped into technological, individual, managerial, and other issues.

Table 3.2 Literature review related to ICT adoption and general ICT implementation (from 1996 to 2004)

Literature review	**Research aim**	**Research method**	**Technical issues (-) negative (+) positive**	**Individual & social issues (-) negative (+) positive**	**Management issues (-) negative (+) positive**	**Others/Notes (-) negative (+) positive**
(Laage-Hellman & Gadde 1996)	Identified barriers of EDI implementation in the Swedish construction industry. They found that both organisational and technical issues influence EDI adoption at both industrial and organisational levels.	Case study of one large Swedish construction company	- Standardisation of communication and information exchange (-) - Lack of uniform codes (-) - Lack of applications that support EDI (-) - Require upgrade both hardware and software to use EDI (-)	- Lack of IT competence among staff on construction site (-) - Small number of EDI adopters from project partners (-)	- Requires change in business processes and procedures (-) - Lack of interest and knowledge of EDI benefits (-) - Lack of top management support (-) - Organisational support barriers - Lack of long-term relationship among project partners (-)	
(Marsh & Finch 1998, Marsh & Flanagan 2000)	Investigated the driver and barriers of Auto-ID adoption from both industry and organisational perspectives	Survey of 80 responses including 26 from manufacturers and suppliers, 25 from small-medium size firm and 29 from contractors		- Employee resistance (-)	- Lack of awareness about IT benefits (-) - Development costs are prohibitive (hardware, software and training) (-) - The benefits of IT are difficult to justify (-) - Unclear about performance benefits from IT investment (-) - High incidence of technologically conservative organisations (-) - Short-term relationship leads to avoiding IT investment (-) - Lack of motivation of other organisations to adopt when others will be benefit (-)	- Client failed to enforce the technology (-) - Too many IT products and components to make decision (-)

(Marosszeky *et al.* 2000)	Identified causes of low levels of adopting IT showing adoption and implementation of IT risk factors	Field work interview on people from large, medium, and small contractors and phone interview with suppliers			- Limited skills and vision in strategic IT use at organisational level (-) - Perceptions of financial risk (-) - Lack of precedent clear benefits of IT investment (-)	- Construction industry fragmented (-) - Low level of trust between potential collaborators (-)
(O'Brien 2000)	Identified issues related to the implementation of project web sites	Observation of the use of project web technologies in construction companies	- Password barriers - Authorisation of information access - Limitation of technology benefits for all	- Range of user behaviours (pragmatist and innovators) - Unclear benefits of IT use - Over expectation of IT functionality	- Resistance of change (-) - Need for new job description (+) - Technology champion (+) - Communication density (-)	- Legal issues (-) - Level of technology maturity - Problems of cost and technological barriers tends to decrease
(Zipf 2000)	Suggested key success of technology initiatives	Case study based on the use of project web technologies in the engineering department of the Port Authority of New York and New Jersey			- Management commitment (+) - Technology leadership (+) - Needs assessment (+) - Budget and resource allocation (+) - Establish business flow (+) - Hardware and software evaluation (+) - Organisational acceptance of change (+) - Pilot project initiative (+) - Support training (+)	
(Tucker, Mohamed & Ambrose 2001)	Developed a framework that consists of factors related to IT implementation performance measurement	Case study of best practice in the Australian construction industry.	- Tangible/Intangible benefits - User utility - Project management functions - Information technology		- Strategic impact - Coordination and integration - Value adding	

(Songer, Young & Davis 2001)	Focused on social barriers of IT innovation (3D, data warehouse, engineering applications, web, data management) across organisation	The survey analysis was based on 69 individuals from 34 companies from the construction industry institution (CII) in the US	- Incompatibility (-)	- Supervisor's willingness (+) - Subordinate's willingness (+) - Individual barriers (staff) * most of respondents perceived themselves willing to learn but they ranked the staff and corporate culture (their environment) as major barriers	- Cost of implementation (-) - Corporate culture (-) - Incompatibility (-) - Unperceived benefits/value (-) - Lack of training (-)	- Respondents of construction industry show the interest on the investment of data management (rationale).
(Whyte & Bouchlaghem 2001)	Identified issues and process that influence VR implementation.	Interview based on CAD managers in three regional offices	-Lack of database standard and VR model (-) - Lack of system support (-) - Take time to generate VR (-) - Slow frame rates to display VR (-) - Unexpected technical problems (-) - Significant different practice between CAD and VR (-)	- Users involvement (+)	- Uncertainty about the projects (-) - Pressures of work (-) - Lack of resources (-) - Organisational support (+)	- Successful uptake of IT requires both strategic decision making by top management and decision making by technical managers. - The role of middle manager can be to coordinate business people and technical people. - Require the need of different type of IT innovation in a range of construction organisations. - Discontinuing maintaining the relationship between developer and in-house development can lead to the unresolved IT
(Stephenson & Blaza 2001)	Focused on organisational change that influences IT implementation success.	Interview with staff on Integrated Management Information System (MIS) within a medium sized construction firm	- Lack of system compatibility to support cross organisation functionality (-)	- Resistance to change (-) - Not enough existing skill base (-) - Fear of unknown (-) - Lack of user involvement (-)	- Senior management resistance (-) - Lack of planning and communication (only focus on short term goal) (-) - Lack of share vision (-) - Not enough training (-) - Cost of investment (-)	

					- Organisational fit (-)	
(Love *et al.* 2001)	Explored barriers of implementing e-commerce in small and medium construction companies	Unstructured interview of 20 Australian small-medium organisations in Victoria	- Lack of suitable IT infrastructure - Not enough IT benefits - Data and information security problems	- Users' lack of IT skills - High turnover of employees - Fear of job loss - Reluctance to make work changes - Users' resistance	- Indirect or hidden cost - Difficulty to measure benefits - Lack of commitment from other project participant users - Reluctance to change business practices - High investment cost	- Financial constraints such as short-term benefits, high cost of maintenance, productivity decline, cost of training, and market uncertainty
(Thorpe & Mead 2001)	Described information transfer in project-specific web sites.	Three case studies of project website were collected on push and pull information.		- Planning and training (+) - Technology champion (+)	- Project participants refused to use technology (-)	Information overload from all users' commitment to project web use
(Weippert, Kajewski & Tilley 2002b)	Identified critical factors for ICT implementation success	Survey and interview of five case studies (an 'e-project' case and four cases of 'Project Center') by evaluating seven criteria of ICT implementation success in five case studies	- System compatibility (+) - Ease of data access (accessibility) (+) - Reliability (+) - Capability (+)	- Internal users and project participants commitment (+) - User involvement (+) - Quality and accuracy of information and data input (+)	- Supported by developers, implementers and researchers (+) -Create a feeling of trust (reliability, relevance, need, etc.) for users (+) - Ensure users provides quality and accuracy information to system (+) - Users involvement (+) - Training and technical support (+) - Champion or IT driver (+)	- Legal issues (i.e. authenticity, integrity, confidentiality) (+)
(Björk 2002)	Observed the current users of EDMS	Review the EDMS studies	- Slow Internet connection - Standard communication	- User resistance - Different users' attitude and skills	- Motivation - Training of users	

(Stewart & Mohamed 2002)	Identified barriers to IT implementation in developing countries	Pilot survey investigates 20 respondents from engineers, project managers, architects and others * Respondents show moderate use of ICT such as email, LAN, online remote network but none use web-based project in this sample	- High cost of IT (-) - Quality and quantity of IT infrastructure (-) - System incompatibility (-)	- Lack of IT skill and support IT (-) - Computer literacy (-)	- Low level of IT awareness (-) - Lack of leadership (-) - Cost-driven strategy and client lack knowledge of IT benefits (-) - Low profits margin - High work load activity (-)	- Language barriers (-) - Industrial fragmentation (-)
(Thorpe 2003)	Provided a practical view of ICT implementation problems	Case study of ORCM (online remote construction management) on road construction projects. The data are collected from survey and interview of ORCM	- Perceived slowness of the Internet - Lack of the local Internet connection - Slow bandwidth and network traffic -> fail to send/attach large file with email. - Slow Internet connection - Information and data security	- People's trust in electronic transaction - Low user satisfaction and perceived benefit of use - Lack of computer literacy - User reluctance	- Cost of system implementation - Obtain the full commitment of others	
(Mohamed & Stewart 2003)	Evaluate users' perceptions on the web-based communication	Survey measures users' perspective on operation, benefits, user orientation, strategic competitiveness, and technology system. The data are based on 42 project participants.	- Operational perspective - Benefits perspective - Technology/system perspective - Strategic perspective - User orientation perspective			

(Alshawi & Ingirige 2003)	Reviewed the five cases that currently use project web technology and identified the benefits and problems	Five case studies of project web technology were interviewed on the background, benefits and problems.	- Incompatibility of system - Difficulty to send large file sizes and security of system	- Different IT skill and competence - Lack of project partner commitment		- Benefits: - improve speed of information transfer and enhance communication - support decision-making - reduction of delivery and copying cost - reduce the storage space for paper work - Summary the benefits of using project web sites related to construction phases: tendering, design & construction and trading (e-commerce)
(Voordijk, Leuven & Laan 2003)	Aimed to understand the factors that lead to the success and failure of ERP in large construction firms by focusing on the fit between the following pairs of elements in ERP implementation: (1) business strategy and IT strategy, (2) maturity of the IT infrastructure and the strategic role of IT, and (3) the implementation method and organisational change.	Case study of three main business units in a large Dutch-based construction firm.	- Fit between maturity of IT infrastructure and strategic role of IT		- Fit between business and IT strategy - Fit between implementation methods and change process in organisation	

(Huang *et al.* 2003)	Identified the criteria for IT adoption decision within construction industry (initial adoption)	Online survey questionnaire was used to collect data. The analysis is based on the 63 respondents that consist of IT consultants, software development organisation, architectural, structural and engineering, transportation, and other industries.	- Relative advantage - Compatibility - Complexity - Observability or trialability - Technologies opportunities - Centrality - Cost - Communicability - Divisibility - Profitability - Social approval and image - Voluntaries - Result demonstrability - Visibility - Preparedness	- Characteristics of key individual	- Characteristics of organisational structure - Innovativeness of organisation - Characteristics of communication environment - Organisational training and learning - Management attitude - External environment - Leadership	- Supply chain change - Process adjustment resulting from the company growth - Process adjustment resulting from increasing complexity of high tech facilities - Client demand and other process problems - Market pull
(Gyampoh-Vidogah, Moreton & Proverbs 2003)	Explored the issues of information management, vision of the future, and the impact of efficiency	Open-ended interview was used to collect the data from three case studies of construction companies. Each company provided four participants including senior partners and contract managers. In addition, follow-up interviews and seminars were conducted to explore in-depth issues.	- System incompatibility - Storage problems - Searching and retrieval problems	- Internal culture - Social uncertainty - Unchanging individual dominants - Reaction to technology and utilisation of employee potential - Lack of motivation to adopt of technology - Employee potential not utilised to best advantage - Lack of internal champion - Lack of management commitment	- Cost escalation and paper waste - Poor access to information - Labour intensive - Delays and misunderstanding - Lack of corporate systems	

(Nitithamyong & Skibniewski 2003)	Identified 36 success/ failure factors and 34 variables measuring success/failure in implementing of web-based construction project management system (PM-ASP)	10 expert opinions ranked factors.	- Type of hosting service - Number of users - Ease of use - Output quality - System reliability - Data quality and reliability - Data security - Frequency of update - Integration among functions - Internet access availability and bandwidth	- Prior experience - Team attitude toward IT/PM - Adequacy of training - Users involvement during planning - Computer experience and literacy - Frequency of use	- Existence of champion - Ability of project manager - Project complexity - Type of owner & contracts - Project size and duration - Level of top management support - Alignment of technology with business objective - Knowledge of construction business - Technical competency - Promptness of responses	
(Villeneuve & Fayek 2003)	Developed a prototype project web technology and identified the benefit of using this to solve information management problems.	Case study to describe the functionality of a project web technology site and provides a guideline for system implementation.	- Immaturity of technology - Existing communication tools - Barriers of control by password restriction comparing to other technology such as fax, phone - Security and legality of data	- Acceptance and resistance of user - Different experience in working with online collaboration	- Commitment from all users to gain full benefits	- benefits of using PWS are * reducing project cost and saving time * improving the construction partnership * immediate and easy access to information and documents * real-time collaboration and sharing documents between both intra- and inter-organisational staff.
(Nitithamyong & Skibniewski 2004)	Reviewed current web-based project management services in the market.	Literature reviews on web-based project management systems	- System reliability - System security - Lack of software interoperability - Internet access and band width problems - Password barriers - Not enough technological functions - Density of communication channels	- Resistance to change	- Difficulties in quantifying costs and benefits - Collaborative maturity	- Legal issues of electronic transaction - Data ownership after project completion

(Stewart, Mohamed & Marosszeky 2004)	Determined the barriers/problems of IT implementation into industrial level, organisational level, and project level.	Survey questionnaire is used to collect data from 140 construction professionals from AEC.	- Security and privacy issues - Poor inter-operability	- Resistance to change by staff - Low technology literacy of some participants - Fear of change and uncertainty	- Low level of IT awareness - Reluctance by management to invest in innovation - lack of IT strategic planning - lack of perceived return on investment - Conservative business practice - Limited resources available to small and medium enterprises - Tight project time frames - Limited IT expenditure on projects - Lack of leadership	- Construction industry fragmented - Security and privacy issues

From the *factor research* view, Table 3.2 presents results from previous research related to initial ICT adoption and general ICT implementation from both industrial and organisational perspectives. These are based on identifying factors that affect only the early stage of ICT diffusion and provide a useful indicator of the decision-making rationale at the initial adoption stage. However, these studies lack detailed insights into the nature and degree of the impact of variables that influence actual implementation. These factors are individual characteristics, technological characteristics, managerial and organisational support, and the nature of knowledge sharing in the workplace environment. Furthermore, data collected for Table 3.2 ICT implementation studies were mainly drawn from top management and IT managers so these studies may only reveal and concentrate on strategic management issues rather than reveal important operational implementation issues. Therefore, rather than focusing on factors related to initial adoption, this research is focused on factors influencing ICT at the actual implementation stage.

To explore the factors influencing ICT at the actual implementation stage, this research proposes that in undertaking quantitative research studies—

> *Variables* ***identified*** *from innovation diffusion, change management, and knowledge sharing and learning theory provide a comprehensive list of factors that influence the level of success of* ***actual ICT implementation*** *within construction organisations.*

According to the *process research approach* in Chapter 2, Section 2.3 provides only a strategic planning process rather than a strategic ICT adoption and actual implementation approach to ICT diffusion. For example, Peña-Mora *et al.* (1999) developed a specific IT planning framework for large scale architect engineering construction (A/E/C) managed projects. Jung & Gibson (1999) created a method for developing a framework for Computer Integrated Construction (CIC) planning. Recent attempts to develop an IT/IS implementation framework have produced a method and a tool to help managers measure and assess implementation success (Stewart, Mohamed & Daet 2002).

There is also evidence that studies are being undertaken to link strategic ICT adoption with its impact on implementation success. These studies attempt to imply causation or at least advance our understanding of the forces at work in the ICT diffusion decision-making process. For instance, Mitropoulos & Tatum (1999, 2000) focus on decision-making in the technological innovation diffusion adoption process. Their studies identified criteria forcing an organisation to decide to adopt new information technologies such as 3D-CAD and EDMS. Skibniewski & Abduh (2000) proposed two possible strategies for web-based project management adoption: *in-house development* and *outsourcing.* Similarly, Whyte & Bouchlaghem (2002) found that VR system adoption and implementation approaches can be categorised as being *strategic* or *ad hoc*. However, few of these studies have focused on ICT implementation from an innovation diffusion process perspective.

To explore the processes related to strategic adoption and ICT actual implementation, this research proposes that in undertaking qualitative research studies—

> *Successful ICT strategic adoption and actual diffusion within construction organisations can best be understood by undertaking a series of representative* ***case studies*** *of the innovation diffusion experience.*

Because this research draws upon variables from the identified three concepts of DoI, change management and knowledge sharing, it is necessary to undertake a quantitative study to test the validity of the proposed variables/factors drawn from the three theoretical areas, within a specific construction context, that may explain how to encourage successful ICT implementation.

Based on the previous research studies, identified gaps in ICT implementation need to be explored further. First, although numerous previous research studies relating to factors influencing construction ICT implementation have been conducted, few have focused on the *users' perception* of ICT implementation. Second, these factors were mainly focused on the initial adoption decision-making process rather than on *actual implementation*. Third, no research appears to have been undertaken on factors drawn from construction innovation diffusion, change management and learning and sharing knowledge perspectives that could fill the identified gap in our *understanding of the ICT implementation process*—that is what is actually going on when ICT applications are being implemented.

The research presented in this thesis extends traditional DoI variables by integrating other variables from change management, and sharing and learning concepts. Thus, it was necessary to identify these variables in order to understand how they may influence current IT innovation processes, in particular ICT application. Five main research questions are established:

1) *What are the essential factors that influence ICT diffusion at actual ICT implementation within large Australian construction organisations?*
2) *To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations?*
3) *How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations?*
4) *How has ICT knowledge been diffused by users within large Australian construction organisations?*
5) *What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?*

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

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

Figure 3.2 illustrates the concepts used to develop the framework of this research. Static factors of innovation diffusion include the factors which influence the individual adoption decision. These factors are technological characteristics, communication channels and the social systems. First, the characteristics of technological innovation (i.e. relative advantage, ease of use, compatibility) are the primary criteria that influence the individual adoption decision. Second, communication channels (i.e. mass media and personal communication) facilitate ICT diffusion by disseminating information regarding the application and by pooling individual experience together. Third, the social contexts (i.e. type of users, leader opinion and culture issues) can also influence an individual adoption decision on technological innovation by personal and social behavioural interaction. Based on the description of static factors, these factors are simply used to determine the primary individual adoption decision. But these factors fail to explain the dynamic nature of the adaptation processes that drives technological innovation into an organisation.

Dynamic factors of change management and the learning and sharing of knowledge complement static factors that facilitate ICT diffusion. Dynamic factors consist of a motivation, training and technical support, supervisor support, an open discussion environment and the sharing and learning of IT knowledge with others. These factors involve the supportive change that facilitates the diffusion of ICT within an organisation. Therefore, integrating both static and dynamic factors help us understand the ICT diffusion within a construction organisation. The integration of the three main concepts (innovation diffusion, change management, and learning and sharing of knowledge) can be grouped into five main areas involving ICT diffusion at the actual implementation stage. These areas are: self-motivation, training and technological support, workplace support environment, and sharing and learning environment.

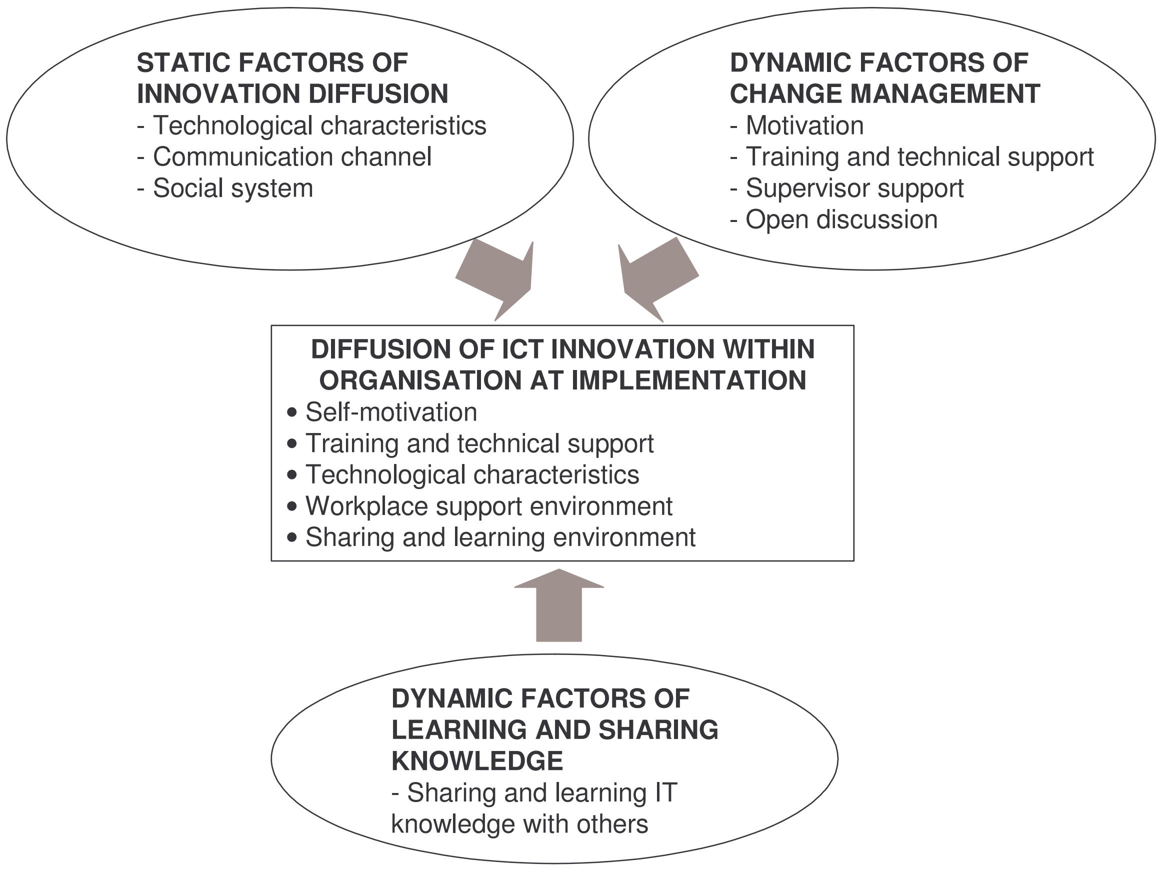


Figure 3.2 Integration of factors related to ICT diffusion from innovation diffusion, change management and learning and sharing concepts

Thus, this research aims to investigate ICT innovation diffusion initiatives that have already been adopted by surveyed organisations. It will seek to unearth: the characteristics of the ICT initiatives; the way in which they were introduced—in terms of colleagues helping and mentoring each other, training support etc. using 1-to-1 and 1-to-many communication channels; how social systems operated; and other organisational culture aspects affecting change management.

Integrating innovation diffusion, change management and learning and shared knowledge concepts led to the focus of this research on the five main issues contained within the box 'diffusion of innovation within organisations at the implementation stage' (See Figure 3.2). Table 3.3 shows the summary of the literature review relating to these five main issues.

Table 3.3 List of selected literature supporting five main areas

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

3.4 Five issues related to actual ICT implementation from intra-organisational diffusion perspective

In the previous section, the framework of integrated ICT diffusion with change management and learning and knowledge sharing was introduced. The framework of understanding ICT diffusion at the actual implementation stage consists of five main areas: (1) self-motivation; (2) training and technical support; (3) technology characteristics; (4) environment for workplace support; and (5) a knowledge sharing environment. These five main areas were developed from the literature related to IT/ICT implementation[7], innovation diffusion, change management, and knowledge management (sharing and learning focus). They are discussed in more detail below.

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

3.4.1 *Self-motivation*

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

3.4.1.1 Personal/Individual characteristics

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

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

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

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

3.4.1.2 User's attitudes

User's motivation to use IT/ICT might also be related to their attitude toward technology such as perceived clear advantage of use, ease of use, relevance to their job, and professional credibility. The first two variables 'clear advantage' and 'ease of use' are found to be associated with their IT/ICT use. Rogers (1983) found that a perceived clear advantage is an important technology characteristics that generally influences innovation diffusion. Davis, Bagozzi & Warshaw (1989) proposed a technology acceptance model (TAM) that predicts a user's intention to use IS. The result shows that perceived usefulness and perceived ease of use are essential variables motivating the use of word processing technology in an education environment. Similarly Igbaria, Parasuraman & Baroudi (1996) found that usefulness and ease of use motivates professionals and managers to use computers.

Furthermore, use of IT/ICT might depend on its relevance to users in performing their job because they would like to improve their work quality, speed and accuracy. Igbaria, Parasuraman & Baroudi (1996) found that users are more likely to use and adopt computer technology if they think that it is useful to improve their productivity and performance. In addition, Igbaria and Tan (1997) suggest that the adoption of

IT/ICT by an organisation might affect both individual and organisational productivity. High satisfaction with IT/ICT can help to increase productivity whereas low satisfaction might lead to decreased productivity.

Finally, the use of IT/ICT may build professional credibility whereby users tend to use technology because they would like to perform their work using more ‘cutting-edge’ technology. Moore & Benbasat (1991) found that the image variables, e.g. prestige, high profile and status, are key elements influencing users’ adoption. Therefore, these can be seen as an important users’ attitudes affecting IT/ICT use and adoption.

3.4.2 *Training and technical support group*

Training is a primary IT/ICT diffusion factor within an organisation to the extent that it helps users to understand how to best use and adopt IT/ICT applications. Training was found to be an essential factor in information system (IS) success during the implementation stage (Akins & Griffin 1999, Alp, Alp & Omurtag 1997, Carlopio 1998, Compeau & Higgins 1995, Sackton 1999). Similarly, Nelson and Cheney (1987) found that training has an impact on users’ ability and users’ acceptance of IS. Without training, most users take time to learn and utilise only some capabilities of IS. In addition, their lack of skill and training was found to be an important barrier to business accessing the Internet (ABS 2002). Likewise many construction case studies found that lack of enough training is one of the main barriers to adopting and using IT/ICT applications (Songer, Young & Davis 2001, Stephenson & Blaza 2001, Weippert, Kajewski & Tilley 2002a).

Within the organisation, there are many different people who have specific roles and responsibilities. Thus, there needs to be specific training for them. Nelson (1991), found that there is a limit for everyone to learn all aspects of business knowledge. As a result, training should provide specific skills that are related to users’ need and work processes. User behaviour also affects their training needs, in particular users who are classified as ‘pragmatists’ (O'Brien 2000). Therefore, it is important to assess users’ training requirements to reduce their knowledge gap between what they already know and what they need to know to best perform their job—that is, by undertaking a personalised user needs analysis (Nelson, Whitener & Philcox 1995).

The assessment of training not only assists the organisation in understanding the knowledge gap but it also improves the effectiveness of training (Carlopio 1998). For example, training assessment helps trainers to prepare the context and level of training to ensure compatibility with users' need and to provide training to the right groups. Nelson (1991) suggests that the organisation needs to assess knowledge and skill requirements that are necessary to perform their job—undertaking a skills audit. He found that IS personnel need organisational knowledge such as business objectives and goals whereas end-users require IS-related skills such as the use of applications.

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

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

Motivation of users to learn and apply IT/ICT in their job has also been recently studied. Training programs should provide quality training. If training quality is low, then it will create disinterest and boredom (Wilson 1997). Therefore, the quality of training is an one essential factor influencing IT/ICT use.

Wilson (1997) found that most of the users applied only 20 per cent or less of an email application function. Thus, training could increase user efficacy levels and improve their performance because IT/ICT self-learning might have limitations. For example, although a manual such as "quick reference guide" can provide an understanding of how the software functions work, it rarely describes how functions could be applied to perform an individual's job effectively. Therefore, users still require actual training and group support to help them clearly understand how to effectively use an IT application.

Users also need technical support to solve problems when using an IT/ICT application. Generally, the function of technical support is to help users and solve problems (Kueppers & Schilingno 1999). This is generally provided by technical support groups or through a help desk facility provided by technicians who develop in-house applications or by specialist software support organisations.

3.4.3 *Technology characteristics*

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

Tornatzky and Klein (1982) found that innovation characteristics have a relationship to innovation adoption-implementation. By using the meta-analysis of articles, their results indicated that three innovation characteristics - compatibility, relative advantage, and complexity - had been frequently found to be factors influencing technology adoption and implementation.

Generally, users are more likely to use technology that has a high relative advantage to them in performing their job. On the other hand, if technology cannot provide advantages to users, they will be reluctant to commit to usage. As a result, the relative advantage attributes have an influence on users' perception of technology (Igbaria, Parasuraman & Baroudi 1996, Lederer *et al.* 2000).

In addition, Ramamurthy (1994) also found that compatibility has a positive influence on organisational IT/ICT adoption and implementation. For example, IT/ICT that was designed to replicate manual or paperwork is easy for users to accept because they feel familiar with the work patterns. Therefore, the higher the compatibility with users' existing work, the more likely it is that the users become familiar with a system. However, their use of ICT is not limited to duplicating manual and paper work systems, but also involves work process re-designing or re-engineering. Thus, to improve organisational productivity, most current IT/ICT systems require complex change management projects.

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

3.4.4 *A supportive environment workplace*

In the above, the focus was on user characteristics, training and technical support groups, and technology characteristics that might affect the IT/ICT diffusion process. However, it could be argued that workplace environment characteristics such as commitment, open discussion, personal anxiety and frustration also affect ICT diffusion.

3.4.4.1 Commitment

The IT/ICT diffusion process can be seen as a process of change within an organisation (Senge *et al.* 1999, Wolek 1975), so we need commitment from both users' and their organisation (Newman & Sabherwal 1996). Individual commitment focuses on end-users who devote themselves to using ICT whereas organisational commitment focuses on top managers who support end-users to use IT/ICT.

Without individual commitment, the success of IT/ICT implementation could not be achieved. According to Ginzberg (1981a), users' involvement in IS implementation is the key driver of IT/ICT success. The same is most likely true of IT/ICT. A basic requirement of IT/ICT adoption is the need to directly or indirectly persuade users to commit and involve themselves with using IT/ICT.

An organisation's top management also needs to be committed to support and allocate adequate resources for technology investment such as ICT. Numerous examples of lack of organisational commitment has been shown to lead to IT project failure (Lenoard-Barton & Sviokla 1988, Thompson, Higgins & Howell 1991).The same most likely occurs with ICT.

3.4.4.2 Open discussion

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

3.4.4.3 Personal anxiety and frustration

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

3.4.5 *Sharing and learning environment*

Innovation diffusion needs a sharing and learning organisational environment. Within an organisation, everyone has his or her own special knowledge on how to perform their job. Therefore, learning and sharing knowledge among staff is important for diffusion of an innovation. Recent research by Rogers (1996) shows that learning is a key factor in innovation development. He suggests that training and development should be shifted to an experiential style of learning.

Grantham & Nichols (1993, p.202) state that "*organisational learning occurs when people in an organisation collaborate to share their different visions, knowledge, experiences, and skills*". Organisational learning is a key IT/ICT implementation factor when IT/ICT application development is frequently subject to change (Attewell 1992, Fichman & Moses 1999). Learning benefits construction organisations to improve their performance, establish new strategy and revise organisational form to reflect current situations.

Tacit knowledge, grown from users' experience, is a valuable organisational asset (Davenport & Prusak 1998, Nonaka 1995). Ideally, tacit IT/ICT knowledge sharing built from users' experience can improve IT/ICT use within organisations and suggest how to use IT/ICT more effectively (Gibson & Smilor 1991). Carlopio (1998) explains that personal change may be best influenced by co-workers, friends, family, peers etc.

Collegial help and mentoring is one way that knowledge sharing can most effectively occur because experienced users can give strong support by assisting novices to use IT/ICT applications through knowledge transfer. Therefore collegial help strongly influences change in an organisation (Senge *et al.* 1999: 345). Compeau and Higgins (1995) also argue that peer and collegial support is vital. This can be activated through groups of colleagues, some highly expert in what has been referred to as a community of practice (Gallivan 2000, Wenger & Snyder 2000).

3.5 Developing research questions based on an integrated model of ICT diffusion

This section provides the rationale for the quantitative research instrument based upon the five categories that are derived from the integrated conceptual model of innovation diffusion, change management, and learning and sharing of knowledge. The questions in the quantitative research instrument examine users' experience of identified variables that are expected to influence ICT diffusion within construction organisations. The theoretical basis for each question is drawn from and supported by the literature. The following section presents the theoretical support.

3.5.1 Part A: Access to electronic communication technologies

Research questions in Part A focuses on users' exposure to information and communication technologies (ICT). It aims to measure the respondent's IT and ICT application and the level of ICT application use to gauge the respondent's IT/ICT general literacy. This experience may have been derived from outside of or from within the respondent's work environment. Respondents were also asked to indicate the extent to which these ICT tools are relevant and used in their day-to-day work activities. These data provided in a consolidated form a picture of the general organisational use of software packages. In Appendix A, Part A provides a sample of the questions asked. The choice of applications was drawn from common IT/ICT applications that the literature discussed in Chapter 2 and earlier in this chapter together with direct observation and experience of the construction industry.

The following sections present the remaining parts of the research instrument in a form that presents the question followed by justification of its inclusion from the literature. In many cases a range of citations could have been used, but generally only the ones considered most relevant have been presented. The purpose of this is to make clear the relevance and appropriateness of the question asked in light of the literature review in Chapter 2 and earlier in this chapter.

3.5.2 *Part B: ICT motivation and users perceived characteristics of ICT*

Research questions in Table 3.4 relate to the questionnaire Part B (see Appendix A) and they focus on users' characteristics and perceptions towards ICT. It focuses on self-motivation and characteristics of ICT that influence the use and adoption of ICT, which in turn, leads to the diffusion of ICT innovation. The code **[ID]** refers to innovation diffusion literature; **[CM]** refers to change management literature; **[KM]** refers to the literature from knowledge management, organisational learning and knowledge transfer/sharing; and **[IMP]** refers to the literature on ICT implementation in construction.

Table 3.4 Motivation and user perceived characteristics literature supporting the empirical research instrument

2 Statement about applying information and communication technology (ICT) tools by respondent or within their work group	Supporting literature
Qb1 I am **confident** with my use of ICT tools that I am expected to use here	**[ID]** Self-efficacy and personal confidence (Murphy, Coover & Owen 1989) **[ID]** Self-efficacy (Burkhardt & Brass 1990, Coffin & MacIntyre 1999)
Qb2 I am a bit of an adventurer and **enjoy** being exposed to **new challenges** such as **exploring** new tools or discovering new ways to use existing tools	**[ID]** Enjoyment on learning (Davis, Bagozzi & Warshaw 1989, Igbaria, Parasuraman & Baroudi 1996) **[IMP]** Managers explore the new technology (Whyte & Bouchlaghem 2001)
Qb3 I **enjoy** learning from others about applying ICT tools that we are expected to use here	**[ID]** Enjoyment of learning (Davis, Bagozzi & Warshaw 1989, Igbaria, Parasuraman & Baroudi 1996)
Qb4 My **skill in using** ICT tools that we are expected to use here is **relatively high** compared to my fellow workers	**[ID]** Previous experience (Igbaria, Iivari & Maragahh 1995)
Qb5 I receive **tangible** rewards (advancement, additional pay, security, or better job prospects etc) from using ICT tools that we are expected to use here	**[CM]** Tangible rewards (Senge *et al.* 1999) **[KM]** Organisational incentive (Klein & Hirschheim 1987)
Qb6 I receive **intangible** rewards (respect, admiration, self-fulfilment, feel good about myself) from using ICT tools that we are expected to use here	**[CM]** Intangible rewards (Senge *et al.* 1999) **[KM]** Organisational incentive (Klein & Hirschheim 1987) **[KM]** Provide incentive, rewards and recognition (Gibson & Smilor 1991)

Qb2.7 There are clear **advantages** from using ICT tools that we are expected to use here for **decision-making** in my job	**[ID]** Relative advantage (Borton & Brancheau 1994, Ramamurthy 1994, Rogers 1983, Tornatzky & Klein 1982, Zaltman, Duncan & Holbek 1973) **[CM]** Usefulness (Huff & Munro 1985, Mahmood *et al.* 2000) **[IMP]** Support decision-making
Qb2.8 There are clear **advantages** from using ICT tools that we are expected to use here for **communications within** my team	**[ID]** Relative advantage (Borton & Brancheau 1994, Ramamurthy 1994, Rogers 1983, Tornatzky & Klein 1982, Zaltman, Duncan & Holbek 1973) **[CM]** Usefulness (Huff & Munro 1985, Mahmood *et al.* 2000) **[IMP]** Enhance communication
Qb2.9 There are clear **advantages** from using ICT tools that we are expected to use here for **communications between** teams	**[ID]** Relative advantage (Borton & Brancheau 1994, Ramamurthy 1994, Rogers 1983, Tornatzky & Klein 1982, Zaltman, Duncan & Holbek 1973) **[CM]** Usefulness (Huff & Munro 1985, Mahmood *et al.* 2000) **[IMP]** Support collaborative workplace (Alshawi & Ingirige 2002)
Qb2.10 There are clear **advantages** from using ICT tools that we are expected to use here for **coordinating** teams	**[ID]** Relative advantage (Borton & Brancheau 1994, Ramamurthy 1994, Rogers 1983, Tornatzky & Klein 1982, Zaltman, Duncan & Holbek 1973) **[CM]** Usefulness (Huff & Munro 1985, Mahmood *et al.* 2000) **[IMP]** Improve in-house coordination (Alshawi & Ingirige 2002, Whyte & Bouchlaghem 2001)
Qb2.11 ICT tools that we are expected to use here are crucial to support me and my organisation in developing and building **professional credibility**	**[ID]** Create image (Moore & Benbasat 1991)
Qb2.12 ICT tools that we are expected to use here have **relevance to me** and allow me to effectively perform MY job	**[ID]** Relevance (Rogers 1983) **[CM]** Usefulness (Senge *et al.* 1999)
Qb2.13 I am confident that ICT tools that we are expected to use here have the necessary levels of **system response rate** to motivate me to use them.	**[IMP]** Speed of communication and document transfer (Thorpe & Mead 2001)
Qb2.14 I am confident that ICT tools that we are expected to use here have the necessary levels of **functionality** to motivate me to use them.	**[ID]** Functionality (Fichman & Moses 1999, Prescott & Conger 1995) **[CM]** Functionality (Eason 1988, Regan & O'Connor 2000)
Qb2.15 I am confident that ICT tools that we are expected to use here have the necessary levels of hardware/software **accessibility** to motivate me to use them.	**[IMP]** Accessibility to facilities (O'Brien 2000)

3.5.3 *Part C: ICT training & technical support*

Research questions in Table 3.5 relate to the questionnaire Part C (see Appendix A) and they focus on users' training and other forms of learning support, which in turn leads to the diffusion of ICT innovation. The code **[ID]** refers to innovation diffusion literature; **[CM]** refers to change management literature; **[KM]** refers to the literature from knowledge management, organisational learning and knowledge transfer/sharing; and **[IMP]** refers to the literature on ICT implementation in construction.

Table 3.5 ICT training and technical support literature supporting the empirical research instrument

3 Statement about applying information and communication technology (ICT) tools for ME or within my work group	Supporting literature
Qc3.1 My immediate supervisor **encourages** me to learn about and/or apply ICT tools that I am expected to use here	**[ID]** top management interaction between business manager and IT manager (Armstrong & Sambamurthy 1999) **[CM]** Senior managers (Regan & O'Connor 2000) **[CM]** Management support (Borton & Brancheau 1994) **[IMP]** Top management support (Whyte & Bouchlaghem 2001) **[IMP]** Manager dedicate himself as champion and implementer (Whyte & Bouchlaghem 2001), technology champion (O'Brien 2000), lack of top management support (Laage-Hellman & Gadde 1996), Supervisor's willingness (Songer, Young & Davis 2001)
Qc3.2 I have **confidence** that I am **capable** of learning about and applying ICT tools that I am expected to use here	**[CM]** Personal capability to learn (Senge *et al.* 1999) **IMP]** Lack of IT competence among staff on construction site (Laage-Hellman & Gadde 1996), Subordinate's willingness (Songer, Young & Davis 2001)
Qc3.3 I am given **enough quality of training** for learning about and applying the ICT tools that I am expected to use here	**[ID]** Quality of training (Akins & Griffin 1999, Alp, Alp & Omurtag 1997, Borton & Brancheau 1994, Compeau & Higgins 1995, Sackton 1999) **[CM]** Quality of training (Carlopio 1998) **[IMP]** No manual of software (Whyte & Bouchlaghem 2001) **[CM]** Received some training (Whyte & Bouchlaghem 2001)

Qc3.4 I am given **enough time for training** for learning about and applying the ICT tools that I am expected to use here	**[ID]** Time for training (Akins & Griffin 1999, Alp, Alp & Omurtag 1997, Compeau & Higgins 1995, Sackton 1999) **[CM]** Time for training (Carlopio 1998) **[IMP]** Support training (Zipf 2000), no time to learn (Whyte & Bouchlaghem 2001), lacks of training (Songer, Young & Davis 2001), initial time of learning was a consuming process (Whyte & Bouchlaghem 2001)
Qc3.5 I am given **enough flexibility in my job demands** (in terms of rescheduling daily demands and activities etc) to learn how to apply ICT tools that I am expected to use here	**[CM]** Flexibility of time to learn (Senge *et al.* 1999) **[IMP]** Work pressure limit of time to learn (Whyte & Bouchlaghem 2001)
Qc3.6 **Our work procedures support** our capacity to use ICT tools that I am expected to use here	**[CM]** Work procedures support to use (Senge *et al.* 1999)
Qc3.7 I have been given sufficient **time to think** about how I can best use ICT tools that I am expected to use here	**[CM]** Sufficient time to think (Senge *et al.* 1999)
Qc3.8 Organisational **technical support** is sufficient (eg. help desk, and getting software operational) to allow me to learn about and apply ICT tools that I am expected to use here	**[CM]** Technical support (Markus & Keil 1994, Prescott & Conger 1995) **[IMP]** Manager support on investment (Whyte & Bouchlaghem 2001) **[KM]** Lack of collaboration between developer and user (Whyte & Bouchlaghem 2001)
Qc3.9 **Ease of use** of ICT tools I need to use **at my workplace** is adequate for me to do my job	**[ID]** Ease of use (Borton & Brancheau 1994, Davis, Bagozzi & Warshaw 1989, Moore & Benbasat 1991, Tornatzky & Klein 1982) **[CM]** Ease of use (Mahmood *et al.* 2000)
Qc3.10 Access **speed** and **reliability** of networked **hardware at my workplace** is adequate for me to do my job	**[ID]** Reliability (Tornatzky & Klein 1982) **[IMP]** Speed of information transfer (Thorpe & Mead 2001)
Qc3.11 **Mentoring support** is sufficient to allow me to learn about and understand how to effectively apply the ICT tools that I am expected to use here	**[CM]** Implementer/technical support (Markus & Keil 1994, Prescott & Conger 1995)
Qc3.12 ICT tools that I am expected to use here are **compatible** with my experience of existing systems and work procedures.	**[ID]** Compatibility (Borton & Brancheau 1994, Fichman & Moses 1999, Huff & Munro 1985, Ramamurthy 1994, Rogers 1983, Tornatzky & Klein 1982, Zaltman, Duncan & Holbek 1973) [CM] Task-technology compatibility (Kwon 1990) [IMP] Lack of standardisation of communication and information exchange (Laage-Hellman & Gadde 1996, Songer, Young & Davis 2001, Stephenson & Blaza 2001)

Qc3.13 I was given the opportunity to **trial and experiment** ICT tools that I am expected to use here.	**[ID]** Trialability (Huff & Munro 1985, Moore & Benbasat 1991, Rogers 1983, Tornatzky & Klein 1982) **[CM]** Demonstrability/triability (Cooper & Zmud 1990, Zaltman, Duncan & Holbek 1973)
Qc3.14 The **result/benefit of using** ICT tools that I am expected to use here were **easy to observe**.	**[ID]** Perceive of usefulness (Davis, Bagozzi & Warshaw 1989) Observability (Tornatzky & Klein 1982) **[ID]** Demonstrability (Huff & Munro 1985, Moore & Benbasat 1991, Rogers 1983) **[CM]** Communicability (Tornatzky & Klein 1982) **[IMP]** Easy to see the benefit (Whyte & Bouchlaghem 2001)
Qc3.15 I believe that ICT tools that I am expected to use here **are better than** ones that I have previously/traditionally used.	**[ID]** Positive attitude toward technology (Coffin & MacIntyre 1999) **[IMP]** ICT perceived as better than CAD (Whyte & Bouchlaghem 2001)

3.5.4 *Part D: ICT workplace support environment*

Research questions in Table 3.6 relate to the questionnaire Part D (see Appendix A) and they focus on the nature of support in the workplace environment, which in turn, leads to the diffusion of ICT innovation. The code **[ID]** refers to innovation diffusion literature; **[CM]** refers to change management literature; **[KM]** refers to the literature from knowledge management, organisational learning and knowledge transfer/sharing; and **[IMP]** refers to the literature on ICT Implementation in construction.

Table 3.6 ICT workplace support environment literature supporting the empirical research instrument

4 Statement about applying information and communication technology (ICT) tools for ME or within my work group	Supporting literature
Qd4.1 MY **organisation** is generally **committed** to providing necessary resources and systems to make ICT tools that I am expected to use here work for me	**[ID]** Organisational commitment to support enough resource (Borton & Brancheau 1994, Lenoard-Barton & Sviokla 1988, Prescott & Conger 1995, Thompson, Higgins & Howell 1991) **[CM]** Managerial interaction (Cooper & Zmud 1990) **[KM]** Organisational commitment (Senge *et al.* 1999) **[IMP]** Management commitment (Stephenson & Blaza 2001, Whyte & Bouchlaghem 2001, Zipf 2000)
Qd4.2 **I** am **committed** to effectively use ICT tools that I am expected to use here	**[ID]** Personal commitment on use (Ginzberg 1981a, Newman & Sabherwal 1996) Voluntaries (Moore & Benbasat 1991) **[KM]** Individual commitment (Senge *et al.* 1999)
Qd4.3 I can **trust my immediate supervisor** that if I make some mistakes when first getting to grips with ICT tools that I am expected to use here I will not be blamed and pressured when learning and practicing these tools	**[CM]** Trust of supervisor when making mistake (Senge *et al.* 1999)
Qd4.4 ICT **tools** that I am expected to use here are making my job too **difficult, complex** or **frustrating** to handle	**[ID]** Complexity (Huff & Munro 1985, Ramamurthy 1994, Rogers 1983, Tornatzky & Klein 1982) **[IMP]** Uncomfortable during learning period (Koskela & Kazi 2003)
Qd4.5 **I am anxious** about making mistakes when learning and practicing using ICT tools that I am expected to use here	**[ID]** Personal anxiety and frustration (Anderson 1996, Igbaria & Parasuraman 1989) Anxiety (Coffin & MacIntyre 1999, Igbaria & Chakrabarti 1990) **[CM]** Fear and anxiety (Carlopio 1998)
Qd4.6 I *feel safe in* **openly discussing** any difficulties about using ICT tools that I am expected to use here	**[CM]** Safe to open discussion about the problems (Senge *et al.* 1999)
Qd4.7 Most of my *colleagues/fellow workers feel safe in* **openly discussing problems** about difficulties in using ICT tools that I am expected to use here	**[CM]** Safe to open discussion about the problems (Senge *et al.* 1999)
Qd4.8 I feel **unduly pressured to be effective** in using ICT tools that I am expected to use here	**[CM]** Pressure to use technology (Senge *et al.* 1999)

Qd4.9 My **immediate supervisor** in my organisation **is open to suggestions** on improving the way that ICT tools that I am expected to use here are used	**[CM]** Supervisor open to suggestions on how to improve (Senge *et al.* 1999)
Qd4.10 My **organisation in general is open to suggestions** on improving the way that ICT tools that I am expected to use here are used	**[CM]** Organisation in general open to suggestions on how to improve (Senge *et al.* 1999)

3.5.5 *Part E - ICT information sharing*

Research questions in Table 3.7 relate to the questionnaire Part E (see Appendix A) and they focus on sharing and learning environment which in turn, leads to the diffusion of ICT innovation. The code **[ID]** refers to innovation diffusion literature; **[CM]** refers to change management literature; **[KM]** refers to the literature from knowledge management, organisational learning and knowledge transfer/sharing; and **[IMP]** refers to the literature on ICT Implementation in construction.

Table 3.7 ICT knowledge and information sharing literature supporting the empirical research instrument

5.1 Statement about supporting information and communication technology (ICT) tools use for ME or within my work group	**Supporting literature**
Qe5.1.1 Our organisation supports our ability to **share experience** of ICT tools that I am expected to use here	**[CM]** Management support sharing (Attewell 1992) **[KM]** Organisational learning and sharing (Attewell 1992)
Qe5.1.2 Our organisation provides **tangible rewards** (bonus, promotion, etc) to those who **share ideas** and experience about ICT tools that I am expected to use here	**[KM]** Rewards/benefits (Marsh & Finch 1998, Marsh & Flanagan 2000)

Qe5.1.3 Our organisation provides **intangibly rewards** (recognition, thanks or public praise) to those who **share ideas** and experience about ICT tools that I am expected to use here	**[KM]** Rewards/benefits (Marsh & Finch 1998, Marsh & Flanagan 2000)
Qe5.1.4 I feel comfortable and keen to **help and explain** (mentoring) **one-on-one** to others on how to effectively use ICT tools that we are expected to use here	**[ID]** Communication channel support innovation adoption (Nilakanta & Scamell 1990b, Rogers 1983) **[ID]** Learning support the diffusion (Attewell 1992) **[KM]** Interpersonal channel (Gibson & Smilor 1991) Co-worker support for use (Borton & Brancheau 1994, Kwon 1990) **[IMP]** Implementer help on using VR (Whyte & Bouchlaghem 2001)
Qe5.1.5 My **colleagues** in my immediate work group are willing and keen to **help me formally** through discussing and demonstrating ICT tools that I am expected to use here	**[ID]** Communication channel supports innovation adoption (Nilakanta & Scamell 1990b, Rogers 1983) **[ID]** Interpersonal communication (Cooper & Zmud 1990) **[CM]** Formal collegial help (Senge *et al.* 1999) **[KM]** Organisational learning (Walker & Lloyd-Walker 1999) **[KM]** Person-to-person help (Gibson & Smilor 1991) Interpersonal communication (Kwon 1990) **[KM]** Co-worker support for use (Borton & Brancheau 1994)
Qe5.1.6 My **colleagues** in my immediate work group are willing and keen to **help me informally** through discussing and demonstrating ICT tools that I am expected to use here	**[ID]** Communication channel support innovation adoption (Nilakanta & Scamell 1990b, Rogers 1983) **[ID]** Interpersonal communication (Cooper & Zmud 1990) **[CM]** Informal collegial help (Senge *et al.* 1999) **[KM]** Organisational learning (Walker & Lloyd-Walker 1999) **[KM]** Person-to-person help (Gibson & Smilor 1991), interpersonal communication (Kwon 1990)

3.6 Summary of chapter

This chapter provides the rationale, citing the literature relating to ICT initiatives undertaken in the construction industry, for the need of a study of ICT adoption strategy and actual implementation to fill identified gaps in the existing literature. The discussion of construction ICT implementation provided some understanding of the ICT implementation drivers and barriers but these studies were shown to lack focus on actual ICT implementation. Thus there is a need for research into both innovation diffusion factors and an ICT implementation processes approach.

The ICT factors approach focuses on variables influencing actual ICT implementation that can be measured using a quantitative research approach. The chapter helps to identify knowledge gaps on how to encourage and manage the process of actual implementation of ICT diffusion within construction organisations. Identified potential ICT diffusion variables were developed from three main theoretical concepts: innovation diffusion, change management, and knowledge sharing and learning. The chapter also provides detailed justification for each question asked in the research's quantitative empirical instrument. This chapter also indicated how qualitative research could fill knowledge gaps of how ICT diffusion processes operate in practice. The next section will discuss the research methodology that was used in this research.

Chapter 4
Research method and design

The objective of this chapter is to explain the research method and design that was applied to conduct this thesis. It contains two main sections. The first section discusses the nature of philosophical assumptions underpinning this study's research approach, strategy, and design. The second section describes in detail the two main research methods used in this project.

Both a survey questionnaire and a case study interview approach are adopted to collect data to explain the nature of ICT diffusion within construction organisations. A survey was developed as Phase 1 of the research project to identify key factors influencing ICT diffusion within large construction organisations. This research investigates ICT diffusion at the organisation level rather than at the industry level. The scope of the survey was limited to explore factors influencing current ICT diffusion practices within large construction organisations. Survey findings informed the interview case study, which was undertaken to explore what current processes of ICT diffusion are being adopted by the case study organisations to determine how they implement their strategic ICT diffusion, and to identify how ICT diffusion factors influence these large contractor firms' ICT diffusion process. The research questions, method and design are described in more depth below.

4.1 Understanding philosophical research assumptions

Research assumptions are philosophically grounded—they relate to a view or perception of philosophers towards reality. Two terms 'ontology' and 'epistemology' are used to explain philosophical assumption characteristics. According to Easterby-Smith *et al.* (2002), *ontology* is the science of being. It is the way that researchers perceive and understand the nature of the 'real world'—for example from the perspective of an individual, an organisation or an industry. *Epistemology* is the theory of knowledge and critical examination of assumptions of what is valid and what is the scope of that validity. This enables researchers to explore the real world as they define it. It is clear that research studies in science and social science have different positions on the nature of research philosophy (Easterby-Smith, Thorpe & Lowe 2002).

Based on different philosophical assumptions, both physical and social scientists can be categorised into positivist or social constructionist groups (Easterby-Smith, Thorpe & Lowe 2002). Positivists believes that the world is actually *concrete* and *external* and therefore their exploration can only be based upon observed and captured 'facts' through direct data or information (Easterby-Smith, Thorpe & Lowe 2002). On the other hand, social constructionists believe that the world is not objective and exterior, and they consider that the world is based on a social construction in which people create and interact. Therefore, the way that people feel and behave is at least as important as the way they are observed or recorded to behave. Social constructionists argue that the real world is determined by people rather than by objective and external observable factors (Easterby-Smith, Thorpe & Lowe 2002).

Understanding philosophical assumptions, therefore, can help researchers to plan a research method and design. Easterby-Smith *et al.* (2002) provide a rationale for understanding the philosophy as follows. First, knowledge of philosophy helps researchers to design research questions and to gather and analyse a collection of evidence answering those questions. It does this by framing a point of view—the ontological position, for example, from an individual or group perspective. Second, it helps researchers to understand the limitations of each research design and to select the appropriate one—the epistemology that guides the rules that determines what is considered valid or not, given the ontological stance.

Although the line between positivist and social constructionist is clear at a philosophical level, Easterby-Smith *et al.* (2002) argued that this line may become blurred at a research design level when the researcher needs to understand the real situation from several perspectives. The researcher may decide to combine the way to obtain data using both qualitative and quantitative data to understand the nature of the real world as perceived by those interviewed and/or surveyed.

4.2 Research approach

Lawrence (1997) suggests that a research approach can be categorised as exploratory, descriptive, and explanatory. Exploratory research can be considered to be use when the research purpose is to uncover or highlight issues of a phenomenon under study. It is also used to acquire evidence to answer a 'what' type research question. Descriptive research is selected when researchers attempt to describe the nature of a phenomenon under study. It is suitable for obtaining data to explain 'how' the phenomenon occurs. Explanatory research is chosen when researchers aim to answer 'why' such a phenomenon occurs. Thus, a research approach is influenced by the research purpose.

A research approach may be also be influenced by the types of data or evidence that is needed to answer research questions. Based on data characteristics, the research approach can be categorised as quantitative, qualitative, or mixed. Quantitative research is focused on the numerical measurement or mathematical models used to test research hypotheses. Qualitative research stresses the importance of the context of participants' accounts to provide a rich picture to verify or reject research hypotheses.

This research aims to identify ICT diffusion factors and processes and explains how these factors support ICT diffusion. Therefore, it can be categorised as an exploratory and descriptive approach using both quantitative and qualitative data. The research first focuses on quantitative data to identify factors that support the use and adoption of ICT applications by using surveys. The reason for using a survey is to collect data from a large number of respondents in a short period of time and to minimise the cost (in terms of researcher resources) of collecting data. A survey approach also gives respondents an opportunity to think before completing the questions, thus potentially enhancing the reliability of data. The research then uses the insights gained from that work in Phase 1 to better understand the ICT diffusion processes observed to be taking place in the case study target organisations for Phase 2 of the study in which qualitative data were gathered and analysed. The work investigates ICT diffusion from the perspective of both the individual and organisation but does not attempt to study this from an industry perspective.

4.3 Relationships between research strategy and questions

According to Yin (1994), there are many ways to conduct research governed by the relationship between research questions and research strategy. He suggests that research strategy could be defined by three conditions: (1) the types of research question, (2) the control of investigator and (3) the focus on contemporary events. Table 4.1 shows research strategies in different situations.

Table 4.1 Relevant situation for different research strategies (source: Yin 1994)

Strategy	**Form of research question (1)**	**Requires control over behavioural events? (2)**	**Focuses on contemporary events? (3)**
Experiment	how, why	Yes	Yes
Survey	who, what, where, how many, how much	No	Yes
Archival analysis	who, what, where, how many, how much	No	Yes/No
History	how, why	No	No
Case study	how, why	No	Yes

Based on conditions illustrated in Table 4.1 above (1) the types of research questions are 'What' and 'How'. Therefore, the possible research strategies could be experiment, survey, archival analysis, history, and case study. Condition (2) indicates that the *experiment* strategy is unsuitable for this research because this research did not involve designing the environment in which ICT diffusion takes place or test the group of people in different types of ICT diffusion settings. Thus researcher did not intend to control the behaviour of participants in adopting and diffusing ICT. Condition (3) indicates possible research strategies are survey and case study because the study is focused on contemporary events. According to Yin (1994), a research study could use more than one strategy and that each strategy might be suitable in specific conditions. Therefore, this research was designed to use both survey and case study strategies.

4.4 Research design

A research design helps the researcher to plan how to collect and analysis data. This research design is categorised as a series of case studies that helps us understand ICT diffusion within leading Australian construction organisations. It consists of both quantitative and qualitative data. In Phase 1, quantitative data were gathered using a questionnaire as the principle tool to gather data about ICT users' experience on variables that influence ICT diffusion at the actual implementation stage. Rather than targeting non-ICT users who may not have relevant experience of ICT use, only experienced ICT users were selected from three large construction organisations that adopt ICT. The resultant findings can help to identify the main drivers that influence ICT diffusion and these were used to inform interviews to be conducted during the Phase 2 case study.

Qualitative interview data was used in Phase 2 to explore what ICT diffusion processes were being followed by the selected experienced construction organisations and to explain how these factors influence ICT diffusion processes. The details of the two phases are illustrated in Figure 4.1.

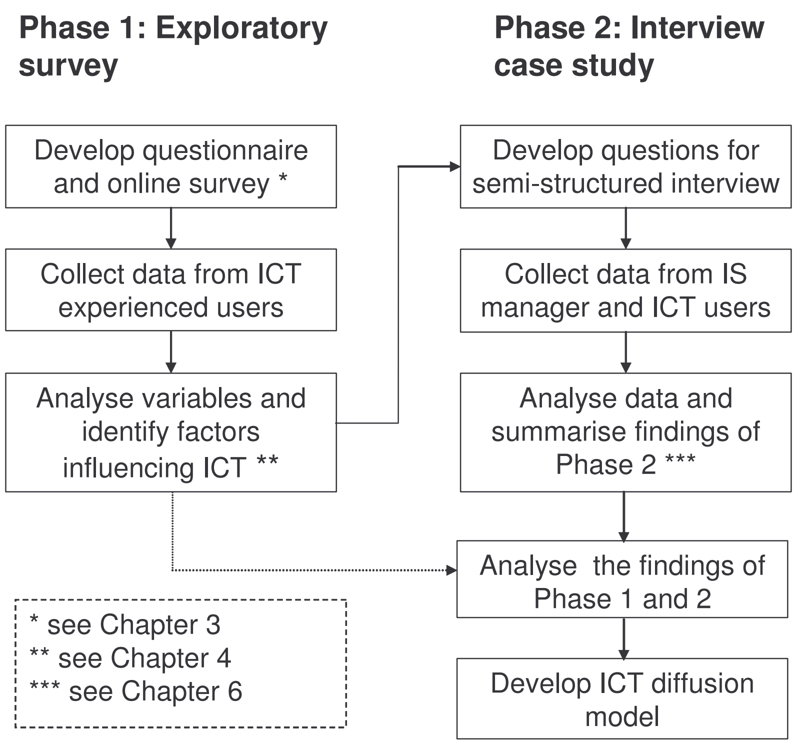


Figure 4.1 Framework of research design

After collecting and analysing data from the two phases, a model of ICT diffusion was formulated to provide an understanding of ICT diffusion at the actual implementation management stage for the selected construction organisations. The model could benefit ICT diffusion processes by providing managers of those processes with a guideline to improve these processes within their organisations.

4.5 Research design Phase 1: survey questionnaire

The survey questionnaire was designed as a first phase of this research and attempts to understand current practice of ICT diffusion from the factor view. This phase attempts to answer the first two research questions:

1) *What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations?*
2) *To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations?*

The primary objective of the survey is to identify the nature and extent of intra-organisational variables influencing ICT diffusion within three large Australian construction organisations. It focuses on individual professional level ICT users within these organisations who are familiar with and currently use ICT applications. This survey not only helps to identify common issues that these ICT users have experienced, but also allows researchers to understand the nature and extent of the supportive environment within these organisations that could facilitate ICT use. These results may help us to better understand the nature of ICT diffusion within leading construction organisations. In addition, this study survey identifies ICT knowledge sources and the way that ICT knowledge is shared within each organisation.

The second objective of the survey is to identify key factors influencing ICT diffusion within an organisation. These factors represent clusters of interrelated variables identified by a rigorous review of the literature. Once identified, these factors can then be used as the basis for conducting interviews with individual ICT users in the second phase of this research study to gain a richer appreciation and understanding of the nature of the workplace environment that drives and/or inhibits ICT diffusion within those ICT literate organisations. The focus of attention throughout this study is directed to individuals who are computer literate and working in construction organisations that have a substantial history of using ICT in their work processes. This type of individual can best illustrate how ICT diffusion operates in practice.

4.5.1 *Rationale of survey questionnaire*

Several previous survey studies provided an overview of general IT use and adoption in the construction industry, such as Rivard (2000) in Canada; O'Brien and Al-Biqami (1999) in Saudi Arabia; Futcher and Rowlinson (1998, 1999) in Hong Kong; Howard and Samuelsson (1998) and Howard, Kviniemi *et al.*(1998) in Denmark and Finland; Doherty (1997a) in New Zealand; and CSIRO (1996) in Australia. The results of these studies contribute to construction research and practice by providing an understanding of current IT use and problems related to IT use. However, these results may be too broad for explaining what factors influence ICT implementation at the particular individual or group level. This research project is focused on experienced users within large construction organisations; therefore, these results more accurately reflect current ICT implementation practice of IT/ICT experienced individuals and organisations.

This survey questionnaire is used to help us understand variables influencing ICT diffusion during actual implementation. The research begins with a study of leading construction organisations that have experience of information technology (IT) business process use and ICT application implementation—this helps us develop a basic understanding of ICT diffusion drivers and barriers. The study also focuses on the ICT users' experience of working in environments and workgroup climates that support or hinder effective ICT use.

This survey centres on ICT implementation within these construction organisations from an innovation diffusion viewpoint. ICT implementation is viewed as an internal process in which organisations attempt to encourage ICT use by staff. Thus, variables influencing an ICT user should be examined to guide our understanding of how ICT initiatives can be successfully implemented.

4.5.2 *Criteria and selection of target respondents*

Client organisations, consulting engineers and construction contractors undertake projects of varying size, construction cost and complexity. In particular, top tier construction contractors undertaking these projects often have an company-wide annual turnover of over a billion Australian dollars and employ a highly sophisticated corporate office staff to oversee the company's business operations. Because a key objective of this research is to understand the ICT diffusion process, it was necessary to focus on companies with a sustained IT and ICT deployment history.

The work was also anchored into a collaborative research centre for construction innovation (CRC CI) research project and so participating industry partners were selected that were both available and willing to participate. Therefore, rather than using a random sampling approach, a purposive sampling technique was applied to select the participants who use ICT from three CRC CI participating partners. Each of these three organisations has a key liaison person who was asked to nominate experienced respondents who were intensive users of ICT willing to take part in the survey. The reason for gathering data from intensive ICT users rather than occasional users was that this group would be best suited to provide information about the way in which ICT applications are diffused in their organisation. In addition, these three leading construction organisations were selected because they have been shown as innovation ICT users. They have won industry or professional excellence awards for their project management approach. The use of nominated respondents added to the validity of the sampling strategy because respondents were drawn from experienced ICT users. The potential for bias in the choice of participating individuals being nominated is recognised. However, because these organisations are involved in the CRC CI there was an in-built motivation for a high participation rate and quality of response to the survey. As the case study unit of analysis is the user rather than the organisation, all respondents were analysed as a single group rather than belonging to three organisations. This chapter also explains how participants could be classed as a single group of ICT users.

4.5.3 *Conduct of the survey*

During early 2002 a pilot survey involving 15 users from two large construction organisations was undertaken to investigate factors that influence ICT diffusion. In addition, two researchers involved in the CRC CI research team also agreed to complete the pilot survey instrument. After the 17 individuals tested the pilot survey, the final survey was developed and refined into an online survey questionnaire.

The aim of the online survey was to automate data collection from participating ICT users from different geographical locations. Each organisation was requested to select approximately 50 experienced people who regularly used IT and ICT applications. This formed a representative pool of users from each organisation to complete the online questionnaire. The types of users responding to the questionnaires matched the general pool of users in the organisation for the research purpose.

From 1st March to 8th May, 2002, the case study survey was undertaken within the three nominated organisations. These were: a state government public works organisation both overseeing and managing construction activities; a major construction contractor organisation with an annual turnover in excess of one billion Australian dollars; and an large and complex international engineering and design construction organisation. All are industry partners of the CRC CI.

4.5.4 *Questionnaire delivery*

The questionnaire was delivered in an electronic format, both online and offline as a 'Word' document. The online version was programmed to allow participants to enter data one section at a time so that they could take a break and re-enter the survey at the point where they left off and to make changes to their entries before finalising their submission. One reason for using this method was to minimise the cost and time of printing and mailing hard copy questionnaires. There are three further benefits of using an electronic online questionnaire. First, the electronic format file provides a clear transfer of the respondent's data compared to interpreting and transposing data from handwritten responses. Second, the researcher can monitor the number of participants who had not completed the survey by the cut-off date and encourage them to complete it (by emailing them or contacting them in another way). This led to a good response rate with most requested respondents participating because respondents could be gently reminded to complete their contribution. Third, the information from the user response was stored in electronic format that could then be automatically transferred to the research database. This increased both the speed and validity of data collection. An electronic offline ‘Word’ document and hard copy format questionnaire was provided for respondents who might not find it convenient to answer it online. Several participants chose to enter data on a ‘Word’ version of the survey and either emailed it or posted it in hard copy form. This was because for some participants, the online participation was inconvenient for them during the time allocated to submit it.

The online questionnaire was developed in three phases: interface design, web page programming and database design. The first stage is designing the web page for data entry. Using a web page publisher software application called Microsoft FrontPage, the questionnaire was generated using a Hyper Text Markup Language (HTML) format[8]. Based on the offline questionnaire as a prototype, the online questionnaire was designed into thirteen web pages as seen in Table 4.2.

Table 4.2 The detail of web pages in survey online questionnaire

Web page Number	Content
Page 1	Welcome message of ICT survey
Page 2	Login
Page 3	General information of participant
	Part A – General ICT use
Page 4	1.1 Access to electronic communication technologies
Page 5	1.2 Software package use
Page 6	Part B – ICT motivation
Page 7	Part C – ICT Training & technical software/hardware support
Page 8	Part D – ICT workplace Support
Page 9	Part E – ICT information Sharing
Page 10	5.1 Statement of support information sharing
Page 11	5.2 Source/medium that used to learn about ICT tools
Page 12	Part F – networks of people helping
Page 13	End of questionnaire

The second phase was writing the web-programming language to transfer data from the web page to a database. There are many web-programming script languages such as Common Gateway Interface[9] (CGI), PHP: Hypertext Preprocessor[10] (PHP), and

[8] http://www.w3.org/MarkUp/Guide/ accessed on 09 Nov 2001
[9] http://hoohoo.ncsa.uiuc.edu/cgi/ accessed on 09 Nov 2001

Active Server Page[11] (ASP). The Active Server Page (ASP) was selected as the web-programming language because the researcher had knowledge of this programming language and also the web server supported the ASP language.

The final stage is the development of a database file to store data from the web pages. Although the data could be stored in text file format, it makes it somewhat difficult to manage data. For example, it is very difficult to write ASP for updating data when compared with database files. Therefore, Microsoft Access was selected to build the database file.

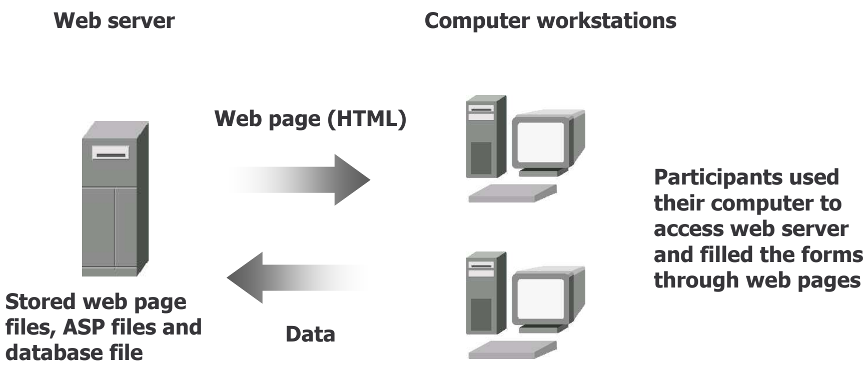


Figure 4.2 The operation of online survey questionnaire

Figure 4.2 shows the operation of the online survey questionnaire. This figure provides a basic idea about how the online survey operates. Three equipment components are needed to operate the online questionnaire. These are a computer workstation, an Internet connection and a web server that supports web programming. First, participants need a compatible computer workstation to interact with the researcher by reading the questionnaire and submitting the data. Second, an Internet connection is required as the communication channel that transmits data between web server and computer workstation—a web server requires a special protocol such as Hypertext Transfer Protocol (HTTP) to communicate using the Internet. Finally, the web server keeps web pages, ASP files and database files.

[10] http://www.php.net accessed on 09 Nov 2001
[11] http://www.asp.net/ accessed on 09 Nov 2001

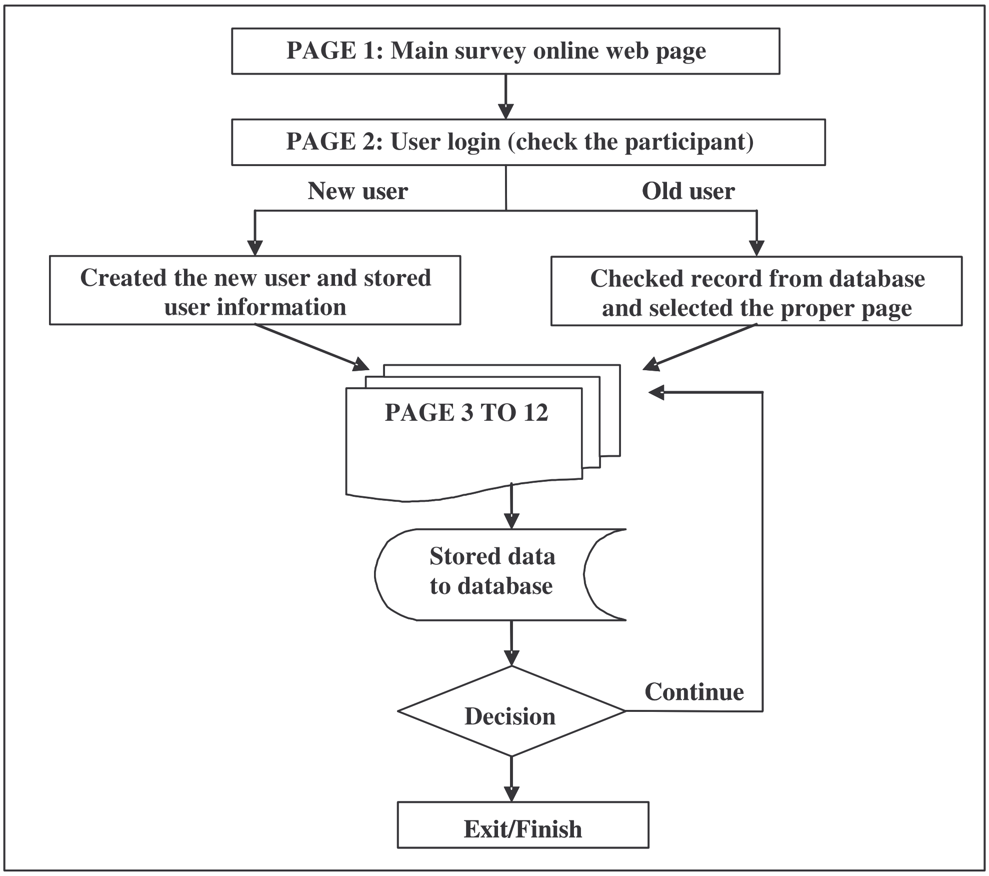


Figure 4.3 The diagram of online survey questionnaire

The online questionnaire was developed using the above concept. Figure 4.3 illustrates the participants' access to the web sever via computer workstations. Web pages on the server need interaction from the participants to enter data and progressing through web pages. After the participants have filled all questions for each page they click the '*continue'* button. On pressing this button, all data entered is transferred and encoded into the database using ASP programming files. When the storage of the data into the database is completed, a statement of completion is shown on the participant's screen to allow participants to continue to the next part of questionnaire or leave the questionnaire. This design strategy was developed because participants needed about 60 minutes to complete the survey and few participants might have that time available at one sitting. In this research, each web page was designed to have its own ASP file for coding data to the database. Details of web page, ASP codes and database files are shown in Appendix A.

4.5.5 *Quantitative data analysis in Phase 1*

Tools for data analysis in Phase 1 consist of analysis of variance (ANOVA) and factor analysis (FA). The analysis of variance was selected to identify the similarity and difference of variables among three groups while the factor analysis was chosen to group the large number of variables influencing ICT diffusion into a smaller coherent group of factors. The details of each analysis will be explained in Chapter 5.

4.5.6 *Validation and reliability in Phase 1*

Quantitative research findings were validated in terms of interpretation of their meaning in two ways:

A series of seminars and workshops were undertaken with a mixture of some respondents and their colleagues. Not all respondents were available for these events

A series of research presentations to professional groups and papers at academic conferences.

Further discussion of the statistical analysis and reliability is presented in Chapter 5

4.6 Research design Phase 2: interview case study

The interview case study was designed as a second phase of this research and attempts to understand current practice of ICT diffusion from both factor and process views. Phase 2 attempts to answer the following three main research questions:

3) How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations?
4) How has ICT knowledge been diffused by users within large Australian construction organisations?
5) What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?

Two objectives were established to answer the above three questions. The first objective is to confirm the validity of factors from Phase 1 and understand how these factors influence the diffusion process. The second objective is to explore current ICT diffusion practices of large Australian construction contractors. A case study approach was selected to obtain qualitative data from experienced IT strategist interviewees, IT implementers, and ICT users from each of three case studies. These findings may help to explain the relationship between factors and process that influence ICT diffusion within the three leading construction contractors.

4.6.1 *Rationale of the interview case study*

The reasons for conducting interviews is to obtain rich information about how users experience factors influencing ICT diffusion and to explore what are the current ICT diffusion practices and process being pursued by organisations from both strategic ICT adoption and actual ICT implementation viewpoints. The reason for choosing this method was to provide qualitative data that can help us better understand how ICT is initiated within the selected construction organisations and to expose factors that supported their ICT diffusion processes. In addition, these case studies help us understand detailed case study data from the participant's viewpoint using multiple sources of data (Yin 1994). According to Neuman (1997), three research approaches can be used: exploratory, descriptive, and explanatory. As this research focused on what ICT diffusion processes are practised in leading Australian construction contractors and on how factors influenced the diffusion processes, both exploratory and descriptive approaches were adopted for interview case studies.

4.6.2 *Question development*

Questions asked of interviewees from the three case studies were developed from and prompted by identified key factors derived from the survey results (Phase 1). These questions, presented in Appendix C, are part of a structured set of interviews. They relate to respondents' experience of how each factor influencing ICT implementation was undertaken on one particular type of ICT system—an electronic document management system (EDMS).

4.6.3 *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 an annual turnover of more than 500 million AUD (Australian dollars). A study of ICT implementation in small and medium Australian construction organisations indicated that these organisations are less likely to adopt ICT (Love *et al.* 2001). This finding was also confirmed by the ABS (2001), which showed that the majority of ICT use is concentrated in large businesses. Therefore, this study focused on large construction companies with ICT implementation experience.

The target contractor companies are listed from the *Business Review Weekly* (BRW 2001) and Australian Constructors Association Annual Report (2001). There are approximately 13 construction companies that managed projects of hundreds of millions of dollars cost with company annual turnovers exceeding AUD$500 millions during the 2001 year. This research investigated ICT adoption and diffusion practices of three of these top-tier Australian construction contractors from that *BRW* list. The researcher selected these three on the basis of availability and the opportunity to conduct interviews using an interview instrument designed with reference to the components from research Phase 1 in Chapter 5. It should be noted that one contractor also participated in a previous survey questionnaire in Phase 1.

A representative participant target group of expected ICT users and an implementer and ICT strategist within each of three organisations was identified for interviewing using advice from a senior management representative from each of the three construction organisations. Most of the interviewees were based in Victoria, Australia, where the researcher was 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 that magnitude of annual workload.

4.6.4 *Case study data collection and interview conduct*

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 one 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 'at the coal face'.

The data collection was conducted via semi-structured and structured interviews. To receive the view from cross-organisations, data were collected from the ICT application implementer/facilitator and 5-6 ICT professional users including project managers, engineers, and foremen. Chapter 6 provides further details of the case study participants and a description of the organisations. Chapter 7 provides details on the case study analysis and the methods of analysis used. Each interviewee was asked to discuss their perception of factors influencing ICT diffusion in their organisation. Each interview took approximately 30-35 minutes. Most[12] of the interviews were taped and transcribed by the researcher and salient points of content sent back to the users for validation.

4.6.5 *Qualitative data analysis in Phase 2*

Miles and Huberman (1994) suggest guidelines for analysing qualitative data. These are categorising and placing evidence in a matrix, putting information into different arrays, creating data display, and tabulating the frequency of different events. This research adapted their suggestions by

- putting individual transcript data into a table
- categorising data based on factors that influence ICT diffusion
- summarising all individual data into a table to compare each case study

[12] An equipment malfunction inhibited recording two interviews but copious notes were also taken for reference and analysis.

Then, pattern-matching to analyse the similarity and difference of main factors among the three cases were undertaken. In addition, the analysis of ICT adoption strategy and actual implementation processes results for the case studies was adopted using the diffusion of innovation framework. This conforms to the '*literal replication*' case study approach (Yin 2003).

According to Yin (2003), a case study protocol should be developed. This protocol helps to increase the reliability of qualitative research conduct. The protocol case study used in this research followed Yin's recommendation approach:

1. Introduction of the case study
    a. Send the letter of invitation and brief introduction to gain the commitment from IT senior manager
    b. Request the list of participants
2. Data collection procedure
    a. Contact participants from the list
    b. Arrange time/date/place for interview
    c. Send the brief introduction of the case study objectives
    d. Prepare tape recorder, blank questionnaire
3. Report case study
    a. Background of case (IT strategist and IT implementer)
        i. Historical data of technology development
        ii. Types of technical support groups and their structure
        iii. Overview of current ICT use in case study
    b. Interview users experienced on factor influencing the diffusion of ICT use (obtain from research Phase 1)
    c. Explore current practice of ICT diffusion processes in each case (IT strategist and IT implementer)
4. Analysis of case study
    a. Within-case analysis
        i. Case study background
        ii. Configurations of ICT system
        iii. The use of ICT in general
        iv. Groups of ICT innovation support

v. Diffusion of ICT at the organisational level
vi. Diffusion of ICT at the individual/group level
vii. Users' experience on factors influencing ICT diffusion

b. Cross-case analysis
i. Analysis of factors influencing ICT diffusion
ii. Cross-case analysis of factors influencing ICT diffusion
iii. Interpreting the meaning of factors influencing ICT diffusion
iv. ICT knowledge diffusion through users
v. Analysis of strategic ICT adoption
vi. Analysis of ICT diffusion process at initial adoption
vii. Analysis of ICT diffusion process at actual implementation

5. Discussion (develop the link between literature and findings)

4.6.6 *Validity and reliability in Phase 2*

As the case study contains the set of subject data, this can be criticised on reliability and validity of research. To increase the reliability and validity, Yin (2003) suggest the use of '*multiple source of evidence*'. In addition, he found that the validity of data can be increased through the review of respondents on the draft report. In this research, validity and reliability was assured by:

1. Collecting the evidence from different viewpoints such as IT strategist, implementer, project managers and foreman.

2. Sending the draft transcript to individuals to clarify points with interviewees to ensure that they agree with what the interviewer interpreted that the interviewee had said.

3. Providing a presentation to the respondent in which the data and findings were clarified and an opportunity for reflection and modification was given at that presentation. Thus they were able to validate and ensure the findings and interpretation of results reflected their true perceptions.

4.7 Summary of the chapter

This chapter explains the research method and design in order to clarify the choice of research method and to provide a rationale for the choice. It begins with a basic background of the philosophical research assumptions, the research approach, research strategy and design. This research adopted both the survey questionnaire (Phase 1) and case study interview (Phase 2) approaches.

Research Phase 1 explains how the survey questionnaire was developed and administered. It consists of information about survey background, criteria and selection of case study participants, development of the online survey questionnaire and basic concepts of factor analysis. The purpose of this was to clearly identify the source of participants and justify the selection of this particular group as being valid for this survey. Also, the data treatment technique was explained and justified. One important aspect of this chapter was that it established that the unit of analysis should be individuals from the three organisations and that it was valid to consider them as a single group for the purpose of analysis because they substantially shared common experiences of ICT use. The use of factor analysis was also justified for the entire sample's data analysis. Another important aspect of this chapter was an explanation of the way that the survey instrument was designed, programmed and undertaken to match the purpose of the study—in trying to understand ICT diffusion an ICT survey delivery approach was adopted, though provision was made to allow data to be gathered using an off-line method. The analysis of the survey will be discussed in the next chapter.

To obtain the more in-depth understanding of ICT diffusion processes, the chapter also describes the research method of interview case study (Phase 2). It explains the rationale of interview case study, case study criteria, interview questionnaire development, and data collection and interview conduct. The interview case study will help to explore the nature and processes of ICT diffusion during the actual implementation phase. In addition, it helps to explain how factors influence ICT diffusion processes and to understand how ICT knowledge has been diffused by users within leading construction contractors that had experienced ICT implementation. The analysis of interview will be discussed in Chapter 6.

Chapter 5
Exploration of factors influencing ICT diffusion within the three leading construction organisations

This chapter analyses results obtained from the quantitative data of the survey questionnaire described in Chapter 4. The analysis of the results will be presented in four main sections. The first section describes the characteristics of the data sample and variables influencing ICT diffusion during the actual implementation stage. The second section gives a justification for combining samples from three leading construction organisations. The third section focuses on combining these variables into group factors influencing ICT diffusion. The fourth section explores the sources of ICT knowledge that users learn from and access during office hours and outside office hours

Results indicate that three groups each present sufficiently similar characteristics to be considered as a single group of ICT users. For example, these groups indicate a similar extent of ICT applications use. Thus their ICT experience levels can be considered to be similar. They also share similar experiences in their use of ICT that the literature argues influences ICT diffusion at the actual implementation stage. These similarities provide a justification for combining the data from the three organisations into one group for analysis. Based on the combined data from respondents, the factor analysis (FA) technique is used to explore the group of factors from 46 variables. The results of FA indicate 11 factors that influence ICT diffusion at the actual implementation stage. In addition, the findings of last section indicate that access to ICT learning sources/media is somewhat limited both within and outside working hours. Thus, ICT learning from these sources needs to be improved, as the overall access to ICT knowledge sources is moderately experienced by ICT users.

5.1 Descriptive analysis of respondents

Table 5.1 presents the proportion of respondents from the three leading construction organisations. Each organisation was asked to provide between 30 and 50 respondents as described in Chapter 4. The total number of usable responses was 117 from 120. There were 35 respondents drawn from the department of public works construction organisation (O_1), 39 respondents from the construction contractor organisation (O_2), and 43 respondents from the engineering consultant and design group (O_3). Respondents from two other building departments in a public construction organisation were not included in the analysis because of poor response rates from those organisations. The CRC CI industry partner liaison person in those two organisations could only persuade a total of 3 respondents to agree to complete the survey and this was considered an insufficient number to adequately be considered as representative of their respective organisations or could be viably tested to be considered as part of the total respondent pool surveyed.

Table 5.1 The proportions of respondents using IT applications

Proportions of Respondents	Group O_1		Group O_2		Group O_3	
	N	%	N	%	N	%
Manager/director	8	23	20	51	19	44
Project manager/ officers	11	31	4	10	3	7
Planner/advisor/consultant	8	23	4	10	N/A	N/A
Professional (i.e. engineer, technician)	3	9	10	26	19	44
Administration	5	14	1	3	2	5
Total (N=117)	**35**		**39**		**43**	

Table 5.1 illustrates the characteristics of the sample from O_1, O_2 and O_3. Approximately, half of the respondents (51-61%) in each group are top managers, directors, or project managers. In addition, there are approximately 10% and 23 % of workers in the planning, advising and consultant groups in O_1 and O_2 respectively. Also, there are approximately 9%, 26%, and 44% of respondents who are professional workers such as engineers and technicians from the groups O_1, O_2, and O_3 respectively. Administrative respondents consist of 14%, 3%, and 5% from groups O_1, O_2, and O_3 respectively. Therefore, the proportion of respondents consists of 51-61% of managerial staff and 39-49% of operational staff. All were experienced and frequent users of IT applications and ICT.

5.1.1 *Descriptive analysis of IT applications used*

This section provides the respondents' views of the types of IT applications used within the three leading construction organisations. Generally these comprise:

technical IT tools specific to the participant's job; standard office applications i.e. word processing; and ICT applications that are used for communication and team coordination. The aim of this part of the study was to better understand the level of participants' IT/ICT literacy skills and the extent to which they share a common level of IT/ICT literacy. Part A of the survey questionnaire was designed to assess their level of IT use. Two criteria were used to measure this. Criterion one is the extent of relevance of IT applications to the performance of the person's job. Criterion two is the level of need to use that technology. The relevance to the person's job is defined as the extent to which the IT application is perceived as being a natural part of the IT user's job where as the level of need is defined as how often the IT application has been used to perform their job.

Figure 5.1 and 5.2 show the extent of relevance to the job and the level of need to use it within the three leading construction organisations. These two graphs show that there are similar trends in the users' perception of IT applications about the 'relevance to the job' and the 'level of need to use' the application. Figures 5.1 and 5.2 indicate that respondents perceived that ICT applications and general office applications had a high relevance to them and they also had a high level of need to use ICT and office applications to perform their job.

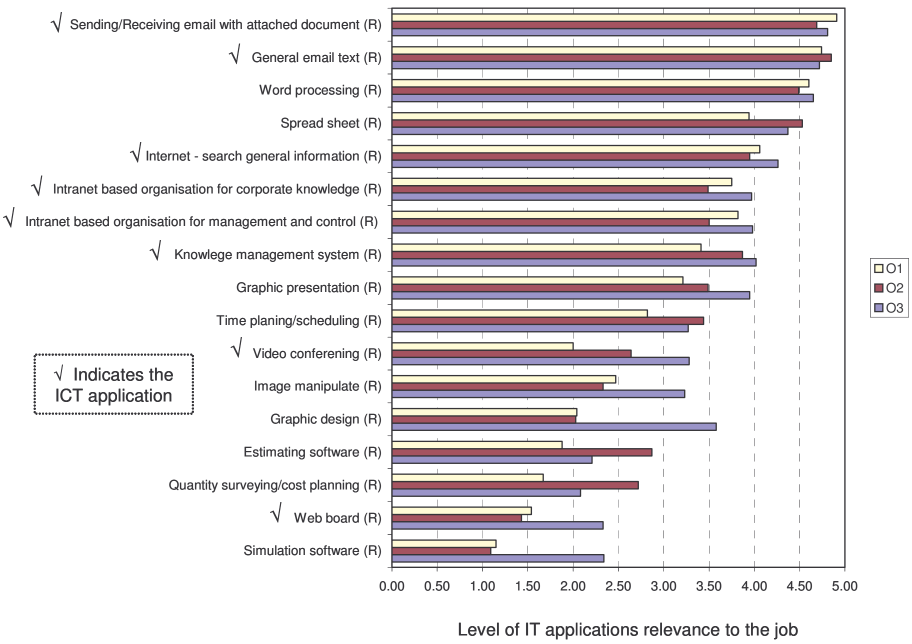


Figure 5.1 The relevance to their job of IT applications among three user groups (R)

Figure 5.1 displays the level of relevance of IT and ICT (indicated with a '√' symbol) applications to the respondent's job. It was found that ICT applications such as '*Sending/receiving email with attached documents', 'General email with text', 'Internet search for general information', 'Knowledge management system', 'Intranet based organisation for management and control', and 'Intranet based organisation for cooperate knowledge management'* presented a high degree of relevance to their job.

Figure 5.2 illustrates the need for respondents from the three construction organisation groups to use these ICT applications as well as their requiring frequent and high level of use of the applications to undertake their job.

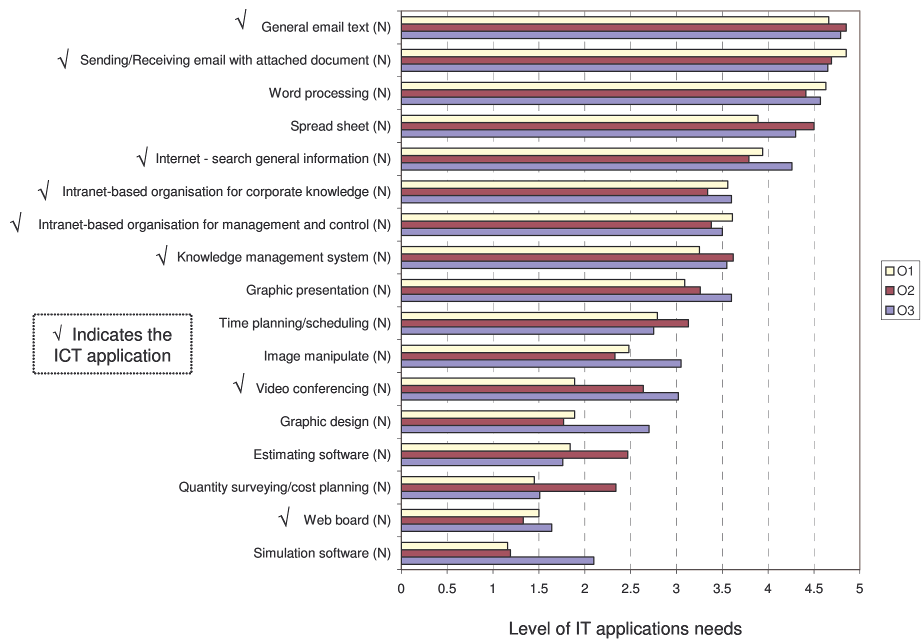


Figure 5.2 The level of IT applications needs to use among three user groups (N)

Two ICT applications, however, presented a mixed response from respondents. First, the respondents from O_3 experienced a medium frequency of use for *'Video conferencing'* and perceived a greater relevance to their job than respondents from O_2 and O_1. Second, *'Web board'* had a consistently low frequency of use among the three groups. Respondents in O_1 and O_2 however, perceived that this had a low relevance for their job compared to the higher rating for participants from O_3.

Engineering applications such as *'Graphic design', 'Estimating software' and 'Quantity surveying/cost planning'* were also found in the different organisations to have different users' perceptions of relevance and need of use. For example, users in O_3 perceived special engineering applications such as *'Graphic design'* and *'simulation software'* more relevant to their job than users in O_1 and O_2. One explanation of this difference is that respondents from O_3 were involved with design and consultancy work and they may perceive these two IT applications to be more relevant to their job than users from the other two organisations.

Furthermore, respondents in O_2 were likely to perceive *'Estimating software' and 'Quantity surveying/cost planning'* as more relevant to their job than users in O_1 and O_3. This finding, as might be expected, suggests that these two applications were used more by the construction contractor organisation than the other two organisations. Consequently, the type of the organisation appears to influence the use patterns of IT and ICT applications. In addition, the use of special engineering applications may rely on the construction stage. For example estimation software may be only required during the bidding stage.

In conclusion, the respondents from the three leading construction organisations show similarities in their high use of ICT applications in general—for example, the level of ICT application use is similar to the extent of general office and specialised technical IT applications use. Therefore, it could be argued that ICT applications have an essential role in construction management by facilitating communication, documentation exchange and team coordination. On the other hand, specialist IT applications such as graphic engineering design, estimating and simulation applications are probably required by specific groups of users and used for only a specific period of time during a construction project, and respondents were experienced and regular users of that technology.

5.1.2 *Analysis of similarities and differences*

This analysis section is focused on the mean value of each respondent's perceived need for and use of ICT. This focus helps to demonstrate that the respondents from the three construction groups share a consistent experience with respect to their ICT use and that they share a similar level of computer literacy in their specialised IT applications. Thus, analysis of the data indicates that the three groups can be considered a single group for analysis, in terms of ICT application diffusion and use. The analysis of variance (ANOVA) statistical method was applied to explore the difference in mean values for each IT application use among groups. ANOVA is appropriate to examine means differences of each variable under assumptions of normality and homogeneity of variance (Norusis 1997). In reality, normality is often violated because data from scales related to social science research topic areas are by nature often quite skewed (Coakes, Steed & Kopanidis 2001). Additionally, homogeneity of variance is hard to find in the variance of two or more groups (Miller 1986).

To cope with the violation of these assumptions, Coakes, Steed and Kopanidis (2001) suggests that data be transformed or a non-parametric test be selected (e.g using the Kruskal-Wallis test). However, Milliken and Johnson (1984) stated that many statisticians suggest that it is better to use ANOVA (parametric) instead of transformation data because the ANOVA approach is robust even though data is non-normality and heterogeneous variance. Therefore, the ANOVA statistical method was used in this study even though data presented non-normality.

Normally, the null hypothesis (H_0) refers to there being no significant difference among groups while the alternative hypothesis (H_1) means that a least two groups of means are significantly different. The output of the ANOVA test (Table B-1) presents the F significance values (column 3) of the assumption hypothesis. Therefore, if the probability of the ANOVA statistic is less than or equal to the level of significance (such as 0.05 in case of 95 per cent confidence), then the null hypothesis is rejected.

5.1.3 *Analysis of IT applications and their relevance to the job*

This section illustrates users' perception of IT applications that are relevant to their job within the three construction organisations. Table 5.2 shows the mean scores of the three groups and their significant mean difference (sig. diff.) among groups in the last column. The details of the determination of the significant mean difference is provided in Appendix B.

Table 5.2 The means of relevant to the job in using IT applications

IT Applications	Relevant to the job (means)				*Sig. diff.*[a]
	O1	O2	O3	All	
Word processing (R)	4.60	4.49	4.65	4.58	*.525*
Spread sheet (R)	3.94	4.53	4.37	4.29	***.024***
Graphic presentation (R)	3.21	3.49	3.95	3.58	***.028***
Image manipulation (R)	2.47	2.33	3.23	2.72	***.004***
Graphic design (R)	2.04	2.03	3.58	2.66	***.001***
Time planning/scheduling	2.82	3.44	3.27	3.18	*.160*
Simulation software (R)	1.15	1.09	2.34	1.62	***.001***
Estimating software (R)	1.88	2.87	2.21	2.34	***.024***
Quantity surveying/cost planning (R)	1.67	2.72	2.08	2.21	***.019***
General email text (R)	4.74	4.85	4.72	4.77	*.592*
Sending/receiving email with attached documents (R)	4.91	4.69	4.81	4.80	*.103*
Video conferencing (R)	2.00	2.64	3.28	2.74	***.001***
Web board (R)	1.54	1.43	2.33	1.82	***001***
Internet - search for general information (R)	4.06	3.95	4.26	4.09	*.317*
Intranet based organisation for management and control (R)	3.82	3.5	3.98	3.78	*.287*
Intranet based organisation for corporate knowledge (R)	3.75	3.49	3.97	3.75	*.271*
Knowledge management system (R)	3.41	3.87	4.02	3.79	***.044***

[a] Sig. diff. shows the level of significant means difference among three groups (bold and italic).

In general, the result shows that ICT applications such as email, Internet, and Intranet based organisation tools have a high relevance to their job. In addition, these applications indicate a similar trend for the level of application relevance to their job. From the mean significance analysis shown in Table 5.2 there are no significant differences in the use of IT applications such as 'Word processor', 'Time planning/scheduling', 'General Email Text', 'Sending/Receiving Email with attached documents', 'Internet–search for general information', 'Intranet based organisation for management and control' and 'Intranet based organisation for corporate knowledge' at a 95 per cent significance level. Interestingly, most of these IT applications have a high relevance to the job (above 3.75) excluding 'Time planning/scheduling' (3.18). Consequently, these respondents from the three groups perceived that ICT applications are of high relevance to their job.

5.1.4 *Analysis of IT applications and their frequency of IT use*

This analysis focuses on the level of participant's need to use IT applications. The measurement is defined as the frequency of IT use from the current user's practice in comparison to the expected level of IT use from the self-assessment of the user's skill. Table 5.3 shows the descriptive means among three groups on level of need to use these IT applications and the significant mean difference (sig. diff.) among groups in the last column. The details of the determination of the significant mean difference is provided in Appendix B.

Analysis of mean value responses indicates that most respondents from the three construction organisations experience a high level of frequency in the use of ICT applications. These ICT applications exclude '*Video conferencing*' and '*Web board*'. The IT applications' level of need of use for their job were differently perceived by respondents from the three groups for '*Spread sheet*', '*Graphic presentation*', '*Image manipulation*', '*Graphic design*', '*Simulation software*', '*Quantity surveying/ cost planning*', and '*Video conferencing*'.

Table 5.3 The mean value responses of level of need to use IT applications (frequency)

IT Applications	Level of need to use (means)				*Sig. Diff.*[a]
	O1	O2	O3	All	
Word processing (N)	4.63	4.41	4.57	4.53	*.379*
Spread sheet (N)	3.89	4.50	4.30	4.24	***.021***
Graphic presentation (N)	3.09	3.26	3.60	3.34	.170
Image manipulation (N)	2.48	2.33	3.05	2.65	***.025***
Graphic design (N)	1.89	1.77	2.70	2.18	***.009***
Time planning/scheduling (N)	2.79	3.13	2.75	2.88	*.413*
Simulation software (N)	1.16	1.19	2.10	1.57	***.001***
Estimating software (N)	1.84	2.47	1.76	2.02	*.056*
Quantity surveying/cost planning (N)	1.45	2.34	1.51	1.80	***.004***
General Email Text (N)	4.66	4.85	4.79	4.77	*.378*
Sending/receiving email with attached documents (N)	4.85	4.69	4.65	4.72	*.333*
Video conferencing (N)	1.89	2.64	3.02	2.60	***.000***
Web board (N)	1.50	1.33	1.64	1.50	*.352*
Internet - search for general information (N)	3.94	3.79	4.26	4.01	*.085*
Intranet based organisation for management and control (N)	3.61	3.38	3.50	3.50	*.797*
Intranet based organisation for corporate knowledge (N)	3.56	3.34	3.60	3.50	*.664*
Knowledge management system (N)	3.25	3.62	3.55	3.49	*.365*

[a] Sig. Diff. shows the level of significant means difference among three groups (bold and italic).

5.1.5 *Classification of IT applications clusters*

The findings also indicate that there are some substantial differences among IT application experiences that are relevant to the participants' job. Table 5.4 uses the average mean value range, as indicated below, to classify IT applications into four clusters.

Table 5.4 Clusters of IT applications classified by means

Means	Relevance to the job	Cluster of IT	Frequency of use	Cluster of IT
Above 4.0	Very high	A	Very often used	A
Between 3.0-3.9	Somewhat high	B	Quite often needed	B
Between 2.0-2.9	Neither low or high	C	Sometimes needed	C
Below 1.9	Somewhat low	D	Rarely needed	D

In terms of relevance to a participant's job, cluster A is classified as being a set of IT applications that respondents have rated a mean value above 4.0 (high relevance of the IT application to their job). Next, clusters B and C consists of IT applications with a mean value between 3.0 and 3.9 and between 2.0 and 2.9 respectively. Finally, cluster D consists of IT applications that have a mean value below 1.9 (somewhat low).

In terms of the participants' level of need to use the IT applications, the latter were categorised into four clusters. First, cluster A is defined as an IT application that has a high level of need to use (very often). Next, clusters B and C consist of IT applications that have the level of 'Quite often need' to use and 'Sometimes need' to use respectively. Finally, cluster D is classified as an IT application that is rarely needed to be used.

Table 5.5 Summary clusters of IT applications

Group IT applications that relevance to their job and need of use	Relevance to the job (1)		Frequency of use (2)	
	Means	*Clusters*	*Means*	*Clusters*
Sending/receiving email with attached document	4.80	A	4.72	A
General email Text	4.76	A	4.76	A
Word processing	4.58	A	4.52	A
Spreadsheet	4.30	A	4.22	A
Internet - search general information	4.08	A	3.99	B
Intranet based organisation for management and control	3.77	B	3.47	B
Intranet based organisation for corporate knowledge	3.74	B	3.48	B
Knowledge management system	3.71	B	3.46	B
Graphic presentation	3.61	B	3.35	B
Time planning/scheduling	3.23	B	2.89	C
Video conferencing	2.74	C	2.66	C
Image manipulate	2.72	C	2.58	C
Graphic design	2.65	C	2.16	C
Estimating Software	2.36	C	2.03	C
Quantity surveying/cost planning	2.22	C	1.80	D
Web board	1.81	D	1.48	D
Simulation software	1.62	D	1.56	D

From column 2 in Table 5.5, classification of IT clusters was evaluated by the means of IT applications on the perception of their relevance to the job. Cluster A has a very high relevance to the job and consists of 'Email with attachment', 'Email with only text’, ‘Word processor’, ‘Spreadsheet’ and ‘Internet –searching for general information’. Secondly, cluster B (somewhat high relevance to the job) consists of ‘Knowledge management system’, ‘Organisational Internet-based networked system for management control and contract administration’, ‘Internet-based networked system for corporate knowledge’, ‘Graphic presentation’ and ‘time planning/scheduling’. Thirdly, group C (neither low nor high) consists of ‘Video conferencing’, ‘Image manipulate’, and ‘Computer aided design’. Finally, group D (somewhat low) consists of ‘Web board’ and ‘Simulation software’. It was also found that perception of the need to use IT closely matches groups of perception of IT relevance to the respondent’s job. However, some IT applications were classified into both group categories such as ‘Internet–Search general information’ (clusters A and B), ‘Time planning/scheduling’ (Cluster B and C), and ‘Quantity surveying/cost planning’ (cluster C and D).

The data also indicate that technical IT applications (for example simulation software) have a low perception of relevance for use related to the respondents’ job. The reason for this could be that this type of application is only occasionally needed on special construction projects where the need to simulate the construction processes has been identified. Therefore, respondents perceived this as having low relevance to their regular job. Surprisingly the perception of web board related with the job was low. It could be said that the web board might be embedded in knowledge systems such as sharing ideas in these organisations so that it is not necessary to use this application separately.

Unsurprisingly, the results show that the IT applications related to communication technologies such as email, Internet – search and Intranet based organisation were of high relevance to the job and were perceived as having a high level of need to use. This is because this research design focused on users who have experience in using ICT applications. It also was found that word processor, spreadsheet, and graphic presentation and project/planning and scheduling applications were also perceived as high relevance to the job and high level of need to use.

However, it should be noted that specific IT applications might also be related to the type of construction organisation. Therefore, the next analysis will compare difference between using IT applications among the three construction organisations.

5.1.6 *Analysis of significant mean differences of using IT applications among the groups*

The objective of this section is to explore which IT applications have no significant differences among the cases related to both the relevance to the job and their level of need to be used by participants for undertaking their job. Table 5.6 summarises the ANOVA testing results for IT applications that are *relevant to the job* and indicates that there are no significant differences among three organisations in using 'Word processing', 'Time planning /scheduling,' 'General email text', 'Sending/receiving email with attached documents', 'Internet–search for general information', 'Intranet based organisation for management and control', and 'Intranet based organisation for corporate knowledge'. Similarly, there is no significant difference in the use of IT applications related to the need of use among the three organisations for IT applications 'Word processor', 'Graphic presentation', 'Time planning/ scheduling', 'Estimating software', 'General email', 'General email text', 'Sending/receiving email with attached documents, Internet–search for general information, 'Intranet based organisation for management and control', 'Intranet based organisation for corporate knowledge', and Knowledge management system'.

Similarly, there is no significant difference in the use of IT applications related to *the level need of use* among the three organisations for IT applications 'Sending/Receiving email with attached documents', 'General email text', 'Word processor', 'Internet–search for general Information, 'Intranet based organisation for management and control', 'Intranet based organisation for corporate knowledge', 'Knowledge management system', 'Graphic presentation', 'Time planning/ scheduling', 'Estimating software', and 'web board'.

Table 5.6 The significant means difference among three user groups

Group IT applications that relevance to their job and need of use	**Relevance to the job** *Sig. Diff.*[1]	**Level of need to use (freq.)** *Sig. Diff.*[1]
Sending/receiving email with attached document	**No**	**No**
General email text	**No**	**No**

Word processor	**No**	**No**
Internet - search general information	**No**	**No**
Intranet based organisation for management and control	**No**	**No**
Intranet based organisation for corporate knowledge	**No**	**No**
Time planning/scheduling	**No**	**No**
Knowledge management system	Yes	**No**
Graphic presentation	Yes	**No**
Estimating software	Yes	**No**
Web board	Yes	**No**
Spread sheet	Yes	Yes
Video conferencing	Yes	Yes
Image manipulate	Yes	Yes
Graphic design	Yes	Yes
Quantity surveying/cost planning	Yes	Yes
Simulation software	Yes	Yes

[1] The significant difference were concluded from the ANOVA table

Table 5.6, indicates therefore, that there were no significant differences among the organisations in their use of ICT applications such as ‘Sending/receiving email with attached document’ when compared to specific IT applications relevant to particular classes of job (such as graphic design, simulation etc). ICT applications that have more relevance to the respondents’ jobs and higher need for use are unlikely to have a significant difference in their use among the three organisations. There were, however, significant mean differences between IT applications among the three organisations. As pointed out earlier, specific IT applications such as ‘Spread sheet’, ‘Video conferencing’, ‘Image manipulate’, ‘Graphic design’, ‘Quantity surveying/cost planning’ and ‘Simulation software’ might be relevant to specific job functions and type of organisations. The details of the analysis of the significant mean difference is provided in Appendix B1 (ANOVA analysis).

It was found from the survey of IT applications’ use in the three construction organisations that the users had a high interaction with ICT applications and also perceived them as highly relevant to their job. This finding is also supported by Aouad *et al.* (1998) that information and communication technology (ICT) is one of the key vehicles for facilitating communication and construction information exchange. Based on the IT map by Aouad *et al.* (1999), Inter/Intranet applications, document management systems, Integrated database can be classified as essential coordination and communication applications throughout the construction process.

The above analysis, therefore, strongly indicates that the sample of users from the three construction organisations is representative of staff who perceived ICT applications as highly relevant to them and that they also experienced a high frequency of using them. Thus, in terms of studying ICT diffusion, it can be argued that it is appropriate to treat the data from all three organisations as one group for the purpose of further ICT diffusion analysis.

5.1.7 *Analysis of ICT applications within three groups*

The above analysis presents the nature of IT application use within three leading construction organisations from the respondents' perspective. One of the common findings is that most of the respondents frequently interact with a large number of ICT applications. This section will focus on ICT applications relative to their level of use and the level of need to use them. The mean values for the ICT applications were plotted onto a Microsoft Excel Spreadsheet program by using radar diagrams to represent the current use of ICT applications within the three users groups (see Figure 5.3 and Figure 5.4).

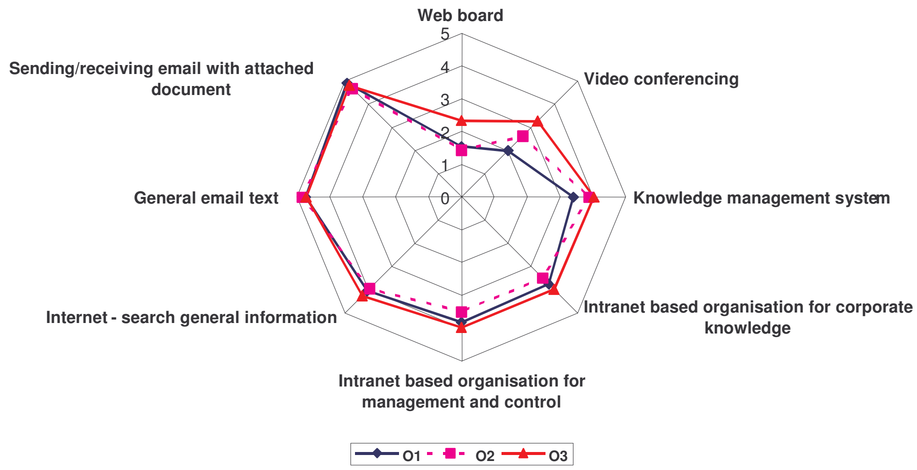


Figure 5.3 The relevance to their job of ICT applications among three user groups

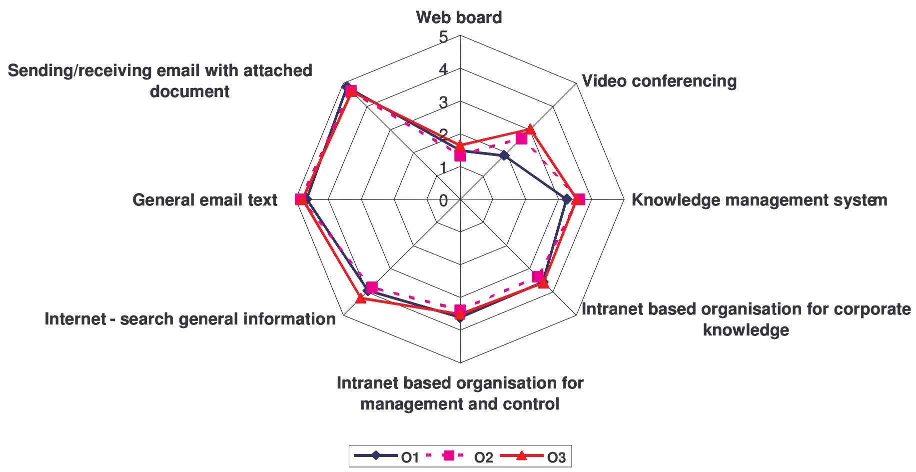


Figure 5.4 The level of ICT applications needs to use among three user groups (frequency)

Figure 5.3 illustrates that users in the three groups had similar perceptions of the relevance of ICT applications to their job, excluding ‘Knowledge management’, ‘Video conferencing’, and ‘Web board’. This may not be surprising because construction knowledge management systems are still under research and development and initial use phase. In addition, Figure 5.4 highlights that users in the three groups experienced high frequency of using ICT applications, excluding ‘Knowledge management’, ‘Video conferencing’, and Web board’. Results from Figure 5.3 and Figure 5.4 indicate that respondents from all three organisations generally share common ICT and IT levels of computer literacy and form a common group of users who perceived ICT applications as highly relevant to them and who have also experienced a high frequency of their use.

5.2 Justification for the sample combination

The primary objective of this section is to justify combining the respondents’ data for each of the three leading construction organisations. As has been argued in the previous section, the characteristics of the respondents’ ICT and IT patterns of use reflect a common level of ICT experience and computer literacy. While the three groups had significant variances in their level of need to use and actual use of specific IT applications, they all shared a common pattern of use for ICT and so it would be appropriate to combine the sample to form one group. The number of participants from each organisation was insufficient to conduct separate factor analysis and so being able to combine them allowed a critical mass of data to allow factor analysis to be validly undertaken. Thus, to increase the sample size, respondents from each of the three leading construction organisations were grouped together and, as was argued previously, this was a valid approach to take.

Having justified the grouping of all respondents into a single group, the next section will provide an analysis of the users' experience of variables influencing ICT adoption and diffusion among the users from the three leading construction organisations.

5.3 Data analysis of the survey questionnaire

The objective of analysis in phase A was to answer the question, "*what are the essential factors that influence ICT diffusion within large construction organisations?*" The analysis of factors is based on perceptions of experienced ICT users in organisations that have a reputation for being experienced ICT users. Therefore, the result should be considered as current practice of ICT diffusion within large construction organisations.

5.3.1 *Description of collected data*

The source of data in this research was obtained from CRC CI research construction organisations (see Appendix B Table 2 for relevant factors that were later analysed). The period of collection was approximately two months and initially, 138 respondents from six organisations expressed interest in completing the questionnaires. However, some of the respondents had to be excluded due to incomplete data (12 respondents) and some because of insufficient numbers of respondents from their organisation to be a representative sample (9 respondents). Therefore, 117 respondents from three organisations were included for analysis in this research. Focus groups were also conducted to confirm the research findings.

5.3.2 *Factor analysis*

Factor analysis is a technique to allow a large number of variables to be distilled into a small number of related factors that could explain most variables that generate the phenomena under study (Hedderson 1991, Norušis 1985, Pallant 2001). The benefit of this concept is that it reduces many variables into a few factors that best explain the phenomenon (Pallant 2001).

There are some requirements, however, for effectively using the technique. First, the number of variables should be at least twenty. Secondly, the minimum number of cases in each variable should be at least ten in order to conduct a factor analysis. In addition, the factor analysis technique is related to the correlation between each variable. Hedderson (1991) suggested that a correlation matrix of variables should be constructed as a preliminary test. It should exclude any variable that has correlation values with the other variables below 0.4 (Hedderson 1991) or 0.3 (Norušis 1985) in absolute terms.

5.3.3 *Steps of data analysis using factor analysis*

Results were obtained using the SPSS[13] software factor analysis so the steps involved will be explained in this section. The explanation helps us understand and interpret the results. The data were analysed by SPSS (release 11) and the format and the sequence of the data matched its requirements. The following explanation of the method of working with factor analysis using SPSS software is based on Hair (1998) and Hedderson (1991). The three main factor analysis steps are: factor method selection, rotational method selection and factor interpretation

The first step is focused on a method of extracting factors using either a common factor analysis or a principal component analysis. According to Hair (1998), selection depends upon the objectives of the researcher. If the objective is to minimise the number of variables into underlying factors for predictive purposes, a suitable method should be a principal component analysis. In practice, the principal components method is commonly used to determine factor extraction (Hedderson 1991). If the purpose is to identify underlying factors that reflect what the variables share in common, the common factor analysis method should be applied. In SPSS, several

[13] Statistical software - www.spss.com

methods are provided for factor extraction. In this research, the objective is to group the variables into factors that would help to describe what are the essential factors that influence ICT diffusion. Therefore, principal component analysis was used in this analysis.

The second step is to define the numbers of factors. Using the principal component analysis method, the principal components (factors) could explain 100 per cent of the association between variables but this would produce as many factors as variables. This adds no value to our understanding so a compromise is struck and the number of factors identified will be optimised to explain something less than 100 per cent of the relationships. Norušis (1985) states that the *eigenvalue* number should be used as the method to identify the optimum number of factors to best explain the relationships of data variables. An *eigenvalue* is the number that represents the proportion of the total variance explained by the factor. The proportion of total variance in each factor is the sum of the square of the proportions of variance in each variable that is the component of the factor. The factor matrix or factor-loading table presents the proportions of variable variance to factor. Norušis recommends that the selected factor should have an eigenvalue above 1.

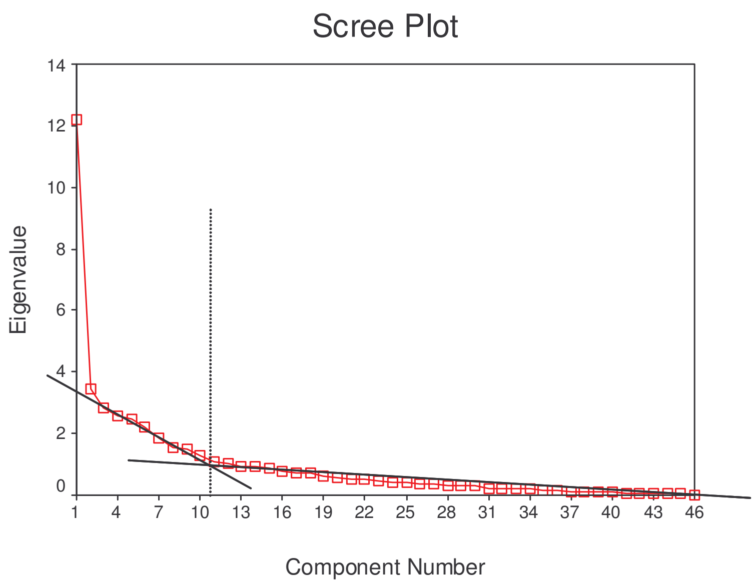


Figure 5.5 The graph between eigenvalues and the number of component factors

Another method of identifying the optimum number of factors is the use of a *scree plot*. The slope of a graph plotting eigenvalues and the component number of factors is naturally divided into a steep slope and gradual slope. Figure 5.5 illustrates the break point in the slope of a graph that identifies the optimum number of factors.

From the above scree plot, the slope has started to change when the component number is around 11. However, Norušis (1985) argued that using the scree plot method for selecting factors might result in selecting a greater number of factors than by using the eigenvalue method. In this research, the number of factors was determined to be 11 using both methods.

The final step in the process is the interpretation of and naming of the factors. Sometimes it is difficult to identify and interpret the relationship between factors and the individual variables based on the factor matrix. This is because some of the variables might have approximated the correlation value in more than one factor. Therefore, a rotation method technique is used that transforms the initial matrix for interpretation purposes. It has no effect on the goodness of fit of the factor, communalities and the percentage of total variance. The varimax method is the most popular of the techniques used for rotation by minimising the number of variances that have a high loading on a factor. This method was used in this research as well for rotation.

5.4 Exploration of ICT diffusion factors

This section aims to explore factors influencing ICT diffusion. In this analysis, factor analysis technique was used to group a large number of measured variables into small highly related groups of variables called factors. In this section, the variables from questionnaire Part B to E1 are analysed. Thus, the factors can be categorised as the representative of the groups of variables that influenced ICT diffusion at the actual implementation stage.

There are, however, methodological requirements to first test the data to ensure that factor analysis is an appropriate statistical technique to use. Correlation coefficients of each variable should have at least one factor that is above 0.30 (Pallant 2001). In this analysis, all the variables (Table B-2) have correlation coefficients of more than 0.30. Additionally, result shows that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy value was 0.737 (well above the acceptable 0.60 value) also that the Barlett's test of sphericity value was significant (p=0.0001). These measures indicate that the clusters of factors are valid and that the approach used to analyse the data is robust. Therefore, the data set is clearly suitable for using factor analysis.

Data was analysed using a principal component and varimax rotation for factor extractions. A *pairwise* rather than *listwise* selection method of cases was used because this questionnaire allowed respondents to select a 'non-applicable' response as well as a 1 to 5 value. As a result, the number of cases was 117. The result of factor analysis shows 11 factors with an eigenvalue exceeding 1, explaining a cumulative 70.45 per cent of variance. In addition, a varimax rotation was used in explaining these factors. The result of this rotation shows that 46 variables were grouped into eleven factors. Cronbach's alpha (∝) analysis was conducted to examine the reliability of variables for each factor (Hedderson 1991, Pallant 2001). Cronbach's alpha is used to measure how well variables can be constructed into one single factor. Factors 1-10 fell within the 0.60 or greater range indicating that these were reliable and that factor 10 was marginally reliable as Cronbach's Alpha is less than 0.60. While factor 11 is discussed, it has a doubtful reliability because it contains only one variable.

Appendix B2 shows the resulting analysis of the use and adoption of ICT applications. Forty-six variables were grouped into eleven factors and each factor was named on the basis of variables under the factor. Factor F1 'Professional development and technical support', accounts for 12.5 per cent of the variance. Factor F2 'Clear advantage of ICT use' accounts for 8.7 per cent of variance. Factor F3 'Supporting individual or personal characteristics' accounts for 8.7 per cent of variance. Factor F4 'Supporting technology characteristics' accounts for 6.8 per cent of variance. Factors F5 to F11 were named as 'Supervisor and organisational support', 'Supporting an open discussion environment', 'Supporting tangible and intangible reward', 'Collegial help', 'Positive feeling towards ICT use', 'Negative emotions towards ICT use', and 'Frustration with ICT use'. It was found that two negative factors were grouped into the last two factors and they account for 4.27 per cent and 3.16 per cent of variance respectively.

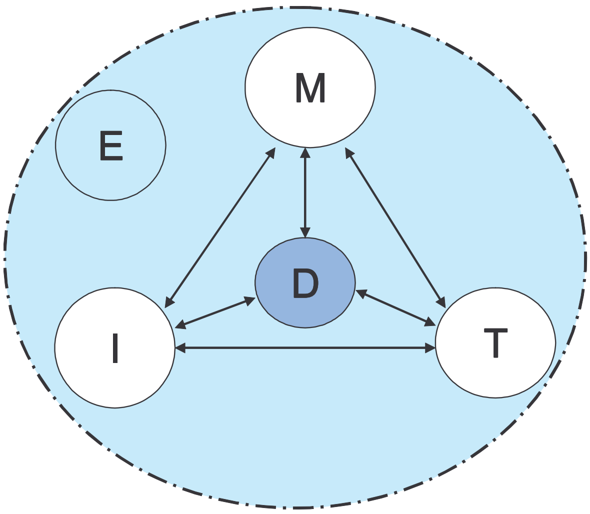
Table 5.7 The factor analysis of variables relating to ICT diffusion

Factor	Factors	Group of Variables	Means
F1	**Professional development and technical support (∝ = 0.9163, $\bar{x}$ = 3.277)**	- Sufficient time to think - Flexibility for learning - Work procedure support - Enough time for training - Technical support - Enough quality of training - Functionality / ease of use ICT - Easy to observe benefit of using ICT - Trial and experiment ICT - Mentoring support	3.19 3.10 3.56 2.98 3.47 3.16 3.73 3.60 2.90 3.08
F2	**Clear benefits of ICT use (∝ = 0.8901, $\bar{x}$ = 4.105)**	- Clear advantage of using ICT for coordinating teams - Clear advantage of using ICT for communication between teams - Clear advantage of using ICT for communication within team - Receive professional credibility - Clear advantage of using ICT for decision-making - Relevance to personal job	4.03 4.21 4.19 4.05 3.83 4.32
F3	**Supporting individual/personal characteristics (∝ = 0.8505, $\bar{x}$ = 4.145)**	- Basic skill of using ICT - Personal confidence - Enjoy to exploring new tools - Personal capability to learn ICT - Help and explain to others (Mentoring) - Personal commitment	3.76 4.23 4.07 4.48 3.99 4.34
F4	**Supporting technology characteristics (∝ = 0.8803, $\bar{x}$ =3.703)**	- Functionality of ICT - Accessibility of ICT - Response rate of ICT	3.71 3.77 3.63
F5	**Supervisor and organisational support (∝ = 0.7326, $\bar{x}$ =3.816)**	- Supervisor encourages the use of ICT - Supervisor openly suggests improvement using ICT - Trust in supervisor when making mistakes - Organisation supports for sharing ICT experience - Enjoy learning from others	3.54 3.92 3.98 3.55 4.09
F6	**Supporting an open discussion environment (∝ = 0.7086, $\bar{x}$ = 3.928)**	- Colleagues feel safe on openly discusses about ICT problems - Person feels safe on openly discusses about ICT problems - Organisation openly suggests ICT improvement - Organisation commitment (resources)	3.77 4.10 3.88 3.96
F7	**Supporting tangible and intangible reward (∝ = 0.5839, $\bar{x}$ = 2.423)**	- Receive tangible reward - Provide tangible rewards in sharing ICT experience - Provide intangible rewards in sharing ICT experience - Receive intangible reward	1.98 1.71 2.62 3.38
F8	**Collegial help (∝ = 0.7859, $\bar{x}$ = 3.895)**	- Colleagues informally help on ICT use - Colleagues formally help on ICT use	4.06 3.73
F9	**Positive feelings towards ICT use (∝ = 0.6504, $\bar{x}$ = 3.623)**	- Better than previous - Speed and reliability of ICT - Compatibility with previous system/ work procedures	3.62 3.59 3.66
F10	**Negative emotions towards ICT use (∝ = 0.5852, $\bar{x}$ =1.780)**	- Feel pressured to be effective in using ICT - Personal anxiety about ICT use	1.71 1.85
F11	**Frustration with ICT use (∝ =n/a, $\bar{x}$ =1.690)**	- Difficult, complex or frustrating to use ICT	1.69

Factor Analysis (Pairwise N= 117) Extraction Method: Principle component analysis, Rotation method: Varimax rotation, ∝ is represented Cronbach's alpha, $\bar{x}$ = means score

5.5 Discussion of results

The objective of this chapter is to identify factors influencing ICT diffusion from the survey data. The conceptual model of ICT innovation illustrated in Figure 5.6 was formed to explain the group of factors. These naturally fall into four main categories: management, individual, technology and environment. The conceptual model illustrated in Figure 5.6 is based upon the nature of ICT diffusion within organisations as developed from the factor analysis results and the categorisation of these into the four categories management (M), individual (I), technology (T) and workplace environment (E).



ICT Diffusion (D)

Management (M) consists of
F1: Professional development and technical support
F5: Supervisor and organisational support
F7: Supporting tangible and intangible reward

Individual (I) consists of
F2: Clear benefits of use
F3: Supporting individual/personal characteristics
F9: Positive feelings towards ICT use
F10: Negative emotions towards ICT use

Technology (T) consists of
F4: Supporting technology characteristics
F11: Frustration with ICT use

Environment (E) consists of
F6: Supporting open discussion environment
F8: Collegial help

Figure 5.6 Preliminary conceptual model of ICT innovation diffusion

This model may help to explain the diffusion stages of ICT innovation as follows. Three stages of ICT innovation diffusion can be observed as ICT introduction, ICT adoption and its diffusion into the organisation. Figure 5.7 presents a theory of how ICT diffusion develops in the three stages. As the organisation begins to adopt an ICT innovation, the influence of technology (T) shifts with respect to the organisational environment (E) and its impact with respect to management factors (M) and personal /individual factors (I). In terms of the environment (E), this research focuses on the work group environment that facilitates the adoption and diffusion of ICT throughout organisation. At the same time, management factors (M) play a significant role in the initial adoption, decision and encouragement of potential users to adoption, and personal/ individual (I) factors involve in the extent of diffusion of ICT into the organisation by adapting their behaviour and learning on how to use ICT.

In Figure 5.7, the first diagram simulates a situation where technology (in this case is ICT innovation) will be introduced and accepted for regular and frequent use from outside to inside the work environment (E). This introduction of ICT influences the management (M) factors and the personal/individual (I) factors. In the second diagram, the technology (T) is drawn more closely into the work environment (E), and in turn the management (M) and the individual (I) are required to adjust and prepare for the new technology. Finally, after the technology (T) is embedded into the work environment (E), the users within the organisation would be automatically used to and adopt it as a normal process, and it sits within the 'normal' workplace environment completely.

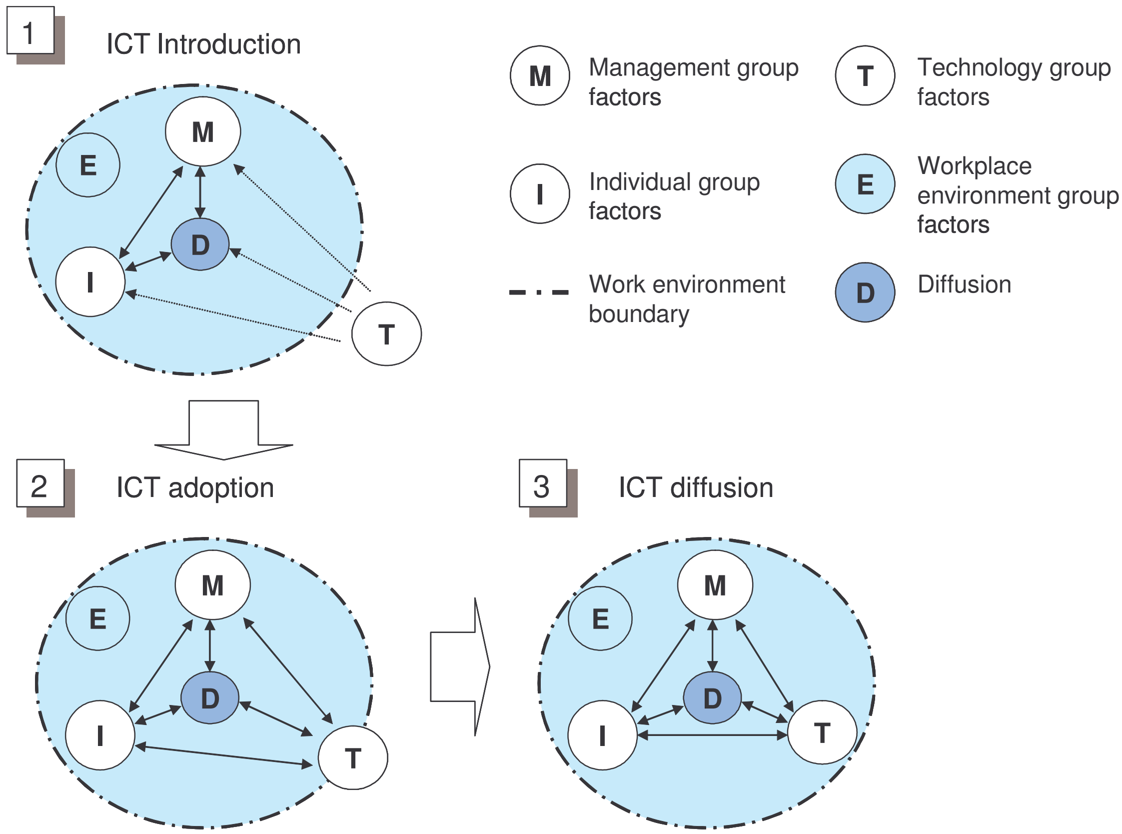


Figure 5.7 The primary conceptual model of ICT diffusion

The level of mean factors in the conceptual model (Figure 5.6) was calculated from the average of means of sub-variables under each factor as presented in Table 5.8.

Table 5.8 The mean's value of eleven factors

Factor Description	Means score ($\bar{x}$)	Rounded means
Individual (I) factors		**3.8**
F3: Supporting individual/personal characteristics	4.145	4.2
F2: Clear benefits of ICT use	4.105	4.1
F9: Positive feelings towards ICT use	3.623	3.6
F10: Negative emotions towards ICT use[1]	1.780	1.8
Environment (E) factors		**3.9**
F6: Supporting an open discussion environment	3.928	3.9
F8: Collegial help	3.895	3.9
Management (M) factors		**3.2**
F5: Supervisor and organisational support	3.816	3.8
F1: Professional development and technical support	3.277	3.3
F7: Supporting tangible and intangible reward	2.423	2.4
Technology (T) factors		**3.5**
F4: Supporting technology characteristics	3.703	3.7
F11: Frustration with ICT use[1]	1.690	1.7

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

If we first concentrate on factors receiving the highest score rating in Table 5.8 we see that these comprise 'F3 Supporting Individual/Personal Characteristics' and 'F2 Clear Advantage of Use'. Each has high levels of mean values (approximately 4.2 and 4.1 respectively). Inspection of these variables reveals that these factors subsume personal characteristics that indicate confident ICT embracers who are adept at learning new things and who clearly perceive the advantage of using helpful and appropriate ICT tools. Also, ICT users seem to believe that ICT initiatives have tangible rewards for them in terms of being more effective compared to using their 'normal' tools for these functions. Further, any negative impact upon them in terms of their feelings towards their ICT past experience, is low and therefore they seem more receptive to embrace applicable new ICT technologies. Table 5.7 indicates the mean scores for each of the identified factors from the factor analysis. For individual factors (I) the overall mean is 3.8 out of a possible 5 (for very high).

Supporting environment factors (E) include 'F6 Supporting an Open Discussion Environment' and 'F8 Supporting Colleague Help' and these have a relatively high group mean value (approximately 3.9). This result indicates that ICT users perceive high support levels being available from their workplace environment such as feeling safe to take part in open discussion about difficulties in the use of ICT applications, and they also appear open to suggestions about improving ICT use. In addition, the high level of help suggests that users in this sample have strong support from their colleagues when using ICT applications.

The management support factors (M) appear to be rated as moderately important with an overall mean value of 3.2. Users' perception of 'F5 Supportive supervisor characteristics' factor mean rated value is approximately 3.8. This indicates that there is a relatively high level of supervisor support and that they maintain a trusting and open atmosphere for providing suggestions and encouragement for a positive experience of ICT application use. However, the mean value of 'F1 Professional development and technical support' is only 3.3. This can be interpreted as users feeling organisational ambivalence towards their professional development and technical support with only average/medium rating for these variables. This suggests that organisations these days generally leave their employees with insufficient time to reflect and think to be able to learn from their experiences and to consolidate lessons learned. Comments and the results suggest that most users did not have time to learn how to adequately use the ICT applications or get the opportunity to trial and experiment with them. Therefore, effective use of ICT applications mainly depends on technical and collegial support.

The results from 'F7 Supporting tangible and intangible reward environment' clearly indicated a perceived low level of organisational support in terms of rewards for sharing knowledge and for assisting in the development of a learning environment for ICT users. The respondents' ratings suggest that rewards related to the use of ICT are quite low (2.4 mean). In addition, intangible rewards have been ranked more highly than tangible rewards for the ICT use. This indicates that intangible rewards may influence ICT use. Interestingly, the respondents received rewards for their ICT use rather than for sharing knowledge about their ICT use. However, the samples were drawn from ICT users and this group was observed as likely to seek out ICT applications (a pull force) rather than be required to do so (a push force).

The general mean for all technology factors was 3.5. Measurement of 'F4 Technology Characteristics' shows that this factor has a moderately high mean score (3.7). Thus, it can be suggested that ICT applications in these three organisations somehow need to be improved in terms of speed, reliability, and accessibility. This finding was supported by additional comments in the questionnaire under the 'additional comments space'. There was a perceived desire for computers and/or increased access line speed to be upgraded. Furthermore, users expressed a need to have more Internet workstations present at the construction site which they can access. Nevertheless, users felt that ICT applications have a relative high functionality and ease of use represented by a low value of 1.7 for the factor 'F11 Frustration with ICT use' through to applications being perceived as difficult, complex or frustrating to use. It should be mentioned that this is a reverse score item in which the calculation of rounded means is need to be reversed before combining with other factors related to technology.

In summary, Table B2 in Appendix B presents the factor analysis of variables influencing ICT adoption and diffusion grouped into 11 broad factors. The average mean scores for these factors are presented in Table 5.7 and indicate the extent to which these factors may affect ICT diffusion. Results show that users in this sample have a high level of personal and individual characteristics that supports their high level of understanding of how to use these ICT applications. Also these results indicated that a supportive workplace environment that encourages knowledge sharing about ICT applications enhances an individual's capacity to develop their personal supportive resources to cope with new ICT initiatives. The data also show that senior management also has an ICT diffusion impact through its mentoring, training, and other support activities, though many of these were provided at a moderate and modest level. The issue of addressing rewards for knowledge sharing and undertaking professional and personal development to improve ICT diffusion seems to be weakly addressed by all three organisations surveyed. There was a higher level of intrinsic rewards evident such as career progression by virtue of having gained valuable expertise in the use of ICT, but there was a lack of addressing tangible rewards systems by these organisations. Technology characteristics such as operational effectiveness, functionality and access had a moderate rating (at 3.5 out of a possible 5) and this may assist in ICT diffusion in terms of being available to demonstrate benefit for the application of these ICT tools.

5.6 Analysis of ICT knowledge sources

Part E of question 5.2 of the research questionnaire investigates the sources of ICT knowledge that users learn from and access during office hours and outside office hours. These sources of ICT knowledge are measured in term of their perceived helpfulness and access frequency. The term 'helpfulness' refers to users' perception value of these ICT knowledge sources while 'frequency of access' measures users' experience of accessing these ICT knowledge sources. The analysis contains the overall users' value perception of each ICT knowledge source, and source of ICT learning both during and outside working hours.

5.6.1 *Overall users perceptions on ICT knowledge sources*

Figure 5.8 indicates that access to ICT learning sources/medium is somewhat limited both within and outside working hours. In addition, there are different rates of access to these ICT knowledge sources within and outside working hours.

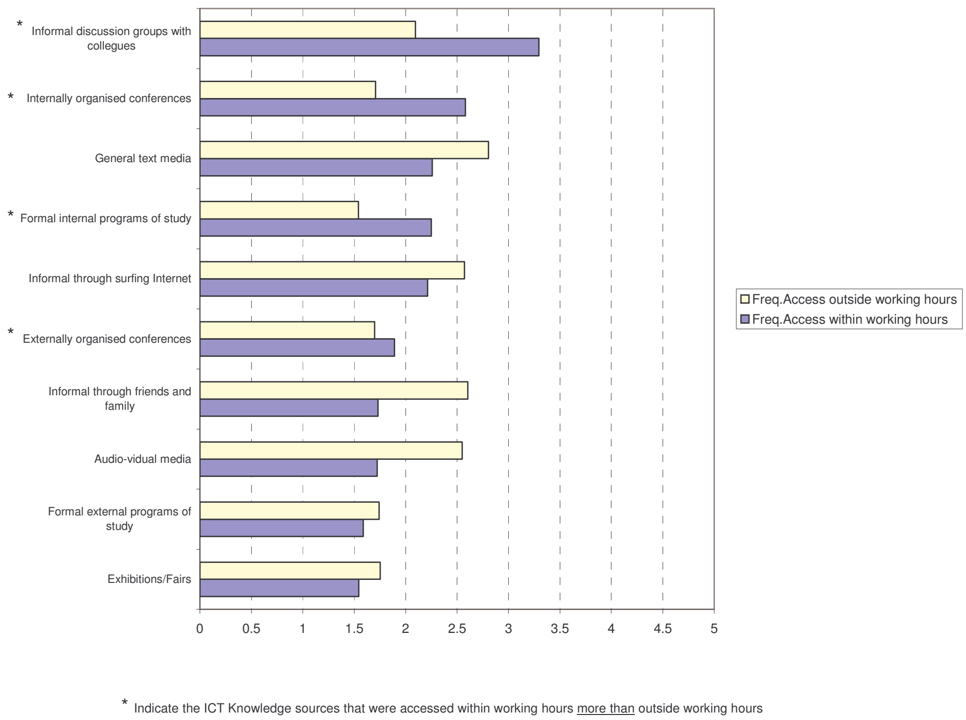


Figure 5.8 Comparing access of ICT knowledge sources within- and outside working hours

For example, learning relating ICT from informal discussion with groups of colleagues, internally organised conferences, formal internal programs of study and externally organised conferences were accessed much more during working hours than outside working hours. However, ICT learning from general text media, informal discussion with friends and family members, audio-visual media, and informal Internet surfing showed higher user access levels outside working hours than inside working hours, whereas exhibitions/fairs, formal external programs of study, and externally organised conferences showed low access levels both within and outside working hours. The next section provides details of sources/media that users accessed to learn about ICT applications.

5.6.2 *Sources/medium of ICT learning within working hours*

Figure 5.9 shows that the majority of users often obtained ICT knowledge from informal discussion groups with colleagues and felt that this source was very helpful. The other four sources that users occasionally learned from are: internally organised conferences, informal Internet surfing, formal internal programs of study, and general text media.

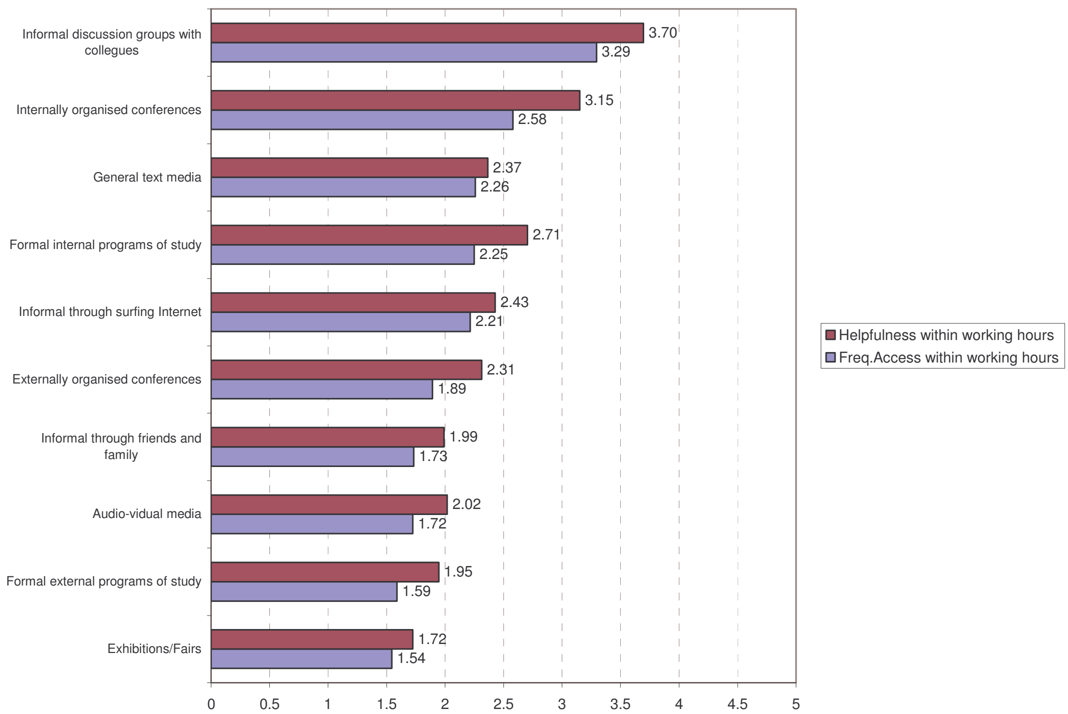


Figure 5.9 Users' perception towards ICT knowledge sources during working hours

However, results reveal that there are several sources of ICT knowledge that respondents have rarely used during working hours. These sources are externally organised conferences, informal discussion with friends and family members, audio-visual media, formal external study programs and exhibitions/fairs. Surprisingly, respondents felt that formal external study programs and externally organised conferences are moderately helpful for them but they only infrequently accessed these sources.

As can be seen from this result, informal discussion groups with colleagues were found to be essential sources of ICT knowledge learning. This result also supports previous findings from factor analysis in which *collegial help* is one of the key factors influencing ICT diffusion. This finding also supports the factor analysis results for 'collegial help' (with survey results of a mean equal to 3.895—see Table 5.8).

Also, formal programs of study and sources from both internally and externally organised conferences are indicated as being moderately helpful for learning about ICT. This supports the 'Professional development and technical support' factor and indicates that knowledge development is not limited to internal training and development programs but that there also a need for external ICT knowledge sources. Figure 5.9 indicates the result that sources such as exhibition/fairs, formal external study programs, audio-visual media, informal discussion with friends and family, and externally organised conferences are found to have low access frequency during working hours (mean less than 2.0). The next section will illustrate the ICT knowledge sources that respondents access outside working hours.

5.6.3 *Sources/medium of ICT learning outside working hours*

Figure 5.10 shows that ICT knowledge sources such as general text media, informal discussion with friends and family members, informal Internet surfing and audio-visual media have been occasionally accessed outside working hours (frequency mean above 2.5). In addition, respondents indicate that these sources are moderately helpful to them. Outside working hours ICT learning through friends and family members and using audio-visual media was reported as having an increasing influence for respondents. Nevertheless, learning through general text media and Internet surfing was found as only of moderate importance for both outside and within working hours. On the other hand, respondents reported formal low access outside working hours compared to other sources for external study programs, internally and externally organised conferences and formal internal study programs. Informal discussion with groups of colleagues outside working hours was found as being less prevalent compared to that within working hours. This may be due to respondents having less social contact outside working hours.

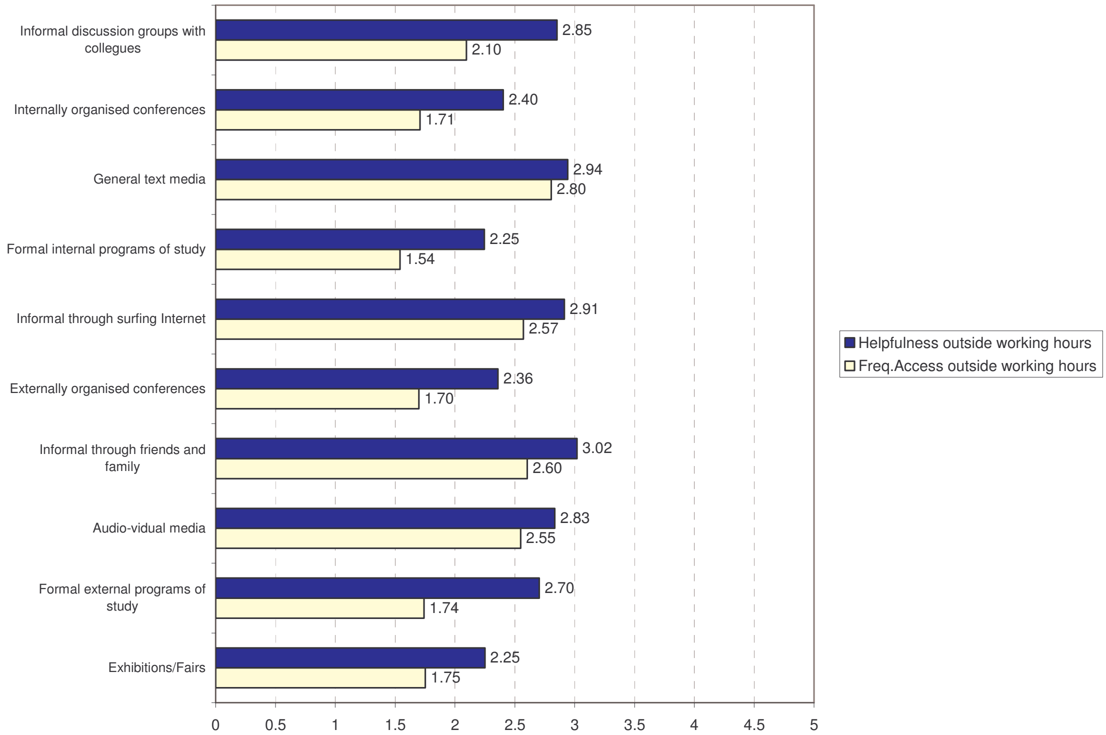


Figure 5.10 Users' perception towards ICT knowledge sources outside working hours

The data suggest that the source and media that ICT users are more likely to acquire ICT knowledge and learn from within working hours are collegial help, internally organised conferences, general text media, formal internal study programs, and informal Internet surfing. During outside working hours, ICT users are more likely to access ICT learning sources from general text media, informal Internet surfing, informal discussion with friends and family, and audio-video media. ICT learning from these sources needs to be improved, as the overall access to ICT knowledge sources is moderately helpful, with poor access to those knowledge sources such as internally organised conferences, formal internal study programs, external organised conferences, and formal external study programs. This finding corresponds to *'Professional development and technical Support'* in the previous section, in which users rated a moderate score for this factor (see Table 5.8 mean value of 3.277).

5.7 Summary of chapter

Research results presented in this chapter indicate 11 factors influencing ICT use and adoption. These factors can be further categorised into management (M), individual (I) and technology (T) factors that all impact upon ICT diffusion and that each of these is influenced (surrounded) by the impact of the workplace environment (E). Individual and environment factors generally have a high impact upon ICT diffusion while Management and Technology factors have a slightly above moderate impact. Results represent the perceptions of experienced ICT users in organisations that have a reputation for being experienced ICT users. They cannot be generalised across the entire construction industry, though they may be good indicators for experienced IT/ICT users. The contribution of this study is to help identify the best ICT diffusion practices that may be adopted.

Some limitations of this survey are acknowledged. First, the analysis of this study was drawn from ICT application users' experience within three leading construction organisations. All participants have extensive and current experiences of IT and ICT use and these results are reflected by the experiences of this type of construction knowledge worker. The reason for this was that this study aims to understand ICT diffusion practices in sophisticated ICT literate organisations in the construction industry. Thus, generalisation from a relatively restrictive sample such as this must be treated with caution and cannot be generalised across the industry to low-level ICT users and ICT-inexperienced organisations. First this is because participants from such organisations would no doubt rate their response to questions quite differently. Second, the analysis of factors influencing ICT diffusion is drawn from a sample that combined ICT users from three construction organisations into one group. Third, the survey only identifies the likely ICT innovation diffusion factors for that group of ICT users. It does not explain how the identified group factors influence ICT diffusion; the analysis only indicates that these factors are likely to have an impact upon ICT diffusion. Finally, the findings of this chapter indicate that access to ICT learning sources/media is somewhat limited both within and outside working hours. Thus, ICT learning from these sources needs to be improved, as the overall access to ICT knowledge sources by ICT users, is only at a moderate level.

It was considered necessary, therefore, to probe further to explain the relationship between variables and the ICT diffusion process. This can be undertaken using a case study approach to track the organisations' ICT diffusion practices. One useful finding from the survey that was considered worth further study was that ICT applications that involve groupware are a common technology gaining acceptance as a vital innovation to be diffused and that this was common to the three construction organisations. The literature review in Chapter 2 further suggests that these types of ICT applications are gaining market acceptance and that it is accepted that more construction industry organisations will need to effectively diffuse this technology to gain and maintain competitive advantage. Therefore, it was decided that a study of ICT groupware diffusion would make a useful focus for further study of ICT diffusion. A well constructed and conducted study into this area would unearth valuable insights into best practice in ICT diffusion in construction organisations that have a history of IT/ICT diffusion over decades. Such a study would make a contribution by moving beyond the explanation of identifying ICT diffusion factors to better explaining how they can operate in practice.

In the next stage of this research, a case study approach was used to gather qualitative data in order to explore the influence of identified ICT factors on ICT diffusion processes. One of the three organisations involved in the survey agreed to participate in this extended study (the first top-tier construction contractor) and two other large contractors in the same market segment were identified and agreed to take part. Thus, study in next phase was designed to specifically focus upon the drivers and barriers to ICT diffusion in first tier construction contracting organisations and forms a logical extension of the survey phase of this research to identify best ICT diffusion practices.

Chapter 6
Descriptive case study - the diffusion of ICT applications within Australian construction contractors

This chapter summarises qualitative data gathered from ICT diffusion case studies for three large construction contractors. The three main objectives are to validate factors that influence ICT diffusion reported upon from the survey and identified in Chapter 5; to explore evidence relating to the ICT diffusion process in these case studies; and to describe how identified key factors influence the ICT diffusion process. To achieve these objectives, the chapter starts with an overview of the case studies. This is followed by summarised details of qualitative data obtained for each of the case studies. Each case description is organised into a consistent pattern comprising the company background, an overview of ICT applications, details of ICT innovation support, diffusion of ICT at the organisational level, and diffusion of ICT at an individual level. Finally, a summary of factors influencing the diffusion process is then discussed.

6.1 Overview of the case studies

This overview provides basic information on ICT diffusion for the three large construction contractor case studies focusing on an electronic document management system (EDMS) in each company rather than considering the general ICT applications. These three cases are symbolically described as CA, CB and CC respectively. Table 6.1 summarises general information for each case.

Table 6.1 General information of case studies

Case (company)	Type of company	ICT system	Implementation duration
CA	Construction contractor	Electronic document management system	5-6 Years
CB	Project management and construction services	Web-based document management system	3-4 Years
CC	Construction contractors	Web-based document management system	1-2 Years

The first case study, CA, is a construction contractor who has developed and implemented an Intranet system used for communicating and managing electronic documents during the project construction phase. The system has been under implementation and use for 5-6 years. The second case study, CB, is a contractor providing project management and construction services. They have developed and implemented a web-based project management system (Extranet application platform) for 3-4 years. The third case study, CC, is a construction contractor who has adopted a web-based document management service and implemented it for 1-2 years. Findings on each of the cases are described in the following sections.

6.2 Case study organisation A (CA)

6.2.1 *Case study background*

Case study "A" (CA) is one of the largest construction contractors in Australia. The company has experience in various types of construction projects such as buildings, civil infrastructure and telecommunication projects. The head office is located in Victoria, Australia, from which it interacts with several regional offices. As these regional offices are managed independently, it was very difficult to transfer and exchange useful information and knowledge between regional offices and between each regional office and the head office. The company sought to improve their within-company communications through an internal network ICT application. The feature of this ICT application was that it potentially permitted CA to not only enhance within-company communications but also to improve the company's construction and business processes. This improvement was focused on issues such as productivity, quality and safety. To achieve this plan, the company was expected to have a computer system that could communicate and integrate all construction information.

Initially, the company explored and evaluated the available software products in the market. However, there were no software applications that were suitable, so the company decided to develop an Intranet application based on a *Lotus Notes* environment, which has database and communication modules. This environment can also run on multiple operating systems such as *WINDOWS*, *OS/2,* which was considered by CA's management to be more compatible in their organisation that has several operating systems. In addition, the environment provides a development tool that allows the company to customise modules and its users-interface to suit their business processes.

During the development period, the organisation established a team that consisted of IT programmers, quality managers and professional workers. Internally, the team worked closely with the quality manager who had a strong background in the organisation's work processes. Not only did the quality manager play an essential role as a champion, but he also was involved in checking and testing the ICT application interface to ensure that it suited the work process as much as possible. In addition, the ICT applications had been tested using trial runs before their actual use. At the same time, the company began to promote awareness of the application. This helped the company to get feedback and suggestions on the application's implementation. In addition, the company provided training to their employees to make them understand the application's benefits and to acquire operational knowledge of the application.

6.2.2 *Configurations of ICT system*

This section describes the ICT system configuration such as its functions and the ways it was connected to the company's IT system. In CA, the ICT application, a document management system, was designed to assist work processes. Its main modules consisted of a tender pack, a project pack, and a project history facility. Authorised staff and clients had access to the tender pack, which was designed to create a tender specification document. The project pack was designed to assist in managing project documents and correspondence during the project construction phase. Finally, the project history was designed to store completed construction information onto a main database for future use. Although these modules have been designed to support different construction functions, each module had a similar document management system approach, as all pieces of information would be stored on to a central database.

Figure 6.1 illustrates the configuration of the ICT system infrastructure. It depends upon the central database server, in which all the information is created, accessed and stored through the user-interface for each module. Each module requires different information and the data structure of the database needs to be configured for each specific module. For information access speed and security reasons, the IT department needed to generate a bank of databases to be accessed by authorised users for each construction project.

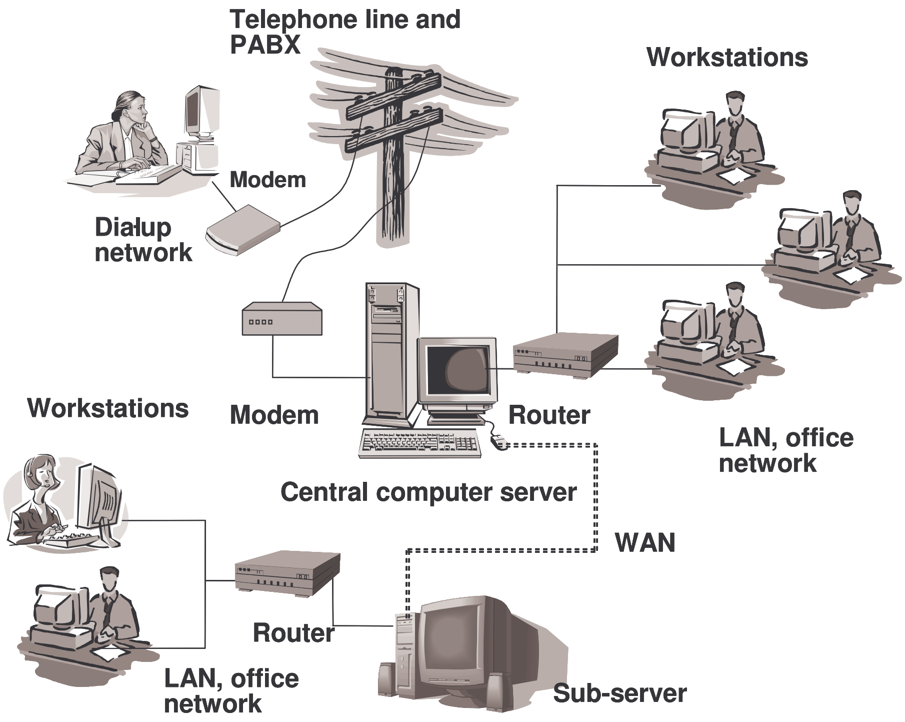


Figure 6.1 Infrastructure of ICT system in CA

The ICT system connection is categorised into three types: local area network (LAN); wide area network (WAN); and dialup network. The first type of connection (LAN) is used in the main office. It links all workstations to a central database sever. The second type of connection (WAN) is used in regional offices and on some construction sites. It has a sub-main database server in which all local information is replicated from the central database server. The dialup type of connection is suitable for remote construction sites or for access by employees who might need to work from home.

6.2.3 *The use of ICT in CA*

The use and adoption of ICT had been recognised throughout the organisation. Most CA construction project participants use ICT modules for their work processes such as tendering, project database management, and project history management. Participants agreed on the nature of benefits of their use of this ICT application for their work processes. Moreover, the use of ICT is well diffused into different organisational levels ranging from the construction project manager to the foreman. Furthermore, individuals specifically depend upon using these ICT modules to carry out their jobs. For example, site engineers use the correspondence module for communication and coordination whereas cost engineers continually use the tender module.

During the bidding period, the tender module helps teams in terms of communication and coordination. The tender team shared information among their group. In addition, authorised users could easily modify and update information in the tender module. Thus the ICT application allowed the team to effectively monitor information details transferred during the tender process. This information was also stored in the project database, which allowed users to refer to during the next tender.

After the company has won a tender bid, the next phase is construction. During the construction period, the project database module plays a significant role in managing documents such as request for information (RFI), letters, contract, drawings and so on. Although the electronic correspondence module allows all documents to be sent to other project participants, its full use was practically confined to within organisation project participants that have ready access to the ICT system, for two reasons. First, there was a the need to translate digital format into hardcopy format to sent information to other project parties who did not have access to compatible ICT systems. Second, in receiving hardcopy information to be stored electronically, this hardcopy information needs to be digitised. The implication of this limitation is that there might be a lack of availability of hardware to digitise hardcopy correspondence from these organisations using scanners, as well as plotters to provide hard copy drawings or schedules to any organisation that does not use compatible ICT systems. Most internal correspondence and information transfer, however, was transacted using ICT.

From an inter-organisational communication viewpoint, most documents transferring between CA and other project participants were still communicated in the traditional way, basically because some project participants did not use ICT. Therefore, much of the correspondence being transferred between organisations was created using ICT but printed onto paper that needed to be sent by fax or post. Another issue was that the ICT application was designed to be used internally within the organisations and thus could not support a free standard information exchange protocol among the project participants.

Case study participants mentioned that the project history modules had problems regarding access speed and IT resources. Some participants claimed that it was very time consuming to connect and access information. Furthermore, the organisation did not allocate a person to manage the system information. As the objective of this research, focused mainly on communication and coordination functions of ICT, consideration of the project history modules were not included in this study.

Generally, the use of ICT had been diffused well in this organisation. Once a construction project starts the IT department will set up a project database. The staff will be given a username and password to access the project database. Thus staff in a construction project could communicate and exchange their information electronically. For example, information included in this project database were:

- Resource and equipment information;
- Project information such as weather and site conditions;
- Project document such as tender document, drawing, etc.;
- Occupational health and safety information
- Site instruction correspondence.

This case study focused on head office users and participants from a construction project in Melbourne, Australia. Although the ICT use was limited to an intra-organisational context, the diffusion of ICT within CA could be classified as 'good' because most participants presented a positive perception of the ICT adoption and there were numerous organisational levels of people who used ICT. Factors that supported the use and adoption of ICT in this organisation are explored in further detail.

6.2.4 *Group of ICT innovation support*

This section provides information about the organisational structure that supports the ICT application. Results from interviews indicate that IT department staff mainly delivered ICT support in CA. Figure 6.2 illustrates the organisational structure supporting ICT application adoption.

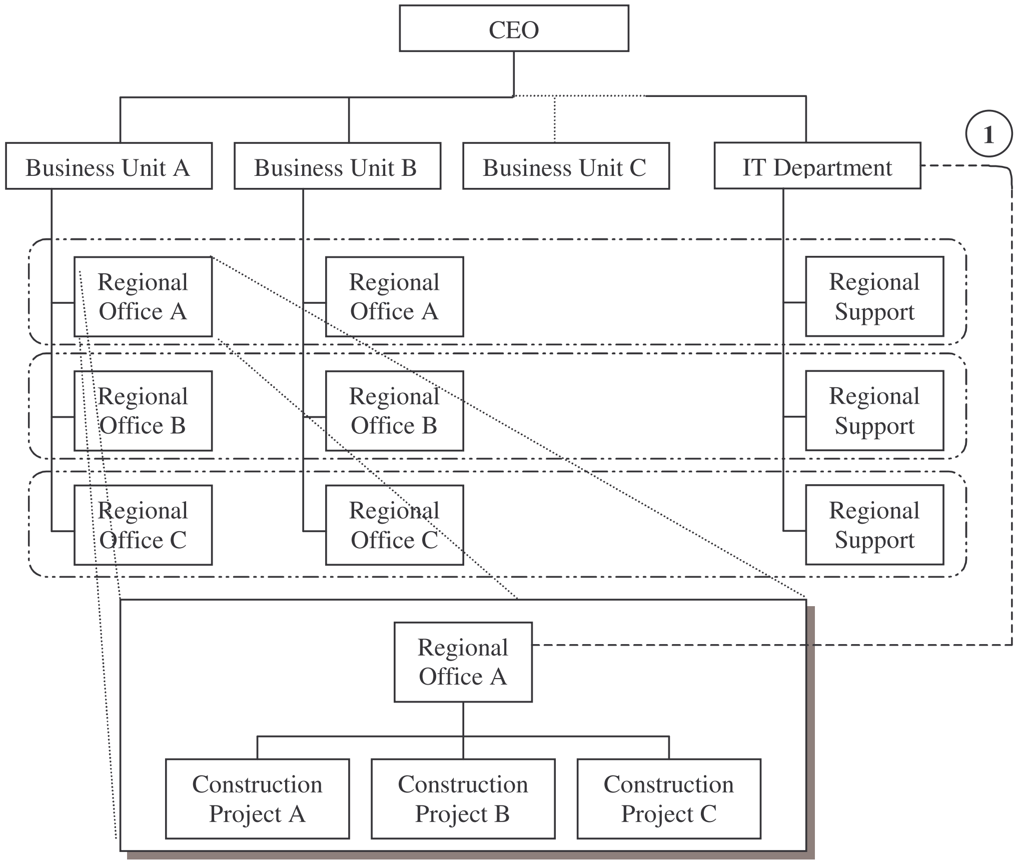


Figure 6.2 Group of ICT innovation support in CA

6.2.4.1 IT department

The corporate IT department was co-located with CA's regional office under study in this thesis. Its main role was to design and develop ICT applications to suit CA's business activities. In addition, it maintained and improved general organisational ICT use. During the beginning of a construction project, the IT department would establish and configure the ICT project database for that particular project. In addition, it had a support role to provide, train as well as generally help staff to implement ICT applications.

Users in CA felt it convenient to contact and receive support from the IT department and this was facilitated by its being co-located in CA's main office. Generally, phone and email discussion using a web board were two methods of contact support. However, some staff preferred to get personalised help rather than phone main office support staff. The IT department also played an ICT support and adoption role for users from other regions. By supporting users in other regions, senior managers in those regions demonstrated commitment to the IT department through their IT department budget allocation for maintaining ICT support services and improving the general system.

6.2.5 *Diffusion of ICT at the organisational level*

In CA, the introduction of ICT was initiated from a quality assurance top management vision philosophy. This ICT development vision was initiated in 1995 and aimed to uniformly improve construction quality. Most CA staff resisted implementing ICT applications at the beginning phase of its introduction and this was similar to their experience with other innovation technology diffusion initiatives. However, as the company began over time to roll out further ICT initiatives, staff increased their commitment to ICT use. The ICT diffusion process generally began by ICT staff facilitating an understanding of the benefits and practical use of existing resources to make the best use of it. Commitment was developed from the five regional managers that this would advance the benefit of quality and OHS and that IT staff could deliver appropriate support. Regional managers were also involved by ensuring IT staff were resourced to support the ICT strategy, and planning how to implement it to suit construction business work processes. General staff with experience of construction processes were also involved in developing ICT applications. They also dedicated their time to testing ICT applications and simplified ICT user-interfaces. Feedback from users' experience helped this group to modify and configure ICT to suit users' work.

6.2.6 *Diffusion of ICT at the individual/group Level*

The use of the ICT document management application such as processing requests for information (RFI s) and general correspondence has been diffused to most construction projects and is used by project managers, engineers and some foremen. Intra-organisational communication is also electronically carried out using ICT. All documents are created, transmitted and shared by staff with a large number of staff using ICT for communicating and coordinating modules of the ICT application.

However, ICT is restricted to internal use within CA as an organisation. It does not interface well other project participants using the contractor's ICT application. This necessitated most documents for communication with sub-contractors and other external project participants to be in hard copies printed from the ICT system. Even though ICT use was stressed as an intra-organisational system, the contractor's users did not expect to use ICT for communicating among inter-organisational project participants. While the ICT has been adopted for use within this organisation, this technology has not been designed for use by other project participants. As it is only internal users that mainly use this system, some sub-contractors rarely communicate with CA using a compatible ICT system. As a result, staff frequently have to scan paper documents into an electronic format to store it in their ICT document management system.

6.2.7 *Users' experience of factors influencing ICT diffusion in CA*

Table 6.2 shows the findings of existing factors influencing ICT diffusion for CA. As the ICT was designed to be used internally, the inter-organisational degree of ICT use is minimal. For example, some participants mentioned that some sub-contractors who did not have their own ICT document management systems prefer to correspond with CA by phone and fax. The organisation plans to use the Construction Industry Trading Exchange (CITE) system in the near future to allow sub-contractors to correspond through the CITE web-technology platform to enable it to communicate electronically with these subscribing organisations to allow greater ICT interaction.

Table 6.2 Users' experience of factors influencing ICT diffusion in CA

Factors	Interview finding (CA)
F1: Professional development and technical support	Participants received within-company training from the IT department. This training provides the basics and concept of using the application. Training session time was approximately 3-4 hours. Most participants were satisfied with the training, but some mentioned that the content of training should be more specific and be updated as the application is upgraded to any new version. Two methods to contact help desk people were by phone or via an electronic email help system. Participants were moderately satisfied with the help desk but responses to their problems needed time to process,

	depending on priority and the type of problem.
F2: Clear benefits of use	Most participants understood the benefits of using the application. They found that it assisted their communication and coordination within their project. In addition, they also recognised that this application provided a benefit in terms of knowledge repository. This helped in their future decision-making.
F3: Supporting individual characteristics	Participants presented adequate personal characteristics of basic IT skills, enjoyment of learning, self-confidence and commitment to use. Basic IT skills and self-confidence were considered the fundamental criteria for individual usage. Furthermore, some mentioned that enjoyment of learning and commitment to use were the essential momentum for individual use.
F4: Supporting technology characteristics	The application consisted of several modules to assist construction processes such as correspondence, site instruction, tender, and site diary. The application was considered as a good tool to help their work processes. Participants mentioned that the functionality of the application was compatible with their internal work process. However, small issues such as user interface and functionality were suggested as needing improvement for application use. The application is based on an Intranet platform, designed for use only by people within the organisation. Therefore, users needed to connect with the organisation network. There were two methods for connection: (1) local Intranet network and (2) dialup network. A main server was located at the head office linked to 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 local Intranet network, its speed was faster than connecting via dial up networking where the speed was limited at 56 kbps. Though there were several ICT modules in use staff believed the concept of using these were quite simple. Participants mentioned that the ICT connection was reliable. In addition, all information was backed up through the main server at the head office. It was very hard to lose information using ICT.
F5: Supporting supervisor and organisation	It was mentioned there is a positive influence from the supervisor regarding the use of the application. Most supervisors encouraged their subordinates to use ICT in helping their subordinate mentoring and support role. Similarly, the organisation supported the use of the application by providing sufficient software, hardware, and training to be effective. They also provided a computer notebook to people who use ICT.
F6: Supporting an open discussion environment	There was an open environment for the discussion of use of ICT applications; however, not everybody could dedicate time for discussion due to their other responsibilities. This organisation also created a virtual discussion environment by allowing users to discuss and make suggestions about problems of using this application through an electronic whiteboard system. Some participants identified their involvement as suggesting the application use. When they found problems or had suggestions, they would discuss this with IT staff. However, one participant claimed that not all people in the organisation had sufficient knowledge of the applications to the level they can confidently discuss detailed issues of improvement.

F7: Supporting tangible and intangible rewards	In terms of using an ICT application, most users interviewed suggesting that a reward is not necessary for implementation of ICT. Tangible rewards did not seem to be of key importance in the use of ICT application because its use provides simple tools that assisted their work performance. Therefore, use of an application did not directly require any rewards—professionalism and pride were viewed as sufficiently important to user to encourage use.
F8: Collegial help	In a contractor type organisation, most respondents mentioned that they helped and supported each other with any problems that they face. A strong culture of collegiality helps to underpin the use and diffusion of the application throughout the organisation. Currently collegial help occurred unofficially in this organisation. Although some participants have a limited knowledge of ICT use, they would find a way to assist colleagues or suggest an expert person who can help or solve problems.
F9: Positive feeling towards ICT use	Strong positive perception of the value of the application's use was evident. Participants felt it assisted their communication and coordination within their project teams. They believed that the application was compatible with their traditional work process and assisted their communication.
F10: Negative emotions towards ICT use	Low level of negative perception relating to the use of ICT application.
F11: Frustration with ICT use	Frustration may occur for people with inadequate basic computer skills. In addition, the low speed of connection also developed frustration due to the need to upload and download attachments from ICT.

6.2.8 *Descriptive of ICT diffusion process in CA*

The findings from Sections 6.2.5 and 6.2.6 describe the ICT diffusion process at both organisational and individual/group levels. This section focuses on the diffusion process at the initial adoption and actual implementation phases. The ICT diffusion process during the initial adoption started from top management and IT staff. CA's quality improvement policy in the early 1990s initially drove its ICT adoption. In 1995, CA started to adopt ICT when Internet technology was in a nascent developmental stage. CA decided to develop its own ICT applications because 'off-the-shelf' software packages did not have enough features to support organisational needs. Therefore, CA could be classified as following a 'proactive ICT adoption strategy' because it invested early in development of ICT applications rather than waiting to adopt suitable 'off-the-shelf' software packages later. However, CA also used a proprietary ICT document management system. Regional senior managers and quality managers supported the IT department in the strategy. It could be classified as 'top-down' ICT adoption.

In CA, the actual implementation focused on senior management support, IT people providing technology fit, and training and technical support. Most respondents had received 3-4 hours of training and had strong help desk support. Also, top management at CA were committed to developing a suitable ICT application for enhancing work-processes. One quality manager said that ICT functionality and simplicity were the key factors required for promoting users' acceptance. Finally, most of the senior project managers were also supportive of the diffusion by facilitating their unit's ICT adoption and feeding comments back to the developer for improvement.

In terms of personal characteristics, participants in CA had strong computer skills, clear ideas on the benefits of using the applications, and self-confidence in using them. Most of them had adopted and used ICT for their normal work processes. The sharing and learning environment in CA supported the diffusion of ICT. For example, a senior manager would often share and exchange his/her technical experience with IT staff. Such a sharing environment helps both support staff and users to understand and continuously improve any ICT initiatives. A particular project manager set up regular morning meetings to create a learning environment within his team on the use of ICT applications for specific tasks.

In summary, during the ICT diffusion process, users experienced positive reinforcement from: training and help from the IT support group; supportive technology characteristics; senior management support; and the sharing and learning environment. A number of IT managers claimed that a sharing and learning environment was particularly embedded in the culture of the organisation during the ICT implementation period.

6.3 Case study organisation B (CB)

6.3.1 *Case study background*

The case study organisation B (CB) is a major international construction contractor with a substantial global presence and is one of Australia's largest construction companies. Generally, the structure of the company comprises several business units. It is engaged in various construction aspects such as design engineering, construction and project management. The case study was focused on the implementation of ICT in the regional office based in Victoria, Australia.

Two main policies pursued by the company are collaboration and innovation. Collaboration is focused on both internal and external teamwork. Innovation in the company meant exploring ways to improve their traditional work processes. One example of their innovative technologies is their development of a web-based collaborative application. The main objective of this application is to enhance communication and coordination among construction project teams. As the company is a main contractor, it needs to be involved with clients, architects, consultants and specialists. Hence, the use of this ICT application can assist them to work productively by enabling rapid exchange of information among project participants. In addition, users can simultaneously access information from several places.

6.3.2 *Configuration of ICT systems*

This section describes the configurations of the ICT system, its functions, and the methods of connecting it. In CB, a web-based document management ICT system was used where users accessed information from a central database server through an Internet connection. The system was designed to facilitate document management, exchange and communication, as all the information was stored in the single place and the staff had the flexibility to access relevant construction information to monitor the current project and to use prior information for future decisions in other construction projects.

Its main modules consisted of a to-do list, calendar, document control register, multimedia/images, correspondence, RFI, general file transfer, and contact details. The description of each module could be described as below:

- *Task-list module* provides notice information to the users when they login to the system. It contains messages or activities that were sent by other users for action.
- *Calendar module* helps the users to plan activities, meetings, milestones, events etc. The user can view the calendar in different modes such as two-day, fortnightly, monthly or yearly view.

- *Document control register module* has the main function to store the document in the database where the authorised users can access the document. This module is also used for monitoring and tracking the progress of a document that has several revisions such as drawings, specifications, and schedules.
- *Multimedia/images module* was designed to store electronic pictures of the construction site for reference, but could also store other media such as sound files, video clips etc.
- *Correspondence module* assists in communication among staff and project participants. It contains a facility for all modes of correspondence such as email, electronic fax, and electronic memoranda.
- *RFI (request for information) module* is used to seek information from other project participant. For example, staff may not be clear about design details so they may send an RFI to get more details from the designer to clarify issues.
- *Site-instruction module* helps the user to notify relevant staff to perform a job and to request them to notify after the completion of the activity.
- *File transfer module* is designed to upload large files for sharing among the team members.
- *Contact module* helps searching for information about staff members to find a person who may have special knowledge within CB.

Access to the ICT system in CB can be grouped into two types: local area network within construction offices/sites, and CB's dialup networking server. Firstly, users can connect to the ICT system using the network in construction offices/sites that provide Internet access. Each workstation obtains through the LAN/office network server, both an Internet protocol and a gateway number for using Internet. In addition, the construction office/site network server needs to subscribe to an Internet service provider (ISP) to obtain Internet access. As the ISP plays a main role in linking users to the Internet, users can access the ICT system via the World Wide Web (WWW). Connection speeds ranged from 14.4 kbps to high-speed. In construction main offices, they are linked to their network through a rental wide area network (WAN) whereas the construction site offices generally use different types of connections such as Asymmetric Digital Subscriber Line (ADSL), Internet service digital network (ISDN) or modem to connect to an ISP etc. The mode of connection depends on the number of workstations, speed requirement and budget.

Another mode of ICT system access is CB's dialup networking server via a modem. This connection was limited for internal CB staff. At a construction site, CB did not provide infrastructure such as computers and Internet access but provided the users with a system account to external project participant users. Therefore, most of the external project participants are required to have their own Internet connection to access ICT system.

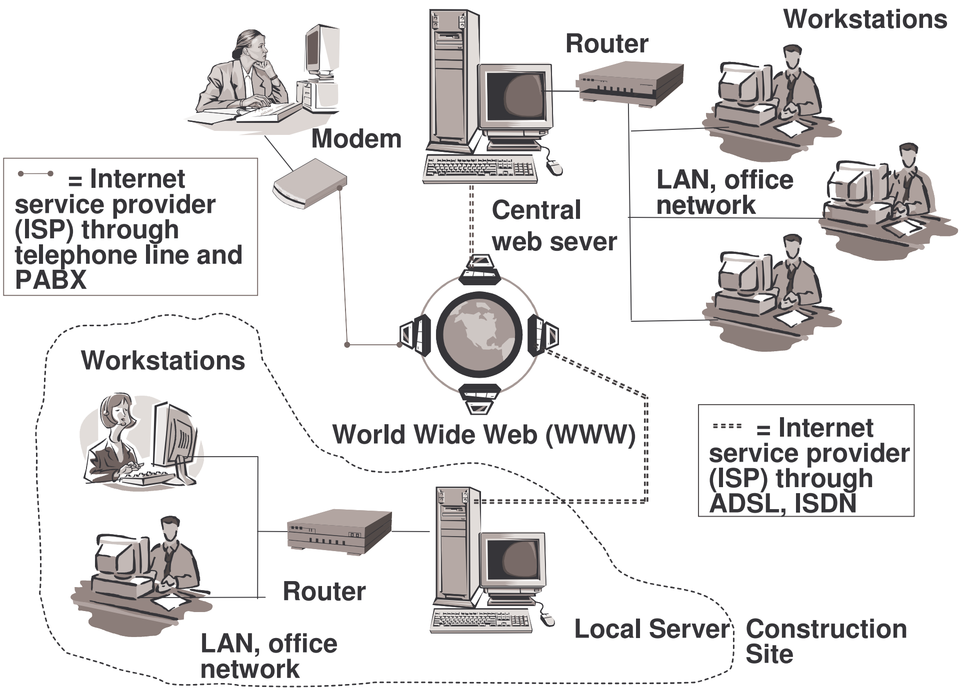


Figure 6.3 Infrastructure of ICT system in CB

6.3.3 *The use of ICT in CB*

CB used a web-based ICT concept for project management to control and manage project construction documents through the Internet. However, the use and adoption of ICT had a mixed response. Generally, project managers and engineers were the main users. Foremen had a low level of ICT use as they were not heavily involved with administrative matters.

Although the ICT is compulsory, not all staff were committed to using it. Users indicated several reasons for their resistance. Firstly, the ICT itself did not provide the necessary functions for some staff. For example, design and construction staff found it difficult to download and upload CAD files. In addition, viewing CAD files on a computer is limited by the monitor size. Secondly, sending files through the ICT was unreliable at times; they could not ensure that files would be sent to the intended recipients. In addition, recipients may not read or even open the correspondence within the required time. Therefore, a copy of most correspondence was also often sent to recipients by fax or post.

The use of ICT provides many benefits to staff at a construction project. Firstly, the use of ICT helps communication within and between project teams involved in the construction project. Users can send and receive new correspondence through ICT. Secondly, ICT allows users to store and search the project information. All correspondence is located in the central server, to which users have access for information and searching for documents through the web browser. Thirdly, by using web-based user interface, users have no limitations on computer platform for connecting to ICT. They only need an Internet browser. Finally, the benefit of using ICT is that users can monitor the work that has been done. ICT can help users to monitor the history of how site instructions were raised and processed to remind them if they are not executed.

However, the use of ICT provides only basic benefits because of limitations in its functionality, flexibility and speed, especially when communication and coordination among project participants is complex. Some project participants, despite their training, did not use ICT effectively because of their unease stemming from a lack of basic computer background, and/or because of inadequate physical resources such as a computer and an Internet connection. The inter-organisational factors seemed to be a particular barrier to the use of ICT in CB. Some mentioned that using ICT caused an increase in their workload because they also had to manage paper-based documents from people who do not use ICT. Therefore, the benefits of using the applications would only occur if all project participants used ICT.

6.3.4 *Groups of ICT innovation support*

ICT implementation is continually improved by this organisation. While ICT functions ideally seem to provide benefits for use in construction projects, there are several problems for operational users that need to be addressed.

In 1997, the company began to implement stand-alone Internet applications such as email and file transfer protocol (FTP) software but there were limitations in using these applications. For example, sending a file via FTP would not identify the sender or nominate a receiver. In addition, there was also a limit to the capacity for attaching large files to emails. Especially during the construction period, a lot of information and documents were exchanged among the project participants.

From problems of document management and information sharing, the company started to explore the existing collaborative applications in the market but found nothing to suit its specific needs. Therefore, the company started to develop a collaborative application in 1998 to improve the virtual project workgroup. This application was designed to use the common web-based interface accessed via a web-browser. A web-based ICT application running a web server and a database server supported construction work processes. The database server had the key role to manage and store all information and files that were transferred through the application. The web server performed the main function of communication between the user and the server through a graphic web interface. Users do not need to install additional software, apart from an Internet connection and Web browser software, because all information and files will be processed through the web server linked to the database server. As the ICT system is web-based, it could interface with users having different operating systems.

This section provides information on the organisational structure for ICT innovation. The results from the interviews indicated that there were two types of ICT support in CB that were implemented by the IT department. The organisational structure relating to ICT support is shown in Figure 6.4.

6.3.4.1 IT department

ICT innovation support in CB was mainly managed by the IT department that had the key role of estimating the cost of use of ICT in a project. The main IT department was located in another region from the one under study here. After the ICT infrastructure decisions were made, they had their technical teams at the construction projects to support the installation of the ICT and implement software to suit construction project management. One of the applications is a web-based collaboration system and CB supported regional IT through an IT representative to coordinate and solve local problems. Also, the IT department supported users through a help desk and used an ICT implementer (person who facilitated the implementation of the ICT application). Users could receive help by contacting people at the help desk by phone or email but most users preferred not to use this facility, and relied on the implementer allocated to support the people.

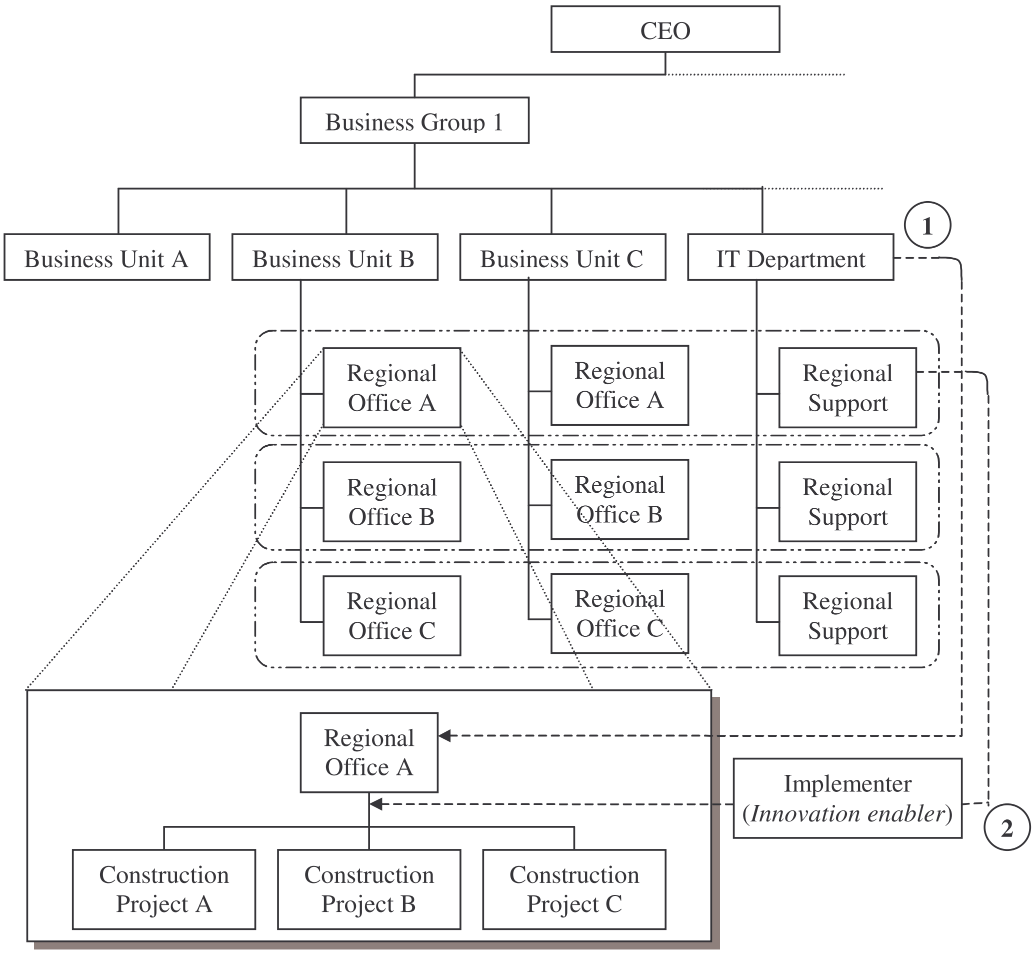


Figure 6.4 Groups of ICT innovation support in CB

6.3.4.2 Implementer

The implementer is delegated by the IT department to facilitate the use of ICT at a project site in CB. The support for using ICT at an individual level mostly depended on the implementer who dedicated his/her time to providing training and seeking solutions to users' problems. Users recognised the implementer's essential role in their ICT application use because of his ready availability to help by phone or to visit their site or workplace. However, often the implementer's effectiveness in meeting the user's needs was limited because IT staff from another region had carried out the configuration, design and programming of the ICT and he was unaware of various associated technical issues.

6.3.5 *Diffusion of ICT at the organisational level*

An e-business group that sought to improve the construction project management drove the initial ICT diffusion in CB. In 1998, CB found that none of the available applications supported a web-based project management platform, and made a decision to develop its own ICT application. The initial development of ICT took approximately 3-4 months including discussion, programming and testing. This was developed from basic concepts, and then programmed to support main business requirements. The main objective of ICT developments were (1) to minimise the overhead costs of document delivery, (2) to reduce the office space for keeping the paper-based drawings, (3) to coordinate the activities of project participants, and (4) to facilitate a virtual work environment.

During the development period, CB teams and sponsors worked with IT development consultants. CB teams consisted of many experts in different areas such as architecture and design, project management, management design, and site construction. The first ICT module was a project directory that stored personal and contact information. It allowed an employee to search for staff's name in the company. As the result, this module could assist users to find out expert staff who could help them on specific problems.

At that time, Internet technology was not used extensively in the construction industry. The diffusion of ICT in CB mainly depended upon the selection of the right tools to persuade employees to be interested in ICT. They started with simple modules (such as project directory and correspondence and RFI management) that persuaded ICT users to get familiar with the system and later added other features such as image database and site progress. In the early adoption period, CB focused a lot on the promotion of the system as, the web-based concept was identified as a radical process. This promotion started with the basic awareness of using ICT within CB. CB also supported users at the construction site. The internal team had the function to explain the benefit of using ICT and support the user when they struggled with using it.

6.3.6 *Diffusion of ICT at individual/group level*

Although the company has a policy for comprehensive use of ICT in all CB construction projects, the deployment decision was still undertaken on large construction projects by a project-by-project basis depending on the ICT budgets. The use of ICT service did include operating cost; hence some CB managers saw this as risky, especially when the benefits of its use could be difficult to measure in monetary terms despite potential time savings, and communication process improvement.

After the project manager made the ICT adoption decision, participant implementation is the next diffusion stage on a construction project. CB's IT department would install the network and the Internet infrastructure. User access through dialup, ADSL, or high-speed Internet connections could be made, depending upon the IT budget that had been agreed.

At CB, the implementer played a key role in ICT diffusion in the construction project by promoting user awareness. He trained key CB people as well as project participants. The factors influencing ICT diffusion and adoption are described in the following section.

6.3.7 *Factors influencing users' experience in ICT diffusion at CB*

Table 6.3 summarises the findings from the user interviews. These list key factors that support CB's ICT use. In addition, the findings point to some interesting external factors that influence ICT diffusion within an organisation.

Table 6.3 Users' experience on factors influencing ICT diffusion in CB

Factors	Interview finding (CB)
F1: Professional development and technical support	All users received basic training in use of an application. The training time is approximately 3-4 hours conducted internally by an implementer. In addition, the trainees receive a manual. The training consists of two parts: introduction and functional use. The first part describes how to access ICT and the second part explains how to use the specific application functions. Additionally, users may request advanced training as required.

	Although there was a help desk that supports the users of ICT by phone and email, most of the participants preferred to get personal help from an implementer. The technical support was mainly supplied by the implementer, who takes on the role of helping users at the construction sites or in the regional head office.
F2: Clear benefits of use	Conceptually, the use of ICT aims to manage and control project information through the Internet. Not all users seemed to clearly understand the benefits of using an application or were not fully clear of the advantages of using the system. At the time of study, users have mixed opinions about ICT benefit because of perceived functionality limitations of flexibility and speed. Some participants mentioned that using ICT caused an increase in their workload because they also have to fax the same document to a person who does not use ICT. Ultimately, the benefit of using an application can only be realised if all project participants use the application. At the time of the study, the implementation of ICT was continually being improved by this organisation. ICT benefits to users are identified as follows. Firstly, it helps communication within and among project teams involved in a construction project. Users can send and receive correspondence through ICT linked with their internal email system. When they receive new correspondence, they will receive a reminder email from ICT. Secondly, ICT allows users to store and search the project information. All correspondence is located in the central server, in which users can access information and search for documents through the web browser. Thirdly, by using a web-based user interface, users have no limitations on the computer platform for connecting to ICT. They need only an Internet browser. Finally, the benefit of using ICT is that users can monitor the work that has been done. For example, ICT can help users to monitor incomplete site instructions and remind users to fulfil the requirements.
F3: Supporting Individual/Personal characteristics	Project managers and engineers generally expressed a confidence in using the applications as they had well developed computer skills from their courses in the university. However, some staff who work at the foreman level did not have sufficient computer skills. Also some engineers felt that the use of the applications did not suit them because of their lack of basic computer skills and they were too busy to learn and use it. The overall impression was that not all users were committed to ICT use. Some of them regarded it is a compulsory tool. Most senior managers and engineers tended use it. Foremen did not use it much. Most participants agreed that personal characteristics such as capability to learn, basic IT skills, and commitment are necessary for the use of ICT. Especially in the early stage of implementation, people don't get to use it straight away. They need to commit their time in learning by playing with ICT and getting used to it. In addition, the commitment for use needs an ICT that provides tangible benefits. Some participants were not motivated to learn the use of ICT because they were not clear of the benefits of its use. Most participants used it as a basic requirement of their job.
F4: Supporting technology characteristics	The functions of ICT were designed to support the communication and coordination of a construction project. The main functions of the ICT consisted of searching company personal information, creating correspondence, managing RFIs and site instructions, registering drawings and reminding people of uncompleted tasks. These functions support a majority of people working on construction projects. But some participants did not agree that ICT suits the scope and nature of their work. For example, foremen normally spend most time on site and they use forms to monitor work progress. At the time of study, they had to return to their computer and input the information again from paper form

	to electronic form. This process increases their workload. The organisation that needs this information therefore should provide a reward or incentive for re-entry data to ICT or provide a facility for data entry at the site workplace, for example, reducing re-entry work by use of a handheld PC to input data onsite and electronically transfer data. Most users received personal accounts to access the ICT via their computers connecting to the Internet. ICT allows access although the users may have different operating systems. This ICT application only needs an Internet browser and connection. Thus, users have no need to install any client software. Due to the web-based Internet platform, users can access the ICT from anywhere. It was mentioned that the ICT was designed to have a minimum speed of 56 kbps per user. However, the response rate of using this application relies upon the speed provided by Internet service provider. At a construction project, the connection speed is varied depending upon the connection types such as modem, ADSL, and cable. These connections are dependent on project IT budgets. In addition, the response rate for use also depended upon the file size. Sending correspondence is quicker than an upload or download of large drawing files.
F5: Supervisor and organisational support	The organisation generally supports ICT use. All staff have been provided with the enough facilities to access ICT such as computers and a user's account. One user stated that the senior management listened him to and feedback for improvement was given during the beginning of ICT introduction. However, when ICT use became mandatory, the momentum for acting on feedback seemed to be lost. Support from managers is essential but in reality they are busy and have little time to act on ICT use issues. ICT use discussions mostly occurred among staff at the operational level, but rarely between workers and senior managers. This indicates that this organisation is lacking a feedback channel for communicating ICT use to senior managers. Interviewees at the engineering level felt that foremen were not required to use ICT and that management put less effort in encouraging foremen to use ICT. This was despite organisation policy requiring them to use ICT for assisting their job.
F6: Supporting an Open discussion environment	It was claimed that there was an open discussion environment where participants felt safe to seek help on any problem. In reality, this was an ad hoc environment where discussion of ICT use was shared only among colleagues. Colleagues' mutual help and interactions sustained the use of the systems. One person mentioned that if they could not solve the problems, then they asked the mentors at head office or help desk. It could be interpreted that participants usually started with solving their problems within the group and then moved to an advanced technical person if they had any limitations on using ICT.
F7: Supporting tangible and intangible rewards	Tangible rewards seemed to be unimportant in ICT use. Most participants disagreed on the need to provide rewards for ICT use. They believed that ICT is only a tool to be used. The organisation tried to develop a rewards system but failed to get a consensus of the best way to encourage knowledge sharing. Their belief is that if the ICT provides clear benefits to making the job easier they will then use it naturally.
F8: Collegial help	Users agree on the necessity of the supporting colleagues. But they could not spare much time in an office setting as they have their own responsibilities to attend to. Not only is time a limitation, but their depth of computer knowledge also limits the mutual help among users.

	Therefore, significant help is mainly received from an implementer dedicating their time to user support.
F9: Positive feeling towards ICT use	Most of the participants agreed on the benefits of ICT as being better than fax and phone, but the culture within the construction industry is not yet ready for an uptake beyond this level. Some project participants preferred to continue using traditional communication. This caused problems to the organisation in initiating the use of ICT. Some respondents believed that ICT was not fully reliable because they lost data while they left their connection to check their work on site. In fact, the connection was configured to automatically close the session for security reasons and to reduce load on the server. The use of ICT was compatible with construction work for document management. However, the use of ICT was not fully applied in case of drawings. For example, they did not have machines to scan drawing as an attachment. Furthermore, some participants mentioned limitations of configuring some formats such as document headings.
F10: Negative emotion towards ICT use	Perceived performance limitations, i.e. functions, speed, and accessibility, produced a negative perception of ICT and this generated one barrier to implementing ICT. In CB, a negative perception invariably developed after the participants began to use ICT. The limitation of ICT use may occur because of some participants had colleagues who were reluctant to use the system and this created problems of mixed electronic and manual methods of working that caused duplication of effort.
F11: Frustration with ICT use	Some issues related to frustrations with ICT use that were cited are functionality and both speed and accessibility performance. For instance, some participants felt anxiety and frustration because the system was not perceived as reliable or response times appeared to be slow. As a result of perceived ICT complexity, users felt it to be unfriendly. In addition, as the use of ICT was made compulsory, staff felt that they were being coerced rather than persuaded to use it.

6.3.8 *Summary of ICT diffusion process in CB*

The ICT adoption initiative for CB was intended to gain it a competitive advantage. During the mid-1990s, a lot of Internet applications such as email and file transfer were being developed to improve basic business communications. CB perceived these applications to have a limited applicability to their construction business because it is a project-based organisation extensively dependent on a relatively less ICT-literate supply chain. The IT manager (who is evidently interested in ICT benefits) supported investment in a web-based document management system. However, CB decided to develop its own ICT system because off-the-shelf software packages did not provide functions that supported its specific organisational needs. CB showed a proactive strategy on ICT adoption. Furthermore, the type of ICT adoption may be classified as both ‘demand-pull’ and ‘technology-push’. ICT was used to improve document management quality, communication and coordination. It focused on the ICT use by the internal staff and other project teams. All project teams exchanged correspondence and information such as drawings, staff contact details, site diary etc. An e-business group managed the investment and made the adoption of this tool 'compulsory' for all construction projects, so CB's ICT adoption approach should be classified as top-down.

CB focused its actual ICT implementation on training, implementer support and senior management support. Before any projects began, all participants received 3-4 hours of training from an ICT implementer. The implementer also took on an additional mentoring role in helping people use ICT. Some users mentioned a lack of responsiveness by the help desk facility and that they invariably asked the ICT implementer for personal assistance. Organisations also supported each user by providing them with a computer, Internet connection access, and a user account. CB senior management supported users on a project-by-project basis followed by a project review to assess effectiveness. ICT users saw two construction project managers in particular as role models because they encouraged their teams to exchange information using the ICT applications. Overall, ICT diffusion in CB depended on the ICT implementer and supportive project managers.

From the ICT characteristics point of view, there were mixed opinions on the benefits of ICT use for CB. For example, most engineers agreed that using ICT assisted them to better manage construction documentation and to improve communication within project teams. Overall, respondents were satisfied in principle with their ICT use, but some of them believed that ICT applications needed to be improved—citing the cost control module as an example. Design project managers, however, argued that ICT applications did not support their role in projects. In particular, they complained about functionality and connection speed. An IT developer observed: *'The design of ICT applications are based on 56k Internet connection, but there are several terminals in an office that share Internet connection…Hence it takes a long time for downloading a drawing file*'. Consequently, the ICT access speed characteristic of is one important factor influencing diffusion as it determines the user's perceptions of improving their work processes.

Although the IT group developed CB's ICT applications with users' representatives, some characteristics of ICT might still be overlooked by management during the implementation period. For example, some project managers did not realise how important providing a suitable Internet connections could be to ICT access speed. Slowness resulted in a negative perception towards ICT use. Consequently, ICT characteristics should not only fit with users' requirements and organisational work processes, but also performance characteristics should be monitored and continuously improved to ensure users' acceptance during implementation. Additionally, all construction project managers should be persuaded to allocate an adequate budget for ensuring efficient ICT use and understand the importance of this in the effective diffusion of ICT.

ICT user backgrounds and skills may also influence how ICT use is learned, even though the organisation may provide training. In CB, respondents were satisfied with training content but people have different experience, backgrounds and skills that can affect their individual learning outcomes. For example, one respondent in a training session asked an implementer, *'What is Netscape software?'* This particular user had no background knowledge of using an Internet browser, and this was a significant barrier to ICT use. Thus, personal characteristics can indirectly influence the effectiveness of managing training support. CB, like CA, demonstrated little evidence of any effective training needs analysis being undertaken to customise or personalise ICT application support/training.

Another factor influencing ICT diffusion is an individual's role. Each user may have a different role on a construction project. Thus the diffusion process at the implementation stage should provide for each person to master related modules that assist them in their job so that the benefits of ICT use are clear to them. For example, a young engineer in CB was involved in coordinating sub-contractors while a foreman was involved with monitoring the quality of construction work produced on site. These two roles would have different needs of ICT use for specific modules such as a drawings register for the engineer or a diary register for the foreman. Therefore, the project manager or implementer should support the basic ICT modules that related to each person's job. Lack of needs analysis and targeted training may result in people wasting time learning modules that are not essential to them while not concentrating on modules that are.

The learning environment could be considered as an important part of ICT application diffusion during its implementation phase. For example, in CB one engineer felt that his construction project employed a large number of experienced staff that could assist new users and improve their ICT acceptance. ICT knowledge transfer from experienced users to novices has a different influence on ICT diffusion than training does. Training provides a common understanding of an ICT application's use but it may not convey how ICT users undertake specific job-related tasks. Therefore, users should learn the basic concepts and then practice its application to their job to gain familiarity with the ICT application. If ICT users on a project have any knowledge limitations of how to use an ICT application, then effective users' adoption may consequently depend upon a supportive collegial environment to deliver required know-how. Similarly, if most users on a project have no experienced staff to assist new users, then their adoption and use of ICT may depend upon an implementer or IT person who has direct experience of its use. Therefore, ICT diffusion during the implementation phase requires an implementer or IT person, plus a collegial environment.

Lastly, ICT diffusion during the actual implementation phase might depend upon its use by external project participants. CB has a web-based document management system that all project participants are intended to use. CB contractually requires external project participants to use the ICT application and provides training to them to gain commitment from them to use it. However, there are still some project participants who did not use the ICT system because they claimed is was too complex and slow when compared to traditional communication methods such as phone and fax. Therefore, CB indicates that slow adoption of ICT by external project participants may hinder the diffusion of ICT within an adopting organisation.

6.4 Case study organisation C (CC)

6.4.1 *Case study background*

CC is an innovative construction company operating in Australia with an overseas parent company. The company has an average income over AUD$1 billion per year from construction projects in Australia. Types of construction projects are building, transportation, and civil engineering infrastructure. The company has received several construction quality and building design awards, which testifies to its outstanding construction innovation and projects performance. The company's policy provides a strong support for construction productivity, safety, learning and sharing improvement.

CC started to invest in an infrastructure of Intranet system in 1995. Several applications had been implemented within CC such as email, a quality register, an innovation database and elements of e-business. One of the ICT applications successes adopted by CC is its project collaboration system, which was implemented in early 2001. The strategic ICT diffusion in CC provides an advanced example to the construction industry and can be used as good example of ICT diffusion. In recognition of the company size, outstanding awards and the use of groupware application platform, this company was selected as the third case study of ICT diffusion within a large construction organisation.

To understand how the ICT applications have been diffused in CC, the case study illustrates the nature of how one particular application has been diffused. A summary of its characteristics, the structure of the support, the perceived factors influencing its diffusion and the nature of the ICT diffusion are presented below. CC is investigated at both the organisational level and individual/group level.

6.4.2 *Configurations of ICT system*

This section provides basic ICT system information about its functions and system configuration. In general, the ICT application is a web-based document management system where users can access information from a central database server through Internet connections. This system is different from CB's system in the way in which the system was developed outside the construction organisation. Therefore, the construction organisation was required to subscribe to a web-based ICT service for its use.

The ICT system used in CC consists of several main modules such as 'jobs-to-do list', 'transmittals register', 'document register', 'correspondence', and 'contact database'.

First, the module called '*jobs to do list*' is the first web page seen by ICT users when they log in and it informs them about relevant messages sent to them by other authorised team members/employees. The notification list will be cleared once the user replies or actions a message. The second module is called a '*transmittals register*'. It assists users to send and receive documents such as drawings, specifications, schedules etc. The transmittal register also helps users to send documents to project participants including status for actions such as 'for approval'. This status can then be changed after the user acts on the message. The third module is a '*document register*' that contains the historical list of controlled documents. This module's main function is to automatically keep a record of documents that flow between users. Thus, it also can be used as the tracking document providing information about document revisions—by whom and when modified. The fourth module is a '*correspondence'* management system. The correspondence module was used to send documents such as general correspondence, RFIs, site instructions, approvals, variations, and claims etc. The correspondence module contains templates such as letterhead, document information, document title, body text, activity history of correspondence, linked documents, etc. The last module is a '*contact database'* that assists users to find out contact details of people working on the same project.

These ICT applications also provide a search function that helps users find messages related to them that are stored in the system. They can only access messages that they are authorised to access and this is far quicker than searching for information from hardcopy office files and folders. In CC, the ICT implementation defined users by code such as 'XX-YY'. XX code refers to the company name and YY code refers to the user name. By using this code, users can narrow a search, sort lists of users and filter messages that relate to them. The ICT system in CC also allows users to set individual preferences for notification when messages are sent to them. There are several options to notify users such as a to-do list, email, and/or text messaging. This preference can help users to be better informed about messages sent to them and to provide alternative ways of responding to information. In addition, it could also be useful for users who do not constantly access a desktop or portable computer.

Figure 6.5 illustrates how CC users can access the ICT system from both the local area network in a construction office/site and from a dialup networking service. Staff can also access the ICT system via a construction office/site server that links to an Internet connection. In addition, they can use a company dialup networking service. CC's ICT system differs from the CB system in the location of web server. Figure 6.5 indicates that the web server in CC is located and maintained from an external web service company. The web service company provides the ICT system that CC can modify to provide a specific user interface to suit the organisation.

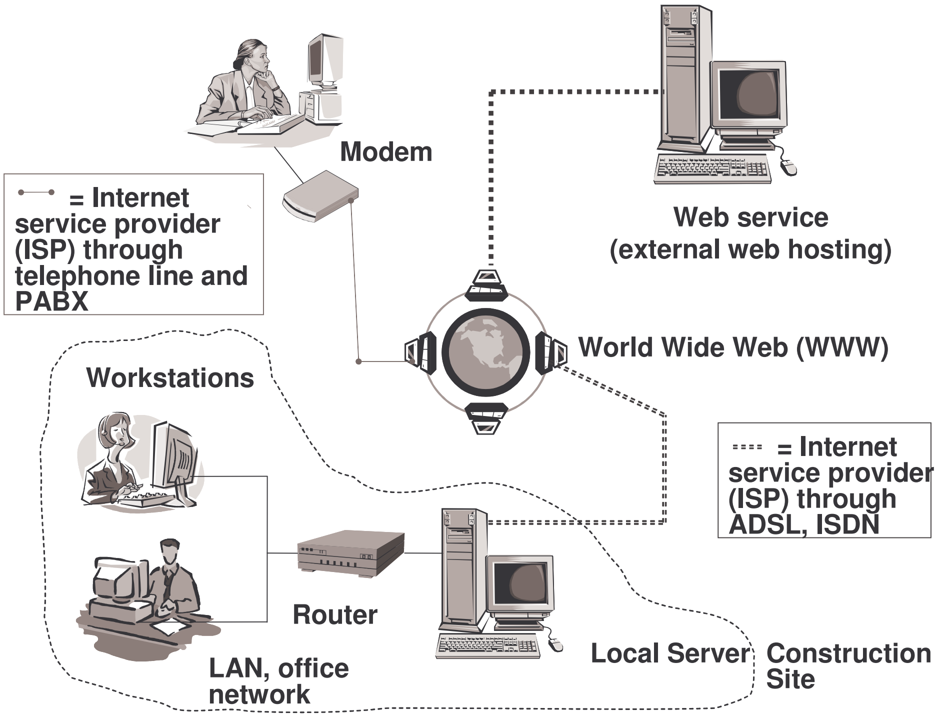


Figure 6.5 Infrastructure of ICT system's CC

6.4.3 *The use of ICT in CC*

Both internal staff and external project participants accepted the use and adoption of the ICT application although it was only used on a pilot project. Internal staff consisted of project managers, site engineers, site administrator and foreman, whereas external users included staff from the owner, the architect, the engineering consultants and the subcontractors. They remarked that the ICT application had suitable web-based Internet document management functions for the construction project. They also used it for coordination and internal and external project team communication between members.

Most participants mentioned that the use of ICT application was suitable for their job. One project manager who monitored his project and used the application to communicate with various teams and the designers provided a particular example of the benefit of using the ICT. He stated that he could access all information that he needed through the central project database in the ICT system. Other respondents (engineer and architect) give an example of benefits of use—construction drawings designed by the architect were sent through the ICT system to allow CAD data for the structural design to be used by the engineer to develop the structural design for direct fabrication of the structure in the factory. This saved design time as well as transmission time compared to sending the drawings by post.

CC indicated that the ICT system was used on a project-by-project basis and commitment from all project participants was obtained before the start. The reason for using ICT on a project-by-project basis was that no standard ICT system of this kind was adopted in the Australian construction industry at that time. Project participants also said that ICT use is largely dependent on main contractors who develop their own systems. The main contractor plays an essential lead role in promoting and ensuring ICT use because project participants who wish to maintain a long-term business relationship with them are forced to follow the main contractors' lead for ICT use to maximise benefits of efficiencies in information transfer and data transfer. Thus, one problem faced by project participants is that they have to learn to interact with several ICT systems when dealing with several main contractors using different ICT systems.

6.4.4 *Groups of ICT innovation support*

This section provides information about the structure of CC's ICT support group. Three supporting groups were identified in Figure 6.6: a technology diffusion centre, an IT department and an implementer team.

6.4.4.1 Technology centre

In the middle of 2001, the company established a technology centre to promote technological innovation into CC's business units. The centre aimed to improve work performance, safety and quality in construction work processes. Groups of people who had a background from the various business units across the organisation dedicated some of their time formally to meet others within this centre once every 3-4 months. One of their objectives was to explore and discuss opportunities for using technological innovations to improve construction processes. The technology centre had no formal power on technology adoption decisions by business units; it only played a support role and gave advice if a business unit was willing to adopt technological innovations.

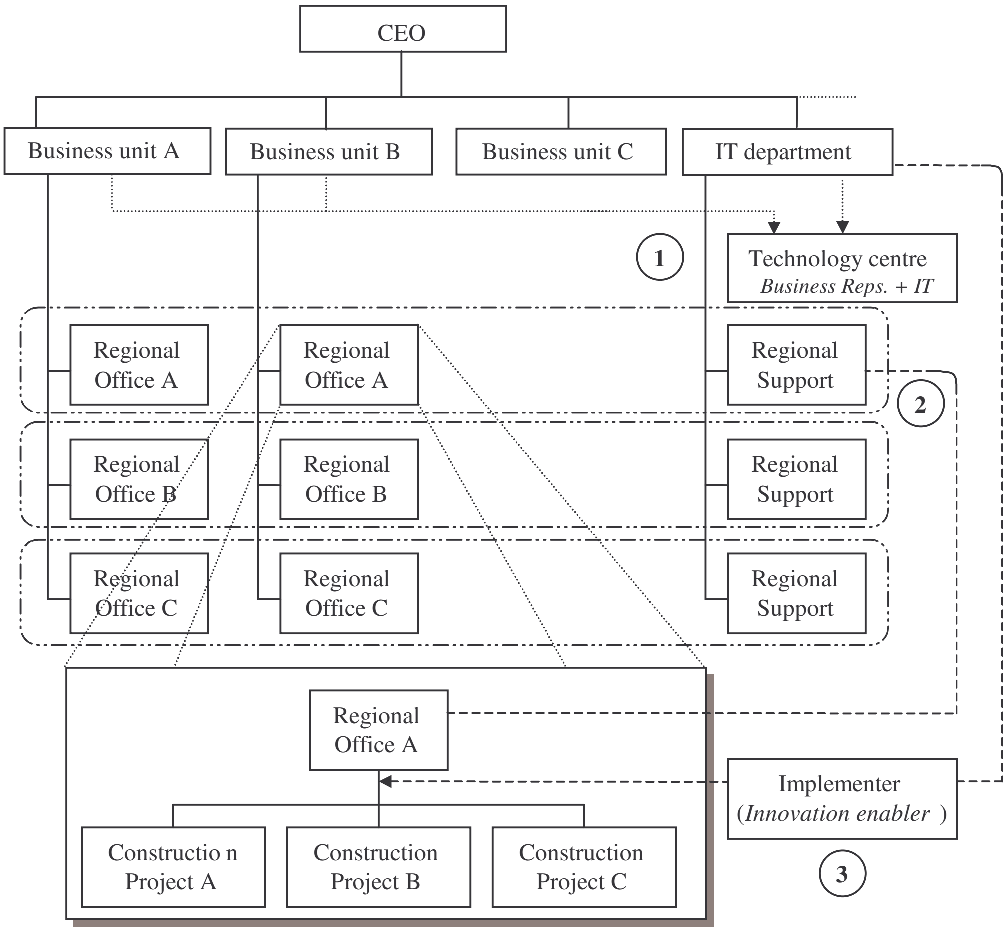


Figure 6.6 Groups of ICT innovation support in CC

6.4.4.2 IT department

The IT support group's main function was to develop and install basic infrastructure support such as setting up Internet connections, the computer network on site, and supporting ICT technical issues. It consisted of two or three people in each region to develop and support the intranet network system. CC adopted an external web-based project service. Therefore, CC's IT support group played a more important role in supporting infrastructure than merely implementing the ICT.

6.4.4.3 Implementer

The implementer was one key person directly responsible for facilitating the ICT application's use for a construction project. The CC implementer played two main roles: training and technical support. During the initial phase of the project, the implementer provided training to construction project teams by not only developing their basic understanding of using the ICT applications but also playing a parallel role in configuring and implementing ICT to match with CC work processes. Importantly, the implementer had a significant role in helping and supporting users who may have experienced problems in ICT use. The implementer guided the ICT diffusion process into a project by:

- Presenting a cost-benefit analysis for the of project manager's use
- Promoting ICT application use to staff at the project level

6.4.5 *Diffusion of ICT at the organisational level*

In CC, the diffusion of ICT at an organisational level started with developing a broad awareness of using ICT applications in potential ICT users. It is clear that members of the technology centre, which consists of IT executives, business construction representatives and technology champions, had influenced the awareness of ICT applications. This group has a formal meeting every 3-4 months to discuss and share ideas about using ICT applications. The technology centre is also open to proposals on ICT innovation from its members who represent colleagues from their workplace. After an ICT application idea is discussed, the members of business units interested in adopting the ICT, and the technological champion, begin to explore the possible implications that this ICT application may have on improving business processes and requirements. During this stage, preliminary information of possible ICT applications is gathered and proposed by an implementer to get the group's approval. Then, the company will test a pilot project using an ICT application on a construction project before starting to diffuse it more broadly through several construction projects.

The decision to adopt an ICT application is part of a long-term strategy by the organisation to prepare for the future of an emerging construction industry trading exchange (CITE). As a result, when CC decides to adopt an ICT product from a company it looks forward to its use with the future advanced CITE ICT standard platform.

Although the company had adopted the use of the ICT in CC construction projects in principle, the decision to use ICT was still based on a project-by-project basis. It was found that there were two main barriers to ICT diffusion associated with this decision: commitment from project participants and the risk of the ICT investment. Firstly, all main project participants were required to commit to the success of the ICT. Without use by all project participants, the ICT would not operate effectively because project participants would have to work in both paper and electronic formats. Secondly, CC has to pay a fee for service for its ICT use and this is not included in any separate project budgets. Therefore, some CC managers did not want to take a risk on the ICT implementation especially when the benefits of its use might be difficult to measure in money terms even though it indirectly presented benefits in terms of time saving and communication improvement.

6.4.6 *Diffusion of ICT at the individual/group level*

After the decision to adopt ICT is made by a project manager, the next stage of diffusion of ICT through a construction project was the implementation of ICT by CC project participants. The IT department began with installing the network and Internet infrastructure that connected the internal CC network. At the same time, the implementer started to configure the ICT application for the construction project and trained key potential CC ICT users. Training was also provided to associated project participants. Therefore, the diffusion of ICT in CC construction project mainly relied on the implementer who plays an essential role in ICT application implementation. The next section deals with the ICT diffusion factors and describes the details of how these factors influence the users and their adoption of ICT.

6.4.7 *Users' experience on factors influencing ICT diffusion in CC*

This section presents findings on factors in relation to one of the applications at CC to help us understand ICT diffusion. Table 6.4 summarises research findings to illustrate the nature of ICT diffusion in that construction organisation.

Table 6.4 Users' experience on factors influencing ICT diffusion in CC

Factors	Summary of Interview Finding in CC
F1: Professional development and technical support	An implementer conducted the internal training for using ICT. As the ICT applications were considered to be quite straightforward the training took approximately an hour and a half. Most of the participants were satisfied with the training and the extent of their initial understanding of the application. In addition, training was provided to CC project staff including staff from associated external project participants. The ICT technical help desk relied on the implementer in the construction project whereas people in IT department supported solving any technical problems in relation to network infrastructure. Most of participants were satisfied with the implementer, who dedicated time for this on site.
F2: Clear benefits of use	Most of the participants experienced the benefits of using ICT that provided essential modules such as managing documents and construction drawings, sending/receiving correspondence, and tracking the sequence of changes on all correspondence including drawings. However, actual use of ICT modules depended on participants' role and their task needs. They also mentioned that the applications provided benefits in terms of cost and time saving in sending drawings between design firms.
F3: Supporting individual characteristics	The majority of participants mentioned that they have basic computer skills but they argued that the use the ICT might not require any advanced IT knowledge. Most of participants mentioned that they enjoy learning to use ICT, particularly if it assists their productivity in their work processes.
F4: Supporting technology characteristics	The ICT characteristic was quite simple. The main concepts of ICT use were designed to support project communication and coordination within CC staff and between project participants. It consisted of three main functions such as daily work list, drawing register, and correspondence. These functions provided adequate support to document management in a construction project. It was mentioned that the use of ICT was reliable and provided a good response rate. However, the participants found that the speed of use relied on the Internet connection speed. In CC construction projects the Internet connection was based on and linked to the company Intranet network that allowed ICT users to external Internet access. Furthermore, ICT was required to install plug-ins such as CAD viewer and Acrobat reader. These add-in applications played a role in viewing the documents through web browser. All of information was stored in the web-based server that the company used. All of the information would be stored in a CD-ROM after the project completion. These can be used as the project library for the company and the project participants.
F5: Supporting supervisor and organisation	Most participants agreed that their organisation supported the use of ICT in many ways. For example, the organisation developed its own Intranet network and provided facilities such as computers and Internet connection in construction projects. In addition, the organisation also encouraged the development of ICT knowledge by dedicating the implementer who has the responsibility for training and technical support. The managerial support was one of the most important factors in the adoption decision because the use of ICT depended upon the project manager's support. As the use of ICT in CC had been implemented for only a year and a half, some project managers who did not observe the

	capability of ICT might have limited knowledge of its benefits. However, it was believed that the use of ICT would increase over coming years. There was some managerial support for practical use of ICT, such as providing basic suggestion or discussion for improvement. There were some evident limitations, however, for a few managerial level people. Interestingly, CC adopted a policy that the cost of using ICT was paid by the main contractor but allowed selected supply chain members access to the ICT applications.
F6: Supporting an open discussion environment	Generally, the work environment was open for people who would like to discuss how to improve it. For example, a young engineer who first used ICT felt safe to open a discussion on the use ICT for work. A project manager mentioned that he usually supported the use of the ICT although he had reservations about his ICT knowledge in some areas. He discussed this with his subordinates and if an issue affected everybody, he would work with the implementer to solve that problem.
F7: Supporting tangible and intangible reward environment	Most of participants agreed that the use of ICT has no direct relationship with tangible rewards. They mentioned that they used the ICT applications because this technology can improve the productivity of their work. In addition, they disagreed with providing tangible rewards for the use of ICT because they believed ICT is a tool to be used to improve their job. Some people believed that use of ICT was motivated by intangible rewards such as pride. For example, a respondent said that his supervisor felt good about his ICT use.
F8: Collegial help	The project teams in CC provided a collegial environment of help in relation to the use of ICT. In addition to the support from the implementer, they also assisted and helped in using ICT on construction projects. For example, a senior engineer who has used the ICT application before assisted new engineers on how to use it for their work tasks. Most participants felt that their colleagues helped create a supportive workplace environment. They shared knowledge and helped in the use of ICT by discussing how to improve its application and use.
F9: Positive feeling towards ICT use	The interviews showed a positive perception of the use of ICT. Participants believed that it assisted their communication and coordination within their project teams. They believed that the application was also compatible with their traditional work process and assisted their communication.
F10: Negative emotions towards ICT use	There were low levels, if any, of negative perception relating to the use of ICT applications.
F11: Frustration with ICT use	Barriers to using ICT were mainly encountered from the external project participants such as subcontractors who were still uncomfortable with ICT applications in use.

6.4.8 *Summary of ICT diffusion process in CC*

Case study organisation ‘C’ (CC) can be seen as having a reactive ICT adoption strategy because it chose to adopt a web-based document management host service instead of developing its own system. The main reasons were ICT immaturity (for this application) and fear of risks associated with being an early adopter, though CC had previously tried to adopt a similar ICT platform on two pilot projects. Their rationale was that a simple ICT application is more likely to be successfully adopted than a complex one. Complex ICT applications may have presented CC with an unacceptably high risk of adoption. In addition, CC plans to adopt a current web-based ICT host service for a pilot project to prepare the organisation to adopt an emerging ICT platform standard in the near future. An e-business unit that consists of business representatives and IT people supports ICT adoption. This group has the essential role of exploring and initiating ICT adoption. In this case, the IT person was allocated to facilitate the adoption and diffusion of this ICT initiative. Adoption could be interpreted here as occurring from both top-down and bottom-up influences. Initially, the e-business unit encourages the support of ICT adoption by suggesting and analysing suitable ICT applications for project use whereas the decision to adopt is decentralised, being made by project managers. In CC, the degree of adoption is influenced by technology-push rather than demand-pull and therefore CC decides to use reactive strategic ICT adoption.

Actual ICT implementation in CC was affected by training and implementer support. As respondents perceived ICT applications as being quite straightforward, training took only approximately one and a half hours to explain how to use the ICT application. Most participants were satisfied with having training for initial understanding of an application. The implementer uses trial projects as an exercise to help users to familiarise themselves before starting to use an application on a real project. The implementer also had a strong influence on helping users on construction sites because he was specifically allocated to support users. Thus, users felt confident to ask him for help. Top management supported ICT use and provided suitable infrastructure such as computer and Internet networks as well as a project manager who had an enthusiastic personal interest in ICT innovation and use. He encouraged his subordinates to use the ICT system. When he had time he would sit down and help to solve their problems. He sometimes had limited ICT knowledge but would contact the implementer to help solve any ICT problems.

The characteristics of CC's ICT systems were quite simple—the main concept was a design that supported project communication and coordination within and between project teams. Modules in ICT systems consisted of job to-do list, transmittals register, document register, correspondence and contact database. These functions provided an adequate document management system for the construction project. It was mentioned that the use of ICT was reliable and provided a good response rate. However, participants noted that access was governed by the Internet connection speed. Participants from CC had enough computer background and clear perceptions of the benefits of using ICT to feel that ICT is simple and can provide suitable benefits for them. As a result, the characteristics of ICT could be identified as key factor that affects the extent of ICT diffusion at the actual implementation stage.

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

Similar to CB, ICT diffusion during actual implementation might be influenced by the commitment of other project participants. It was found that the implementer in CC would consult and gain the commitment of these external participants before starting to use an application on a project. The main reason is that, if one party agreed to use the ICT system, it may influence others to use the system. However, when people have to work in both electronic and paper mode they are forced to limit the benefits of ICT use. Consequently, the impact of ICT diffusion on project participant intra-organisational diffusion of ICT should be recognised and addressed.

6.5 Summary of chapter

Findings drawn from three interview cases of ICT diffusion address three main important issues: factors influencing ICT diffusion, strategic adoption, and processes of adoption and implementation. This chapter focused on ICT diffusion issues that have been established in each case. Detailed analysis of these findings will be discussed in Chapter 7.

The first finding shows that the processes of ICT diffusion are influenced by four groups of factors. These are related to managerial support, the individual's characteristics, technology characteristics, and a supportive collegial workplace environment. First, the management support can be separated into training and technical support, and senior managerial support. Senior management plays a particularly significant role in introducing ICT systems into the case study organisations. Senior management also supports the ICT diffusion processes through providing enough resources such as computer infrastructure, Internet connection and user accounts, and recruiting technical staff to support training and technical help. Second, supporting individual characteristics such as basic computer skills, personal commitment and learning ability are found to be key factors influencing ICT diffusion because these characteristics help a new user to know how to begin to use ICT for their individual job. It should be understood that the benefits of ICT use also depends upon the nature of the technology's performance characteristics. Third, the characteristics of technology (i.e. functionality, accessibility, reliability etc.) influence users' perception of any benefits and its ease of use. Findings indicate that technological performance may be managed through the processes of technology acquisition, selection, and the top management adoption decision. Finally, it is also evident that workplace environment factors such as collegial environment and an open discussion environment influenced the extent of ICT diffusion by helping ICT users to distribute and exchange knowledge.

Strategic adoption of ICT is also one of the key issues influencing ICT diffusion at the organisational level. This strategic adoption approach also influences the practical implementation of the system. The cases indicate that strategic adoption of ICT could be classified as proactive or reactive depending on the external environment. A proactive strategy was evident in two cases that appeared to begin to gain competitive advantage from using ICT. It was found that this strategy might be suitable for a controlled environment. On the other hand, a reactive strategy was evident in one case that attempts to adopt ICT under an uncertain environment. In particular, the ICT application required cooperation from both internal and external participants.

Therefore, it could be initially concluded that the category of technology platform (i.e. Intranet and Extranet) can define the scope of access to potential users (internal or external users), which in turn may affect on the strategic adoption design. It could be argued that ICT diffusion at the organisational level is mostly influenced by senior management support and the functionality of the technology used.

The final finding of these case studies indicates that ICT diffusion could be categorised into organisational and individual/group levels. The processes at organisational level focus on the introduction of ICT into an organisation such as ICT acquisition and strategic adoption, while the processes at individual/group level focus on how to encourage, educate and support actual use to expected ICT users. These processes involve formal support to end-users such as providing enough infrastructure, training and technical support. It is also evident that the learning and sharing environment occurs in an informal way and this can influence the extent of ICT diffusion.

Chapter 7
Inter-case analysis

Factors influencing ICT diffusion, and how ICT was diffused within each of the three-construction contractors studied at the organisational level, both at individual and group levels, were described in the previous chapter. This chapter is focused on a cross analysis of the three construction contractor case studies. This analysis compares similarities among, and dissimilarities between, the three cases, and is based upon five research questions: (1) What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations? (2) To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations? (3) How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations? (4) How has ICT knowledge been diffused by users within large Australian construction organisations? (5) What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?

7.1 Analysis of factors influencing ICT diffusion

The survey phase of this study identified eleven factors that influence ICT diffusion from the three ICT-sophisticated construction organisations, and the degree of strength of the importance of these factors was reported earlier. Further, in Chapter 6, a qualitative study of the three construction contractors was done as a case study to analyse the degree to which these factors were present within the organisations. This helps to provide an answer to the research questions:

1. *What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations?*
2. *To what extent have the ICT diffusion factors been experienced by large Australian construction organisations?*

To answer this question using qualitative data from another perspective, the analysis in this chapter is focused upon determining the common pattern of ICT users' experience as a result of diffusion factors that are embedded in the organisations. The analysis comprises two steps: development of criteria for evaluating the presence of ICT diffusion factors (F1 to F11) followed by the evaluation of the extent of the users' perceptions of each criterion. First, the criteria were established to evaluate the extent that four groups of ICT diffusion factors — management, individual/personal, technology and workplace — were present in each organisation. These criteria help to evaluate and to understand the interview transcripts relating to several ICT diffusion roles that users performed within each organisation. The criteria provide a descriptive scenario or a word-picture that describes the users' perceptions of factors influencing ICT diffusion for each case. Then, results for each organisation can be compared, distinguishing patterns that emerge across all three cases. A detailed analysis of these patterns provided in the following sections helps answer the research questions:

3. *How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations?*
4. *How has ICT knowledge been diffused by users within large Australian construction organisations?*
5. *What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?*

7.1.1 *Evaluation criteria for presence of factors influencing ICT diffusion*

Table 7.1, Table 7.2, Table 7.3 and Table 7.4 present criteria for assessing and evaluating the degree of respondents' experience (of each of the previously identified group of factors) supporting ICT diffusion. These tables were established to help the assessment of users' experience of ICT diffusion factors into four main categories: (1) management, (2) individual/personal, (3) technology and (4) workplace environment. The tables provide a word-picture descriptive scenario that describes a low level, medium level and high level of perceived presence of each factor.

These measurement tools allow a coherent comparison to be made across the three case study organisations and this helps us better understand the impact of ICT adoption strategies for each contractor and to judge the effectiveness of the contractor's adopted strategies.

Table 7.1 Criteria for evaluating the presence of management factors

1) Management factors	***Evidence for evaluating presence of factors supporting ICT diffusion***		
	Low level of perceived presence of factors (L)	***Medium level of perceived presence of factors (M)***	***High level of perceived presence of factors (H)***
F1: Professional development and technical support	Organisation provides a minimum level of effort for training through using a vendor that gives basic knowledge about benefits of ICT application and key functions/features.	Organisation provides training that delivers an adequate understanding of how to use the application but it does not focus upon applying it to the ICT user's work activities	Organisation provides training that delivers, intensive detailed, training on how to use and apply the ICT applications to the ICT user's work activities.
	Organisation did not provide technical help or help desk support—ICT application training provides only superficial knowledge about how to practically use the ICT application.	Organisation did not provide technical help desk support—Organisation provided basic technical training and knowledge of how to practically use the ICT application.	Organisation allocates an implementer and technical help desk to assist staff's ICT use—Organisation provided provides enough training and knowledge to facilitate self-confidence in ICT use.
F5: Senior and organisation support	Senior manager was unaware of ICT use benefits and was not committed to ICT use and adoption.	Senior manager encourages staff to use and adopt ICT to support and benefit their role in the organisation.	Senior manager encourages staff to use and adopt ICT because he/she is convinced of the benefits of ICT. Sometimes this support extends to one-to-one training or mentoring.
	Organisation provides few resources to support training and advice.	Organisation commits to provide minimum resource for the identified ICT support and training.	Organisation commits to provide appropriate resources and continues to improve ICT infrastructure.
F7: Supporting tangible and intangible reward	Organisation has evidence of having no *tangible* rewards strategy for ICT use.	Organisation applies an *ad hoc* or poorly considered *tangible* rewards strategy for ICT use that can be justified.	Organisation has ample evidence of a coherent *tangible* rewards strategy for ICT use.
	Organisation has evidence of having no *intangible* rewards strategy for ICT use.	Organisation applies an *ad hoc* or poorly considered *intangible* rewards strategy for ICT use that can be justified.	Organisation has ample evidence of a coherent *intangible* rewards strategy for ICT use.

Table 7.2 Criteria for evaluating the presence of individual/personal factors

2) Individual factors	***Evidence for evaluating presence of factors supporting ICT diffusion***		
	Low level of perceived presence of factors (L)	***Medium level of perceived presence of factors (M)***	***High level of perceived presence of factors (H)***
F2: Clear benefit/ advantage of ICT use	ICT user does *not* understand the benefits of using ICT in their job.	ICT user understands *a few* (limited number or superficial) benefits of using ICT in their job.	ICT user *clearly* understands many/most of the important benefits of using ICT in their job and their business organisation.
F3: Characteristics of individual (potential user)	Few or highly limited personal skills (user has insignificant or no basic computer skills) Less capability of learning (user does *not have the cognitive resources to learn* about the use of ICT application). Low personal commitment (user does *not have any commitment* to use ICT or resists change.	Moderate personal skills (user feels somewhat confident in being able to apply previously gained basic computer skills) Moderate capability of learning but ICT user *needs time* to learn and understand the use of ICT application. Moderate personal commitment (user is *committed to use* ICT to meet organisational requirements.	High personal skills (user feels confident having basic computer application skills and familiarity with Internet applications ICT user can quickly and *independently* learn and understand the use of ICT application. High personal commitment (user *strives* to use and explore better way to use ICT).
F9: Positive feeling towards ICT use	User has *negative* perceptions of ICT use. Either overtly or covertly resists use.	Is unenthusiastic about ICT use or persuading others to use ICT.	User enthusiastically endorses ICT use and actively persuades others to use it.

Table 7.3 Criteria for evaluating the presence of technology factors

3) Technology factor	***Evidence for evaluating presence of factors supporting ICT diffusion***		
	Low level of perceived presence of factors (L)	***Medium level of perceived presence of factors (M)***	***High level of perceived presence of factors (H)***
F4: Characteristics of technology (compatibility, functionality, connection speed, accessibility, reliability, and implementation rollout flexibility)	ICT application is in-compatible with other organisational software/systems.	ICT application is partially compatible with other organisational software/systems.	ICT application has high compatibility with other organisational software/systems.
	ICT application provides *poor* functionality for users to do the task/process.	ICT application provides *basic* functionality to do the task/process.	ICT application provides *advantageous* functionality for user need and adds value to do the task/process.
	ICT application is *generally inflexible* and does not allow its configuration to match a user's need.	ICT application allows for *minor configuration changes* to suit a user's need.	ICT application has *high flexibility for change* to allow configuration to suit the user's need.
	ICT infrastructure provides a *low-speed* connection (using 56k modem).	ICT infrastructure provides a *medium-speed* connection (using both 56k modem and ISDN connection but it shares with several computers).	ICT infrastructure provides a *high-speed* connection (using ISDN or cable/high capacity wireless suitable for connecting a large number of devices).
	ICT provides *severely limited access* across the system with users finding it difficult to transfer data or move from one module to another.	ICT provides *isolated difficulty to access* the system with users occasionally finding it difficult to transfer data or move from one module to another.	ICT has *rarely* presented users with difficulty in accessing the system or finding it difficult to transfer data or move from one module to another.
	Low reliability for ICT use, i.e. often shutdown and/or unavailable for use.	Generally reliable for ICT use, i.e. rarely shutdown and/or unavailable for use.	Very reliable for ICT use, i.e. almost never shutdown and/or unavailable for use.
	Low flexibility in the ability to stage and phase ICT application module use.	Provides limited flexibility in the ability to stage and phase ICT application module use.	Provides very high flexibility in the ability to stage and phase ICT application module use.

Table 7.4 Criteria for evaluating the presence of workplace environment factors

4) Workplace environment factors	***Evidence for evaluating presence of factors supporting ICT diffusion***		
	Low level of perceived presence of factors (L)	***Medium level of perceived presence of factors (M)***	***High level of perceived presence of factors (H)***
F8: Collegial help	User has *no* time to help and share ICT use experience with others. User experiences *little or no* ICT use help from colleagues.	User has *limited* time to help and share ICT use experience with others. User experiences *occasional* ICT use help from colleagues.	User has *sufficient* time to help and share ICT use experience with others. User experiences *frequent* ICT use help from colleagues.
F6: Supporting an open discussion environment	User feels threatened to ask for ICT use help. User feels unwilling/unable to provide feedback or response on ICT use. There are no channels to provide feedback on ICT applications.	User feels slightly uncomfortable to ask for ICT use help. User feels comfortable and able to provide feedback or response on ICT use. Feedback on ICT application problems are purely one-way with limited reaction.	User feels *free* to ask for any ICT use help. User feels that feedback or response on ICT use is welcomed and expected. Feedback on ICT application problems are responded to promptly (two-ways)

7.1.2 *Cross-case analysis of factors influencing ICT diffusion*

In Table 7.5, the values high, medium and low are based upon the ICT user's perceived experience of ICT use as determined by the criteria developed in the above tables. The value of F1, for example, is judged as high because it refers to the high embeddedness of professional development and technical support to facilitate effective ICT application use within each organisation. Respondents were asked to provide their general feeling about this aspect. The researcher then interpreted interview data into three point scales from low to high as indicated in Table 7.1, Table 7.2, Table 7.3 and Table 7.4. The detail of the evaluation can be found in Appendix D

The analysis of factors influencing ICT diffusion begins with intra-organisation factors. It was found that, although there are some differences between the details of the intra-organisational 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 three cases related to group users' experience of the presence of factors F1 to F11 is shown in Table 7.5.

Table 7.5 Comparison of cases about group users' experience on present factors

Factors	CA	CB	CC
F1: **Professional development and technical support**	**H**	**H**	**H**
F2: ***Clear benefits of use***	**H**	*M*	**H**
F3: **Supporting individual characteristics**	**H**	**H**	**H**
F4: Supporting technology characteristics	**H**	*M*	**H**
F5: Supporting supervisor and organisation	**H**	*M*	**H**
F6: Supporting an open discussion environment	*M*	*M*	*M*
F7: Supporting tangible and intangible rewards	L	L	L
F8: **Collegial help**	**H**	**H**	**H**
F9: ***Positive feeling towards ICT use***	**H**	*M*	**H**
F10: Negative feeling towards ICT use	L	*M*	L
F11: Frustration with ICT use	L	*M*	L

L = Low level of perceived presence of factors
M = Medium level of perceived presence of factors
H = High level of perceived presence of factors

From Table 7.5, the pattern of factors existing in the three case studies indicated that the 'supporting tangible and intangible' factor (F7) might not be an important factor influencing the diffusion of ICT. This is because most participants felt ICT should be used as a tool to enhance their work productivity. The 'supporting tangible and intangible' factor was perceived as benefits of ICT. These included productivity improvements including time saving, thus making users' 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 value for the 'clear benefits of use' factor (F2) and high values for 'positive feeling towards ICT use' factors (F9) in CA and CC. Thus, unclear benefits of ICT use in CB 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 (F5). CA, CB and CC show a high level of organisational 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 CB is limited because some project managers do not see clear benefits in using ICT on their construction projects. In CA and CC there is strong evidence of top manager support, where most project managers encourage the use of ICT.

Factors F9, F10 and F11 involve the interaction between the individual and ICT technical characteristics. However, factor F9 has the opposite relationship to factor F10 and F11. For example, CA and CC 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.

Personal development and technical support (F1) have been found to be essential factors in the adoption of ICT by the individual in all three cases. Training can help 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.

Interviewees mentioned that those people conducting training courses should be aware of the computer user's background. Therefore, personal characteristics (F3) such as basic computer skills, commitment to ICT use, and enjoyment of learning could assist in ICT application adoption. Based on the interview findings, respondents perceived themselves as having high level personal characteristics. Also, users might need time to familiarise themselves with the ICT applications if they have no prior computer skills. There was little evidence of any comprehensive ICT needs analysis being undertaken.

Finally, these three cases indicate a high level of help from colleagues in ICT use (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 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 to improve ICT use (F6).

Although the primary objective of research focuses upon internal organisational factors that influence ICT diffusion, the findings from three cases interestingly highlight the importance of both internal and external factors to ICT diffusion. External factors are included in the next discussion because interviewees highlighted their concern about external issues that affected their adoption of the ICT applications under study. CB and CC (that adopted a web-based project management system that involved other project participants) especially experienced these inter-organisational factors. Thus, the above comparison of factors helped to identify a way of defining intra- and inter-organisational factors that affect ICT diffusion. The interpretation of the underlying meaning of factors influencing ICT diffusion will be discussed next.

7.1.3 *Interpreting the meaning of factors influencing ICT diffusion*

This section focuses on the research question about '*How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations?*'. Findings from the ICT diffusion case studies within three construction organisations can be categorised into two factor groups: intra- and inter-organisational factors.

Intra-organisational factors are focused on those 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. Based on the case study, the intra-organisational factors could be grouped into four main categories: management, individual, technical, and environment categories. These categories could then form an ICT diffusion framework within construction organisations. Figure 7.1 shows the details of factors under four main categories.

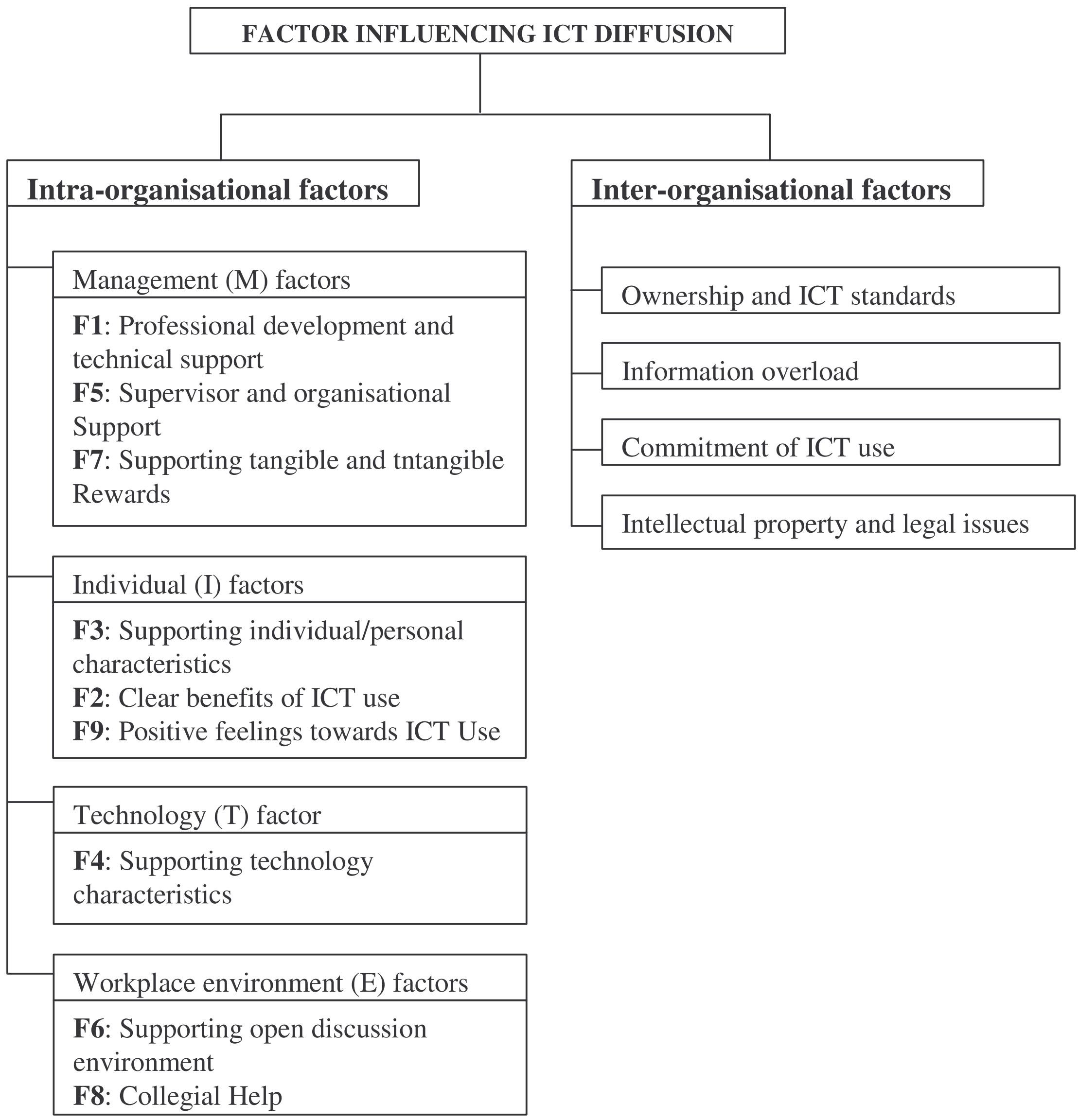


Figure 7.1 The diagram of intra- and inter-organisational factors

7.1.3.1 Intra-organisational factors

The summary of factors influencing ICT from three cases is described in Table 7.6. The purpose of this table is to provide a discussion of the interpretation of the analysis of the interviewees' data within the framework of the identified 11 factors affecting ICT diffusion to answer the question about how ICT diffusion takes place.

Table 7.6 Detailed discussion of management factors influencing ICT diffusion

Management (M) factors	**Discussion of factors influence ICT diffusion**
F1: Professional development and technical support	*At the initiation and introductory stage:* Training was one of the basic factors that influenced the development of an understanding of ICT use for the studied application. Training also appears to guide users to become familiar with its functions and interfaces of the application to their organisation's other ICT applications. This knowledge helps them to avoid wasting time by learning through trial and error. However, the amount of training appears to rely upon the characteristics of the ICT application. For example, CC participants felt that the ICT application was so simple that they could start using it within a short time period even though they only received one and half training sessions. *At the full implementation stage:* The IT help desk individuals directly influenced helping ICT users to solve specific problems associated with the practical use of an ICT application during the full implementation phase. The case studies indicated two interaction channels being adopted to provide support from an IT help desk: phone/email and face-to-face. Interviewees stated that face-to-face personalised help from an ICT implementer provided a more satisfactory level of support than phone because users can better learn from their interaction with the implementer. However, these ICT users sometimes felt that the response from the IT help desk is not quick enough. Consequently, these users might request assistance from colleagues located near them. It should be noted, though, that the collegial help might result in ICT use knowledge limitation because of any limitations that the colleagues may have in knowledge being required. A further potential problem is that colleagues may inadvertently be transferring poor rather than best practices. *Personal support*: Internal IT support appeared to be generally delivered through an IT department and an ICT implementer. The IT department group tended to focus on technical infrastructure problems whereas the implementer's major role was focused on ICT application issues. The IT department group was mainly involved in building up the infrastructure network at the early stage of the construction project and in maintaining infrastructure until the project was finished. The IT department also generally provided a help desk support facility. The implementer, however, played an essential role in supporting the use of ICT throughout the construction project's duration and this led to the diffusion of ICT through users at the operational level.
F5: Supporting supervisor and organisation	*At the organisational level*: Organisational support mainly influenced ICT diffusion through providing adequate ICT infrastructure and resources. All organisations had a policy of encouraging ICT use to improve project document management and implementing other business applications that improve the integration of information flows between construction work processes. Therefore, organisational support appeared to influence the company's ICT strategy. This policy in turn was used as a framework to develop and/or adopt ICT for managing information and document flows. At the construction project level, supervisor support was one of the most important factors in the initial decision-making for ICT adoption. This could happen in two ways. Project managers might intentionally block ICT diffusion if they did not perceive there to be any clearly benefits of using it on their project.

	Alternatively, a project manager who has understood the benefits of using ICT might be still be reluctant to support and encourage ICT technology adoption due to the organisation's allowing limited resources to be budgeted on the project.
F7: Supporting tangible and intangible reward environment	Most of participants believed that there should be no tangible rewards provided for use of ICT. Interviewees mentioned that they used ICT because the technology can improve the productivity of their information management related work. Some people believed that ICT use was motivated by intangible rewards such as pride and personal achievement. For example, one interviewee stated that his supervisor felt good about his use of ICT. This comment indicates individual and personal motivation factors to be the principal motivation driver.

Table 7.7 Detailed discussion of individual/personal factors influencing ICT diffusion

Individual (I) or personal factors	**Discussion of factors influence ICT diffusion**
F3: Supporting individual characteristics	Having basic computer literacy skills is a fundamental individual factor that influences the use of ICT applications. The need for having basic computer literacy skills also depends upon the complexity of ICT application. Sometimes, basic skills may moderately affect the ICT use because the functions to be applied were quite simple. However, adequate computer literacy skills could accelerate the understanding and learning of how to use ICT applications. Basic computer skill such as, how to use the Internet, influenced personal confidence in ICT use for other applications such as document management, using search engines and even the process of logging on or off a system. Enjoyment of learning new things was found to be also an important individual characteristic, that can drive users to explore and learn new technology. For example, one young engineer who did not receive training learned to use it by himself. However, enjoyment of self-learning may be more useful if users receive basic introductory ICT training. In addition, enjoyment of learning can influence the continuous improvement of ICT application use because users enjoy exploring better ways of using the technology, such learning how to use short-cut key functions rather than menu options. Users' commitment is another important factor. Three types of commitment were observed from analysis of the data: intra-organisational, individual, and inter-organisational. Project managers and operational users can drive commitment. For example, a project manager committed to the use of the ICT would personally start to use it and encourage staff to follow by example. Cross-organisational teams may be committed to work together and find that ICT helps them better communicate or conduct their work tasks. At the individual level, commitment can be developed through long-term use of ICT applications that provide useful benefits to those individuals. On the other hand if users do not observe the benefit for their use, they might stop and never use it in future. Generally, people develop confidence in ICT use and this helps them experiment and develop their ICT use profile.
F2: Clear benefits of use	Clear benefits of the ICT application's use were found to be the key factor that promoted ICT use. Most interviewees agreed that ICT use generated benefits. Especially, they perceived that ICT use provided improved information management, document sharing, communication, and information integration benefits. One widely accepted benefit was that, because information and documents were stored in a central database, this formed a knowledge repository that users can access in future. Therefore it is important to make user aware of

	and to understand the scale of benefits of ICT use in improving their work processes. However, it was noticed that participants did not use all ICT modules available to them but only the particular module relating to their task. Thus, perception of benefits for ICT use may vary according to the user's role in the construction project team. In addition, a person's role may continuously change after finishing their project job and so their perception of benefits of use might also depend upon their evolving role on construction projects where the technology is used.
F9: Positive perception of ICT	Positive perception of ICT can be used as an indicator of ICT diffusion within a group as it also influenced the persuasion of new users and convincing them to adopt the technology. The interviews showed a positive perception toward ICT use and this appeared to positively affect ICT diffusion in general. In CB, some users had a less positive perception of ICT that in turn could lead users to restrict their ICT use to a minimum. Some users stated that occasionally they felt frustrated and anxious during the actual implementation phase of the studied ICT applications. This occurred when for example the ICT system crashed, but this frustration only occurred rarely. Therefore, organisations should focus on the users' perception of ICT use and continue to improve ICT applications and their supported IT infrastructures.

Table 7.8 Detailed discussion of technology factors influencing ICT diffusion

Technology (T) factors	**Discussion of factors influence ICT diffusion**
F4: Supporting technology characteristics	The characteristics of ICT such as functionality, accessibility, reliability, and speed of Internet connection were essential factors in ICT use. ICT functionality, the appeal of ICT functions and their user-friendliness and scope of features offered to users, is an important technology characteristic because it can draw the attention of users towards ways in which the functions offered can improve their work or make their work easier. Generally, the ICT application, in particular, the electronic document management system (EDMS) was designed to improve information management, document sharing, communication, and information integration management. Furthermore, functionality appears to vary in appeal to a users' role such as project manager, project administrator, site engineer, and foreman manager. A user's role can also be influenced by the level and complexity of using functions in an ICT system. For example, a project manager has a wider need for potential gains from ICT use and sees the benefits gained from it more than a foreman who has limited exposure to potential benefits. Thus, the ICT functions should be designed to fit with organisational work processes to optimise leverage of information sharing and coordination.

	Adequate accessibility to a computer infrastructure and Internet connections was a basic requirement for ICT use. Most users received access to an Internet login account and had a computer connecting to it. Thus both adequate hardware to access the system and access to the ICT system itself was necessary. Reliability and access speed also affect ICT users' effective use of ICT. Data transfer speed affects the time that users need to spend in sending a document. Speed also is governed by the Internet information pipeline connection. While speed might influence the user's perception of efficiency of ICT, the reliability might affect the trust of the users in the ICT application's value to them. If the ICT system were not reliable, this might cause frustration when using the system. Frustration leads users to return to previous modes of doing their job and rejecting the ICT application. Thus, the ICT characteristics have an impact upon the individual's adoption decision.

Table 7.9 Detailed discussion of workplace environment factors influencing ICT diffusion

Workplace environment (E) factors	**Discussion of factors influence ICT diffusion**
F6: Supporting an open discussion environment	Generally, the work environment was open for people who would like to discuss ways of how to improve their ICT use. For example, one young engineer interviewed when first exposed to using ICT stated that he felt safe to openly ask and discuss ways to use ICT for his work tasks. Another interviewee, a project manager, stated that he usually supported ICT use although he had limited knowledge of many aspects of the ICT application. He discussed any difficulties with his subordinates and, if an issue affected many people, he would work with the implementer to solve that problem. This supportive environment with openness to discuss difficulties helped to optimise ICT use.
F8: Collegial help	Within project teams, an environment of collegial help prevailed regarding ICT use. They received not only support from an implementer, but colleagues also mutually assisted each other in using ICT on the construction project. For example, a senior engineer who had used an ICT application before helped one of his novice engineers on how to use ICT for his work. Most of participants felt that there was plenty of collegial help around their workplace environment. They shared and helped each other by sharing and discussing knowledge about how to improve their ICT use.

Summarising discussion of management factors

Three main management factor groups affecting ICT diffusion were: professional and/or technical development support; supervisor and organisation support; and reward systems.

The first factor revolved around training and development that helps ICT users to understand the basic advantages and operational features of an application to get them starting to use it effectively. This will start diffusion through the organisation, especially for users who have low-level background knowledge in the ICT application's use, and might be otherwise lost, anxious and fearful. In addition, training and development provides a channel for passing 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 is an effective approach for building diffusion by increasing the number of ICT users. Support plays an essential part in helping ICT diffusion because it encourages ICT users to continue using an application once it has been introduced in their work processes, even though they may encounter problems during its use. When users encounter ICT application problems, if they cannot find help to fix them, they often lose motivation and eventually avoid using that application.

The second management factor is supervisor and organisational support. The findings suggest that ICT application diffusion is strongly influenced by supervisor and organisational support behaviours. The data provide a number of examples of project managers who have few basic ICT skills but who nevertheless attempt to encourage and share knowledge with subordinates. The evidence suggests that there is a clear relationship between ICT diffusion, and supervisor and organisational support. The intermediate factor, benefits of ICT use, becomes clearer, triggering motivation to support the budgeting and application of support resources.

The third factor, involving management, is the issue of supporting a reward system. A reward system can be divided into two parts: tangible rewards and intangible rewards. Tangible rewards include material benefits that ICT users could 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. The interview results suggest that tangible rewards were believed to be unnecessary for ICT diffusion, whereas intangible rewards through self-fulfilment have a minor influence on ICT diffusion. Evidence from the interviews, suggests that developing a tangible reward systems has been poorly considered by senior management and as an issue too difficult to tackle.

Summarising discussion of individual factors

Individual participant behaviour is a core element of ICT diffusion because it is the individual ICT user who bears ultimate responsibility for enhancing work processes through applying ICT tools. Without the users' adoption of the ICT application, diffusion within the organisation cannot occur. The conceptual model, generated in Phase 1 of the research in Chapter 5, indicates individuals influence ICT diffusion in three ways: through clear benefits of ICT use, the individual's ICT knowledge, personal characteristics and their having a positive perception of ICT.

Clear benefit of use, however, might also depend on an individual's characteristics such as their experience and ICT skill. Individuals' initial experience of an ICT application is important because they may not immediately recognise benefits they are gaining from its continual use. This is why previous beneficial experiences of other ICT applications that have provided rewards 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 develop confidence in, and a positive perception of ICT use in general. Individuals' characteristics include their individual skills and learning capability (ability), their motivation to learn and their reactive or proactive response to ICT management and technical support systems.

An individual's skill is their personal capacity to apply and transfer general ICT skills to their personal work. People have various requirements at different times for using a range of ICT applications for their work. Those who are capable of applying it to their work processes may have experience of similar technologies and are computer literate. For example, the Microsoft Office suite has many common user interfaces—learning one application assists users how to use a related application. 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.

Summarising discussion of the technology factors

The influence of technology on ICT diffusion could be addressed at three levels: individual, management, and environment. 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 people create a hostile environment for technology use). Software and hardware jointly influence ICT application characteristics. It can be argued 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, so transfer rates must be very fast;
- User accessibility: this relates to ICT applications being readily available through web-based Internet access using user-friendly standard browsers or other user-interfaces.

Summarising discussion of workplace environmental factors

The workplace environment 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, which these can be based in physical facilities or in virtual communities. This environment provides an important support to the novice user and also increases the diffusion of work groups 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 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 a dialogue to take place between colleagues to jointly solve problems. Users working in a closed discussion environment could 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.

7.1.3.2 Inter-organisational factors

Figure 7.1 indicates four inter-organisational factors: ownership and ICT standards; information overload; commitment of ICT use; and intellectual property and legal issues.

Ownership and ICT standards
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 when different project participants have 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. This 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 with and transferring information to other ICT systems.

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 contained in a transmitted message. The data suggest that information overload was a problem that featured with communication between companies using ICT. This problem corresponds with previous research (Thorpe & Mead 2001). This criticism of information overload was based upon problems that users experienced in managing and searching for information. Traditionally, copies of information to parties were limited to those who directly needed to know things. With ICT, it is possible to be able to copy any number of people in on documents being transferred and so from the individual's perspective the system generates a vast amount of documents and information that needs to be searched when trying to identify a specific piece of information. The establishment of a communication chart or map (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

carbon copy message (Cc:). This can help recipients to identify or filter the relevant email to them. Development and training of use of search engines can also help with finding relevant information from a database or information repository.

Commitment of ICT use

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 organisations 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 one architectural company adopted the principal contractor's ICT in order to foster a long-term relationship despite having their own ICT. This raises interesting issues about ICT diffusion being a supply chain driver and a relationship-enabler.

Intelligent property and legal issues

The implementer and senior project manager in case study (CC) raised the issues of legal and intellectual property. They mentioned that sending electronic documents such as construction drawing details or document files to other project participants raised legal validity problems that were of concern to them and inhibited their full support for the ICT application. Also, files can be copied and reproduced by other sub-contractors more easily electronically than by re-drawing design details from hard-copy drawings. These users also had concerns about unintentionally sending electronic message that could have a legal impact. For example some systems easily permit people to be added to an email 'send' list. Thus, confidential documents can be easily transmitted to unintended parties. There is also a potential for more of fraudulent email being sent through the system where these document management systems are in place.

7.2 ICT knowledge diffusion through users

In this section, the focus of analysis is moved forward to identify how ICT knowledge has been diffused throughout users within construction organisations. One of the more interesting findings of this ICT innovation diffusion study was that people-support, in terms of a COP, was an evident element of the four clusters of characteristics. Thus human capital infrastructure appeared to provide a pivotal role supporting ICT innovation diffusion. This section is focused upon explaining the roles of communities of practice (COPs) that support the ICT diffusion within construction organisations. The literature argues that the COP concept has an essential role in knowledge-sharing and, in turn, can develop a more knowledge-productive culture of learning in construction management organisations (von Krogh, Ichijo & Nonaka 2000, Wenger 1999, Wenger & Snyder 2000). In this section, the role of a COP in case study examples from three major Australian construction contractors is presented. Part of the study concentrates on how these firms diffused ICT applications through COPs.

Table 7.10 categorises the interviewees into five groups: IT strategists (senior level management champion and initiative driver) implementers (given the task of encouraging diffusion of the ICT groupware initiative), project managers (responsible for construction teams on projects using this technology), site engineers, and site foremen (both the latter groups are direct users of the technology in coordinating the physical and administrative work being undertaken on site). The reason for adopting this categorisation approach is to gain an understanding of the factors influencing ICT diffusion from multiple perspectives.

Table 7.10 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*

7.2.1 *Case study A's communities of practice*

Figure 7.2 illustrates five examples of COPs that facilitated ICT diffusion. One of the senior engineers had a role in validating the ICT initiative and informally created the development of COP(1) with staff from the firm's IT department. When he experienced problems with using ICT applications from a practical and/or technical perspective, he would resolve them with the IT people.

One office project manager helped establish COP(2) by providing time in the morning to talk and exchange ICT knowledge with his colleagues. He spent his morning time providing specific training and discussion about ICT problems with his subordinates and encouraged their feedback and participation. COP(2) assisted the diffusion of ICT through this team because it shared problems and new ideas on how to apply ICT to assist traditional work processes. COP(2) also facilitated additional feedback to be channelled between users and ICT tool developers. COP(3) is a different group of individuals that often communally solved *ad hoc* problems through the gatekeeper, usually by phone, and if they could not get through to IT people. COP(4) also solved *ad hoc* problems, but on a one-to-one basis through the gatekeeper linked to IT people.

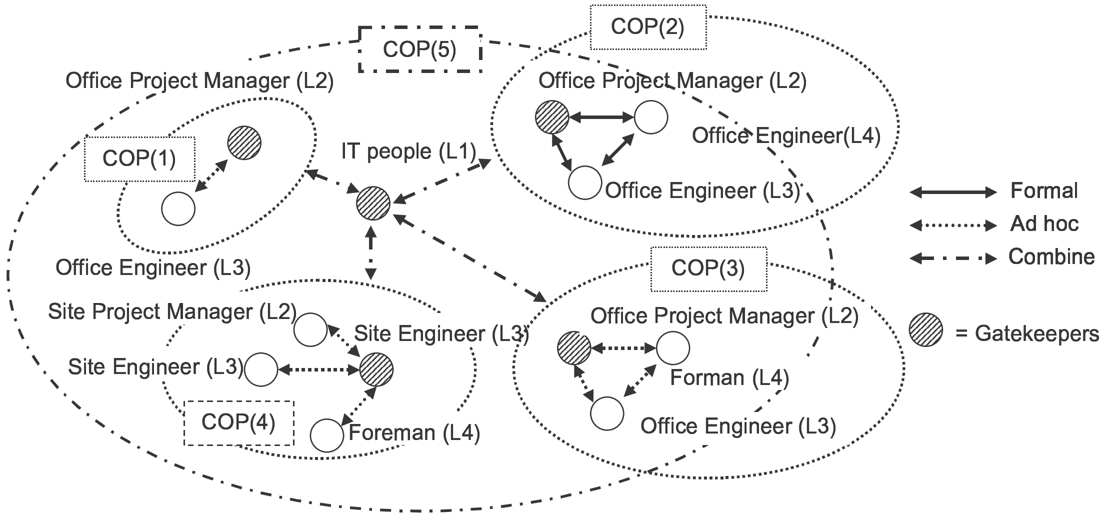


Figure 7.2 Case study A's communities of practice

COP(5) used an email discussion group to facilitate ICT use, to communicate with each other to get help. COP(5) helped users who had problems with relation to the ICT use. Members post their questions for the IT staff of other COPs to respond to. Users shared their experiences and problems and also suggested solutions. This reduced repeated questions on the use of ICT and reduces IT staff workload in repeatedly responding to the same problems.

7.2.2 *Case study B's communities of practice*

Figure 7.3 illustrates two examples of a COP that facilitated the ICT diffusion. At the organisational level, ICT use depended upon the implementer, who had the most technical knowledge. The implementer was at the centre of and developed COP(1) associated with use of the all-embracing ICT web application. He transferred his knowledge to users and also received feedback from COP(1) and used email and phone extensively to communicate and help solve problems of ICT users. Thus, a virtual COP to improve effective ICT use was created. In general, case study B presented a strong culture of helping each other. It was also mentioned that the culture of helping was not limited to IT issues, but people could ask for help in many other areas of expertises within CB.

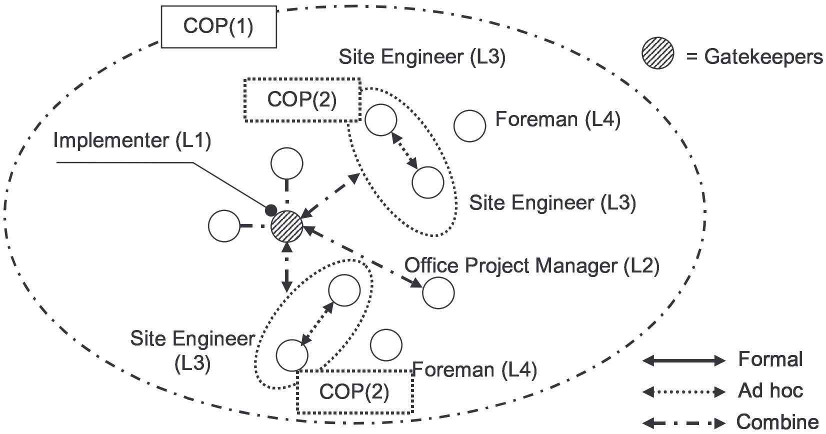


Figure 7.3 Case study B's communities of practice

At the project level, use of ICT discussion and help within COP(2) started with colleagues who worked on the same construction project. Most participants confirmed that they sometimes share and exchange ICT use knowledge. However, they had time and ICT knowledge limitations. Technical ICT assistance was mainly received from implementers. In addition, construction foremen have more responsibility for technical aspects of construction, while site engineers, project administrators, and project managers handled most of the administrative tasks. COP(2) indicates the frequent situation where very small groups that help each other were formed and disbanded mainly for ICT issues to be solved at a low functionality level. because they tended to get help from the ICT implementer when trying to use the ICT application at higher functionality levels.

7.2.3 *Case study C's communities of practice*

An external project web service developed the ICT application in this case. The implementer also had a role in facilitated customisation of the ICT application to suit the company's work processes and provided strong support for diffusion of ICT within case study C (CC) and other project participants. The strength of COP(1) in Figure 7.4 is mainly dependent upon the implementer who had the knowledge and background of both the construction and computer context. He started his own communities by providing training on how to use the application for his teams and main project participants.

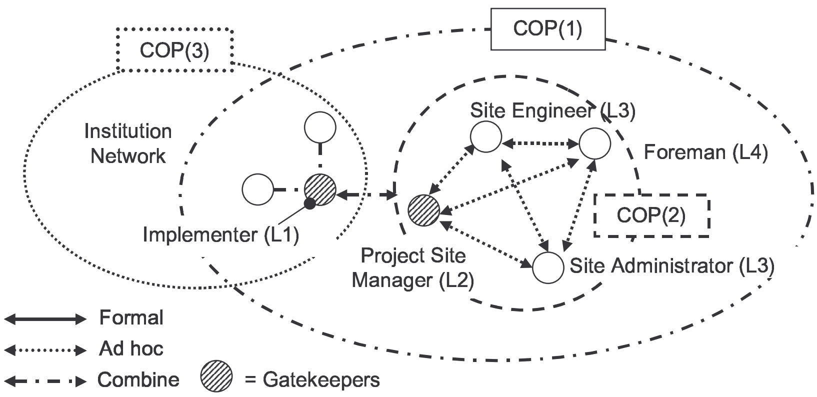


Figure 7.4 Case study C's community of practice

In addition to COP(1), the implementer, interacts in COP(2) a COP of colleagues. Several COPs(2) existed for collegial help and they have a positive influence on novice engineers who did not receive any training sessions to develop skills to be able to use the ICT application. A COP(2) member mentioned that his senior engineer helped him use the ICT application. The project manager also encouraged and helped his sub-ordinates by providing advice on ICT use. Although he has a limited knowledge, he tried to resolve problems regarding its use through the implementer. COP(3) is the organisation-wide network for each business group. CC started a technology centre with key functions to promote and expand a range of ICT technological innovations into business units (BUs). The centre aimed to improve work performance, safety, and quality in construction work processes. It consisted of people who were 'the experts' from different BUs across the organisation. They dedicated time to meet every 3-4 months. The technology centre provided support and advice to BUs on adopting ICT innovation.

7.2.4 *Discussion on communities of practice*

In all three cases it was clear that IT groups held a significant and pivotal position in the ICT diffusion process through a combination of help desk, one-to-one and one-to-many communication channels. The use of groupware for email and Intranet access for resolving diffusion issues was also substantial in all three cases. Rich communication channels were also used—the COP provided reflection and feedback, facilitating interrogation and idea clarification/testing. From the three cases, several types of COP networks emerge: institutional, implementer or technical support; project manager/engineer focused; and collegial support. Each has its individual focus, resources and behaviour/attitude implications.

It is important to realise that the literature on COPs stresses that COPs are already 'out there', they exist as social networks of friends with shared interests and experiences who want and need to communicate. COPs can often evolve in an ad hoc manner from an association of 'mates'—past co-workers who have gained a bond of trust and commitment through joint effort of working on projects or specific tasks together. They can also develop from membership of a special interest group such as a professional association where members may well have never worked together before but share a passion and commitment to sharing and re-conceptualising knowledge about specific issues. Thus there is a relationship within organisations, as highlighted in the case study reported above (Peansupap *et al.* 2003), and between organisations. The study was restricted to within-organisation COPs and so this will be discussed first before moving on to discuss COPs across organisations.

7.2.4.1 Institutional network

An institutional network is defined as a strategic group, interested in development of technology innovation within an organisation. Development of ICT required staff that had construction process experience in all three cases—the aim being for business process needs to drive ICT development so customisation, testing and piloting, feedback and fine-tuning is required to be delivered by construction management experts and ICT experts. This COP principally links business process domain experts with an ICT strategist. Resources required include high-level domain expert input and substantial face-to-face time with reflective management behaviour.

Introduction of CSA's ICT was developed from a meeting of regional managers responsible for quality assurance with IT experts. This group dedicated time for testing ICT and designing simple user-interfaces. This type of COP was a temporary one, formed until the objectives of ICT development had been defined and rolled out. After the development of the ICT initiative, the IT department took over responsibility for implementation. As with CSA, ICT in CSB was developed by senior mangers with expertise in construction from the e-business group and IT consultants who identified relevant ICT opportunities. This group has been formed to design and develop the ICT tool for developing and managing construction projects. Therefore, the initiative group of CSA and CSB may be classified as *a task-oriented team* (Storck & Hill 2000a).

CSC initiated a technology centre to promote and explore technological innovation relevant to its business units (BUs). Groups of people with backgrounds from various BUs across the organisation dedicated time to formally explore and discuss the opportunities of using the technological innovation in construction processes. Thus the initiative group of CSC may be classified as *a strategic community alliance* (Storck & Hill 2000a).

7.2.4.2 Implementer or technical support network

CSB and CSC had a key champion with sufficient drive and enthusiasm to be the ICT initiative implementer who envisioned the ICT strategy. A COP would then be built or emerge, nurturing the ICT implementer whose role is to transfer ICT knowledge within project teams to expected users. The implementer plays a significant role in training and being a mentor to users who have a background of construction processes sufficient to understand any potential problems and/or implications of using ICT in construction processes. This person would also be involved with the software company who provided the ICT service and would participate in the development of the ICT initiative. CSA was dependent on the ICT team for training and development. Typically implementers reside at the hub of the COP, they are the organisation's experts and main resource in making sense of the ICT and its development. They require resources to sustain the COP that links and permits ICT initiative knowledge to be cross-levelled and diffused widely across the organisation, as suggested by (Nonaka & Takeuchi 1995a). Their behaviour is supportive, inclusive and that of an enthusiastic knowledge activist (von Krogh, Ichijo & Nonaka 2000).

7.2.4.3 Project manager/engineer and collegial support network

It became clear from the interviews that project managers play a significant role in ICT diffusion by developing their own community of practice. One of the office managers in CSA mentioned that his team uses part of the morning time to discuss how to best use ICT. He found it very helpful for new engineers who received ICT training but may take time to understand how to apply it in their work. He also attempted to support resources for delivery and feedback from end-users to IT staff to improve the application to meet end-user needs.

Furthermore, the collegial network being considered as the first source of help to users (who have limited ICT knowledge) is consistent with a study of 2000 aerospace engineers, which found that well-informed technological gatekeepers with an intimate knowledge of the technical tasks being undertaken were the preferred first choice for finding salient information or knowledge (Anderson *et al.* 2001, p151). Personal communication with a peer who knows the context of the problem provides a rich and clearer communication channel for assistance. It often allows users to observe and learn from real examples by real or virtual demonstration (Wenger, McDermott & Snyder 2002). It is easier and quicker to get help from colleagues relating to ICT use.

The existence of the internal workgroup COPs such as CSA COP(2, 3, 4) and CSC COP(2) link colleagues together as well as providing gatekeepers to the ICT support COP members. In CSA COP(4) the pattern was individuals interacting on a one-to-one basis with the gatekeeper through to the ICT support group. In this kind of COP from a collegial perspective there is a dyad relationship in which the gatekeeper supports the user and learns, filters and consolidates typical difficulties colleagues experience with ICT application. This is then fed back to the ICT developers and the gatekeeper becomes a valuable focal point in that COP. However, the value of colleague interaction is minimised, compared to the more connected CSA COP (2 or

3) in which there is more cross-group interaction. A more isolating COP model is evident in CSB COP(1) where most of the help is gained from a dyad relationship between the ICT implementer and people in that COP. In this example it is necessary for temporary or small scale COP to emerge as illustrated in COP(2) but often their skill level for answering urgent questions is limited.

The resource implications for maintaining collegial support is a need for committed gatekeepers who are provided with the means and motivation to support the COP. Additionally, any COP that is linked via groupware needs that ICT application to be effectively diffused for it to be of any use. There needs to be an attitude and behaviour consistent with openness, knowledge-sharing and also motivation and rewards for participation, even if these rewards are intrinsic (Nahapiet & Ghoshal 1998).

7.2.4.4 Relationships between each community of practice

The above discussion on communities of practice provides the understanding of how each community of practice plays the essential role in ICT diffusion. This discussion will focus on the relationships between each COP both within an organisation and between organisations.

Relationships of COP within an organisation

The three case studies show that COPs can help construction firms diffuse ICT knowledge by COP members sharing experiences and insights and helping each other to solve problems related to their ICT use. This discussion underlines the concept of a COP by focusing on relationships between the identified within-firm COPs. These relationships play a significant role in linking several communities together. From our case studies, the institution of COPs has the complementary role of sharing the message of potential and realised ICT benefits through construction business managers. For example, one senior construction manager may need to find a solution to improve their work business processes. Members who have ICT experience may suggest a solution to the manager. At this stage, the solution may be a preliminary concept to improve the business process. Within institutional COPs, this intra-relationship can help members be aware of the availability of current ICT tools or to develop interest in the use of an ICT application. Facilitators of an institutional community of practice (who provide leadership and support) should comprise key representatives, such as top management, to reinforce ICT diffusion throughout the organisation. Such people provide policy drivers. Perhaps a senior quality manager who is involved in improving construction processes could be appropriate, likewise senior project managers who have practical experience in the field or perhaps senior IT managers who have a strong background of IT knowledge contribution. These representatives may have significant roles in connecting and linking COPs and facilitating knowledge sharing between COPs.

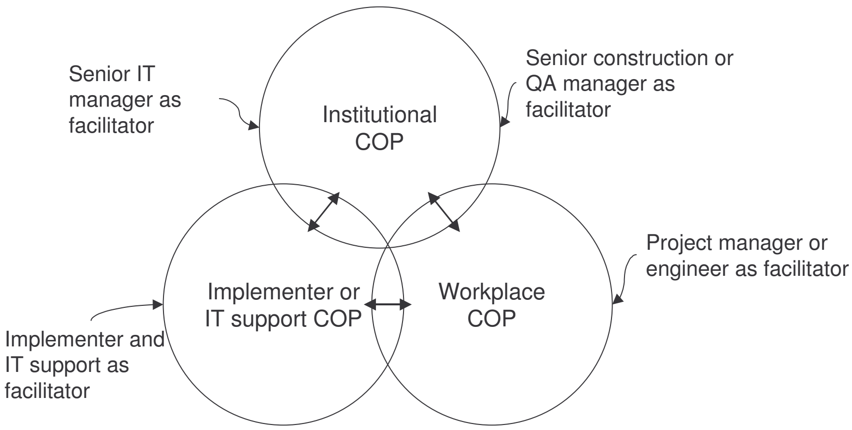


Figure 7.5 Three types of COP within an organisation

Figure 7.5 illustrates that the first relationship in attempting to integrate or link a COP within an organisation is the connection between the institutional COP and any COP facilitated by the ICT implementer or IT support groups. A senior IT manager can play an important role in linking these two COPs. If the senior IT manager is a member of these two groups then he/she can work with IT members to seek more technical information on how to best apply ICT applications to improve construction work processes. Groups of implementers or IT support personnel may share their technical experience with senior IT managers and this in turn provides feedback to COP members within the institutional COP. On the other hand, the adoption decision of ICT application to support the business need may depend on several business constraints in which groups of implementers or IT support staff may not have sufficient experience. Therefore, the relationship between these two groups may help IT people to understand business operation realities, which in turn provides a suitable ICT application for business needs to address the issue of improving such processes through the use of ICT supporting infrastructure. Meanwhile, people in business units can improve and update their understanding of ICT application knowledge.

The second relationship is a connection between the institutional COP for any project manager or a collegial COP that may be based around workplaces. It could be suggested that a senior quality manager or senior construction manager can play an essential role in linking these two COPs. Experienced construction managers[14] may help share their experience of how to encourage colleagues to use ICT applications. The experience may be useful to business managers in adapting strategic management plans or to improve ICT implementation strategy. Some experience may be useful in highlighting best practice knowledge where BUs receive help on decision-making for future projects. Senior construction managers may also learn from business planning people and that could have a positive impact on their future projects. For example, if a construction firm successfully used web-based project management tools, then this message may be fed through a COP in which business managers and construction managers can learn and share options about how to best diffuse these tools.

Finally, the connection between ‘implementer or IT support COP’ and the ‘workplace COP’ (see Figure 7.5) can help people share experiences of combining both construction and IT technical knowledge. Most members in workplace COPs have high levels of experience of construction procedures and processes. Thus, sharing this construction experience with members of implementer or IT support COPs should be helpful for improving ICT application to suit users’ requirements. On the other hand, knowledge about ICT applications also helps members of workplace COPs to understand limitations associated with ICT applications. Linking COP types can improve mutual understanding of ICT innovation support staff and operational users to help each party improve their application of ICT rather than blaming each other for poor implementation of any ICT initiative.

Relationships of COPs between organisations

The above discussion centred on intra-organisational COPs. This section focuses on inter-organisational COP relationships. These groups also provide benefits for each

[14] It should be noted that experience relates to relevance—it is probable that younger organisational staff may have considerable ICT use experience to share with older staff and older staff may have deep insights from their industry experience on how best to apply ICT tools in a practical manner.

member organisation because they facilitate sharing and learning from each other. Figure 7.6 illustrates these relationships.

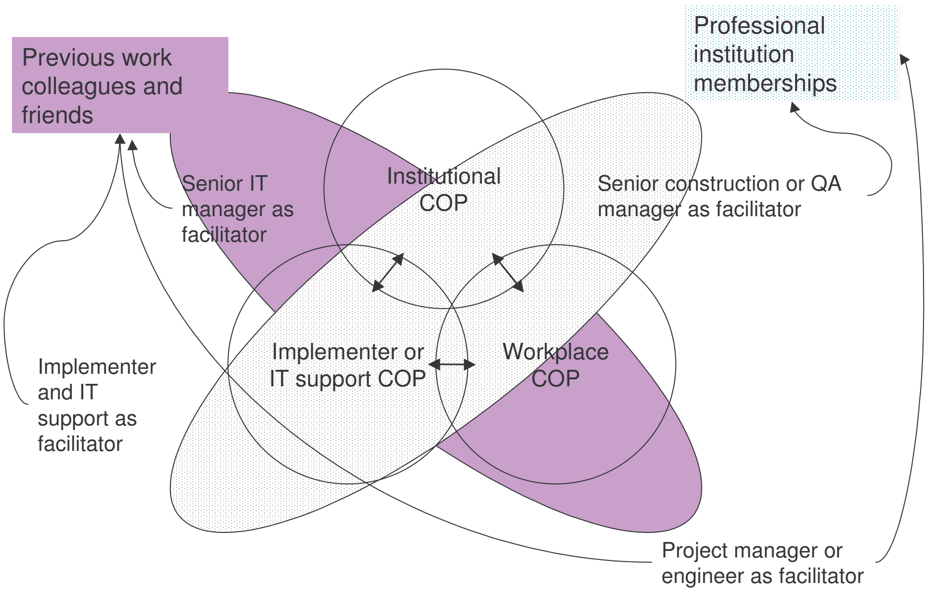


Figure 7.6 Relationships of COP between organisations

It is essential to recognise that these COPs already exist, cannot be controlled by the organisation in any heavy handed way and if suppressed will merely go 'underground'. Thus, it is wise for organisations to embrace them and to actively and proactively help shape them to align organisational objectives where appropriate with the COP rather than vice versa. For example, members of professional institutions may share information about standards of using ICT in the construction industry and these may develop into a useful collaborative network such as the Construction Industry Trade Exchange (CITE) in Australia and similar cross-industry initiatives elsewhere. Additionally, previous co-workers and friends may influence sharing the knowledge of ICT applications through membership of formal or informal social networks and COPs. People feel comfortable to ask those close to them that they trust, therefore these COPs could sometimes help staff learn how to use ICT applications even though the individuals concerned are affiliated with competing organisations.
In conclusion, this analysis shows that there are three types of intra-organisational COPs that can be developed to positively contribute to ICT diffusion. 'Institutional' COPs help to establish the strategic direction for ICT development and evaluation of potential ICT use. 'Implementer or technical support' COPs link users with ICT support staff through gatekeepers who can help with the process of interpretation and reframing problems and difficulties. Supporting work group COPs provide technical

support gatekeepers in the 'project manager/engineer network' and 'collegial support' COPs to provide much of the necessary one-to-one or small group support. In addition, work colleagues and friends, and professional institution members may effectively harness knowledge from externally organised COPs.

7.3 Analysis of the strategic ICT adoption in the case studies

In this thesis, strategic ICT adoption is defined as an organisational decision to adopt a specific ICT system under a circumstance at a particular time frame. Within each organisation there are several ICT applications that management may adopt and implement. ICT systems in the three case studies could be described as one Intranet and two web-based document management systems. As the strategic adoption in each framework occurred at different times (see Figure 7.7) senior managers decided to adopt ICT system specifications consistent with the technology at the time in each case.

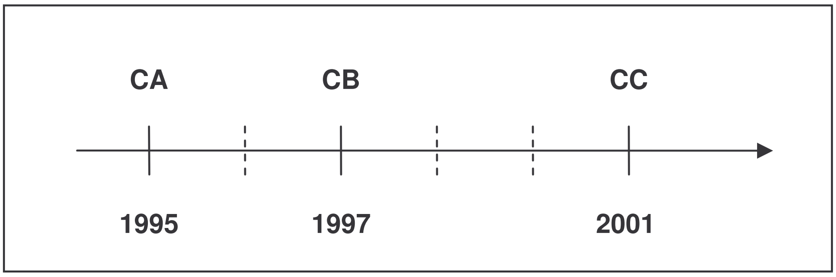


Figure 7.7 The time frame of ICT adoption in three cases

Figure 7.7 illustrates the different time frames of the ICT adoption for the three case studies for the electronic document management systems (EDMSs). CA adopted an Intranet document management system in 1995. The organisation explored several off-the-shelf software products and concluded that the functionality of those software products did not support their organisation's work processes. Thus, the IT senior manager in CA decided to develop their in-house ICT system and invest in implementation of the system. At the time of study, IT senior manager in CA said that internal staff and some clients who may request access to it have used the current system.

CB started to adopt a web-based document management system in 1997. The IT senior manager of CB explored the available ICT software products for this type of application and concluded that there were too many limitations. Therefore, the e-business managers in CB decided to build an in-house ICT system—a web-based document management system. The development of the ICT system was designed to be used by CB's internal staff and other linked project participants.

CC chose to adopt a web-based document management system in 2001. The adoption of the ICT system was introduced by one of the IT senior managers who initiated the idea of using a web-based document management system. He started to gather information about functionality and cost of these systems from several ICT software products and services. Then he proposed the idea to his senior management and the organisation authorised that two ICT systems would be piloted during 2001. The two pilot studies indicated that the simpler and less functional ICT system was better to be adopted and used in CC, but the more complex and more functional ICT application did have enough users' adoption and management support. At the time of this study, CC had no plan to develop an in-house web-based document management system but preferred to use the service from an external web-service. Further, this organisation expects to use an industry standard application CITE expected to be operational during the end of 2004.

7.3.1 *Characteristics of ICT adoption at an organisation*

From the above three cases, it could be interpreted that CC has reactively responded to the adoption of this particular ICT application because it is purposefully waiting for ICT system development maturity. On the other hand, it could be suggested that CA and CB have been proactive with their ICT adoption because they decided to develop their own in-house ICT systems instead of waiting for the growth of ICT development in the market. It can be argued that CA and CB, who decided to adopt ICT systems earlier than CC, should have obtained more time to gain benefits from a differentiation, thereby getting a competitive advantage. In fact, this would depend on the effectiveness of ICT adoption and implementation. The research data indicates that CA's system is limited to internal staff and a few clients, but CB's system is intended to be extensively used by both internal and external project teams' members. This kind of adopting an ICT system by internal and other project participants can create an uncontrolled environment for ICT in CB. In other words, an early adoption of ICT could result in a greater risk because it would require a similar adoption by external users. The latter may find it difficult to manage and control their ICT application use (subjecting them to potential ICT adoption risk).

In this study, the aim is to understand the current practices of strategic ICT adoption within large construction organisations. The next section will focus on the way that the three organisations adopted and implemented ICT systems for an EDMS application. The discussion will focus on strategic adoption versus ICT characteristics.

From the above analysis, the three case studies demonstrate different strategies of ICT adoption. CA and CB are examples of organisations taking a proactive strategy in ICT adoption whereas CC appears to have taken a reactive strategy. Each case will be analysed as follows: the purpose of ICT use, the type of potential adopters/users, the ICT initiative sponsor, the adoption direction, the force behind the adoption decision, the ICT adoption approach, and the ICT adoption strategy. Table 7.11 provides summary ICT adoption findings for these three construction contractors.

Table 7.11 Characteristics of ICT adoption in three construction contractors

Nature of ICT adoption	CA	CB	CC
Purpose of ICT use			
- Reinforce quality assurance policy by using ICT to manage construction project document	√	√	√
- Help communication and coordination both *within* and *between* project teams	√	√	√
- Improve information accessibility and provide a single source of information	√	√	√
Potential adopters/users			
- Internal staff	√	√	√
- External project participants	-	√	√
ICT initiative sponsor			
- Support from regional senior managers, quality managers and IT people. This group initiates the adoption of ICT.	√		
- Support from e-business group forming expertise and IT staff. This group initiates the adoption of ICT.		√	
- E-business unit group built the technological community of practice that has the role to explore and initiate ICT adoption.			√
Direction of adoption			
- Top-down and a task-oriented team	√	√	
- Top-down and a strategic community of practice			√
Force behind the adoption decision			
- Demand *pull*	√	√	√
- Technology *push*	√	√	√

ICT adoption approach			
- Develop in-house ICT development			
▪ *Program a user interface based on a commercial software database environment*	√		
▪ *Design application's user-interface in which it is connected to a commercial software database*		√	
- Adopt external ICT product/service. It was selected to use external web-based project management service.			√
ICT adoption strategy			
- The strategic adoption of ICT is classified as being proactive because the organisation develops its own ICT application to support its needs because there was no readily available ICT application at that time.	√	√	
- The strategic adoption of ICT is classified as reactive because its current ICT use is part of a strategy for preparing staff to adopt a next generation industrial ICT platform.			√
Adoption decision			
- The adoption decision is made with senior management commitment to invest resources in ICT system.	√	√	
- The organisation developed ICT decentralisation adoption by suggesting and analysing suitable ICT application for project use.			√

All case studies (CA, CB, and CC) show similarities of adoption purposes. These purposes are to improve quality assurance of construction project documents, to help communication and coordination both within and between project teams, and to enhance information accessibility and provide a single source of information.

For potential adopters, CA's system is focused more on internal staff only whereas CB and CC are focused more on both internal staff and external project participants. As the focus of potential users from CB and CC involves both internal and external project participants, it should gain greater commitment from ICT users from both groups otherwise the adoption and use of ICT may be inhibited because of a confused mixture of communications in both electronic and paper form. As a result, the internal adoption of ICT by the main contractor may seem successful but its involvement with other project participants indicated a resistance to the use of ICT. This may slow ICT adoption and diffusion by a main contractor who needs to be an early adopter.

As main contractors need to gain competitive advantage, early adopters need sponsors who can initiate and support ICT adoption. The adoption usually starts from the commitment of senior managers and IT specialists. ICT use needs a shared understanding of both practical construction processes and ICT technical knowledge to identify possible applications to manage and reinforce current processes. In addition, the development of ICT needs financial support from senior managers. Sponsors in CA and CB consist of senior managers, the quality manager and IT people (indicating a top-down influence direction). In CC, the e-business manager has the main role of building a core strategy and technological COP and then persuading middle managers and site engineers to use ICT (top-down and bottom-up). The use of this COP helped to develop a commitment for the ICT application throughout top managers and middle managers in CC.

The force behind ICT adoption in CA is similar to that in CB. In CA and CB, both demand-pull and technology-push forces trigger adoption of ICT. They seek solutions to particular problems (demand pulling supply) or ICT suppliers may ‘sell’ a technology solution for a generic problem (technology pushing demand). On the other hand, the force of ICT adoption in CC is a technology-push influence rather than demand-pull.

The ICT adoption approach of CA is to select an in-house ICT development strategy. The development of CA application was based on a commercial software database in which IT programmers can customise the interface to suit the organisation’s needs. This was slightly different from CA and CB that adopt an in-house ICT development strategy, but they developed web programming that interfaces with a commercial software database. On the other hand, CC chose to outsource by adopting an external ICT product/service. CC chose to use an external web-based project management service.

The ICT adoption strategy of CA and CB can be classified as proactive because these organisations developed an ICT application to support their own needs as there was none readily available at that time. The strategic adoption of ICT in CC is classified as reactive because its current ICT use is part of a strategy for preparing staff to adopt a next generation industrial ICT platform.

Finally, the adoption decision in CA and CB is made through senior management commitment to invest in ICT systems, whereas CC had decentralised the analysis and adoption of suitable ICT applications for project use.

7.3.2 *Interpreting ICT adoption strategies*

As general construction organisations typically do not have sufficient experience in strategic ICT adoption, this case study of ICT within three large construction organisations may be useful in providing an understanding of how an organisation strategically plans to adopt and diffuse ICT. This section will provide the analysis of strategic ICT adoption.

7.3.2.1 Strategies for ICT adoption (proactive/reactive)

From the case studies, CA and CB show proactive strategic ICT adoption whereas CC demonstrates a reactive strategic ICT adoption.

CA was involved in the development of an in-house groupware application that supported internal construction processes such as generating a database of information for tendering and producing a project history package to gather lessons learned. Two reasons for developing ICT were that (1) the organisation was expecting to gain a competitive advantage from early adoption of ICT and (2) other off-the-shelf ICT applications at that time lacked functions that supported its organisational needs.

Similarly, CB was also involved in the development of an in-house collaboration system. The ICT system was a web-based document application that supported project collaboration and document exchange. The e-business group in CB decided to invest in the development of its own ICT application because CB expected to gain an advantage from using ICT for communication, collaboration and quality assurance.

Furthermore, CB intended that other project team participants would use the system. CC showed a late strategic ICT adoption by using web-based document management. For instance, CC adopted an external web-based document service rather than develop an in-house ICT application. Interviewees mentioned that adoption of this ICT involved two trial pilots before moving to the diffusion of this application throughout the organisation. The senior IT manager stated that adopting this ICT later was due to an industrial standard web-based document management not being available at that time. As a result, the organisation intended to use current ICT as the antecedent for adopting an industry standard web-based document management at a future time. From the three case studies, it can be concluded that there is a direct relationship between the characteristics of ICT and its strategic adoption as illustrated in Figure 7.8. In general, when construction organisations seek to gain a competitive advantage from early ICT adoption, they tend to choose a proactive strategy. By using this strategy, organisations are required to commit to investing in developing their own ICT application, because during this early period, off-the-shelf ICT products may provide fewer functions and applications relevant to their organisational business processes. As a result, a proactive strategy should be carefully used, especially when this applies to an Extranet application platform that depends upon its adoption by both internal staff and users from other organisations. In other words, the adoption of an Extranet application platform is far more complex than adopting an Intranet application platform because the adoption involves both internal and external groups of users.

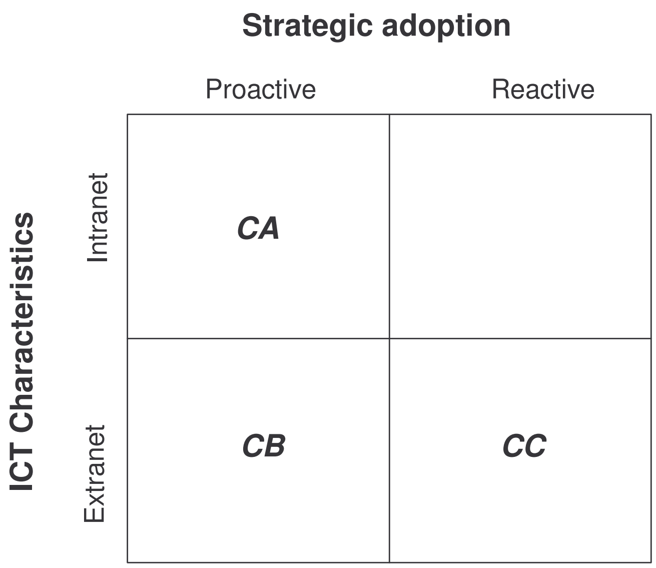


Figure 7.8 Relationship between strategic adoption and ICT characteristics

External groups of users appear to have less influence upon the adoption of a proactive strategic adoption of Intranet ICT application. For example, CA provides an example of proactive ICT adoption strategy—using an Intranet ICT platform. Most respondents had a positive perception of their ICT use. Respondents also believed that their use of ICT increased the competency of their company. For example, they also used it as a document management system for all document communication on their construction projects. Many respondents used it extensively to manage their ‘requests for information’ (RFIs). When they received the RFI, they would input reference information such as received date and document number that they could use to refer back to hard copy forms of this information. Some respondents in their head office scanned hard copies of documents and stored them in the system.

Their proactive strategic adoption of the ICT Intranet may have confronted them with fewer problems because users felt that it could be deployed as an internal document communication and management tool. Despite some limitations perceived by subcontractors who did not use the Intranet, CA users did not recognise this as a significant ICT application barrier. More importantly, the Intranet application was designed to fit in with the internal professional user’s needs and organisational procedures. For example, respondents mentioned that the ICT application was compatible with the work process in which they could correspond through a template such as fax, memo, RFI, letter etc. Thus, all correspondence could be created and stored in the system so that they could send it through ICT or print it and fax to other construction project participants. Finally, as the Intranet ICT application was developed for intra-organisational use, the users could receive full support from their organisation such as Internet access or computer. The above evidence suggests that external factors have limited influence on the development of a proactive strategy of ICT adoption in construction companies.

CC shows a successful example of using a reactive strategic adoption. The company used an Extranet ICT platform that was serviced by an outside company (outsourced). This organisation intentionally used this strategy because it expected that future industrial ICT platforms would be the next generation of document management systems in which everybody had the same platform of document management. Thus, the organisation intended to use the current ICT application service as a pilot project to prepare its staff rather than developing its own system—this was a strategic action.

Thus a reactive adoption strategy may be suitable for an Extranet ICT application platform because the extranet application involves a commitment from both internal and external multiple users. However, a proactive ICT adoption strategy may be difficult to be successful and requires many resources to provide internal and external staff. In addition to the development of an ICT extranet application to be functioning, the readiness of other construction project participants is required. It is necessary to provide top management resources and may also involve the use of full capabilities of the ICT application to require its adoption by project-external participants to pursue a proactive ICT adoption strategy.

7.3.3 *Possible risks from early adoption*

This section focuses on possible risk that may occur from early adoption. From the above section, the nature of adoption may be categorised into a proactive strategy (early adopter position) and reactive strategy (later adoption position). The case study findings reported here also highlight the risk that may occur due to the selection of an early adopter strategy—possible risks are discussed as below.

7.3.3.1 Technological readiness and standardisation

In an early adoption phase, technology infrastructure development uncertainty may be a significant risk, especially if the organisation decides to develop their ICT system. The early adopter may select the incorrect software technology that may be replaced with a more effective one. In addition, the early adopter may be faced with a nascent technological infrastructure, for example, a slow bandwidth for Internet connection with associated high hardware and software costs.

The development of ICT should include import and export functions that are compatible with the standard of information exchange such as STEP and IFCs. This standard facilitates interoperability—different ICT systems communicating and exchanging information between organisations and data formats. Without appropriate communication standards, each organisation independently develops its own system and finds difficulty in communicating and transferring information between systems.

7.3.3.2 Ownership barrier

From the contractor's viewpoint, the issue of ownership may influence the early adoption of ICT into the organisation. The introduction of ICT into the project participants may be very difficult. Problems may be created if project participants have their own traditional ICT standards and systems, so they may not want to use the lead contractor's ICT platform. Other project participants may be forced to enter information into both their own and other ICT systems, resulting in wasted time.

7.3.3.3 Industrial culture barrier

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 the traditional way to organisations that do not use ICT while also using the lead contractor's ICT platform for communication. This may trigger a risk to early ICT innovation adoption where users need to gain benefits from the application but fail to do so because of a need for information 'double-handling'.

7.3.3.4 Critical mass influence effect

Success of ICT use requires a critical mass of adopters; organisations that are not early adopters may be faced with a critical mass risk. First, some potential users may wait to see demonstrable benefits of ICT use. Second, organisations may not have experienced staff to cope with supporting this new technology. Therefore, this situation is similar to a 'chicken or egg' situation because adoption reluctance of the late adopters may create a critical mass risk to early adopters who attempt to introduce a new ICT system.

7.3.4 *Summary of strategic ICT adoption*

This section aims to increase understanding of early and later ICT adoption and to identify associated risks. The data from three case studies of large construction contractors shows that construction contractors should be aware of the risks of being ICT early adopters, especially if it requires commitment and participation from external project team members. This section also discusses issues that organisations should be aware of related to strategic ICT adoption. As the case studies are focused upon leading construction organisations, further research on strategic adoption should be undertaken to compare this group with small to medium construction organisations.

7.4 Analysis of ICT diffusion process at initial adoption

Generally, the three cases drawn from AUD$1billion+ annual turnover first tier contractors showed similar main objectives for ICT initial adoption. These objectives were to gain competitive advantage from using ICT to improve quality control by integrating construction document management and to improve communication and coordination. These organisations invested in ICT groupware communication applications such as those used for communication and coordination—processing requests for information (RFI), and sending drawings and a variety of correspondence. These communication applications permitted users to access, exchange and search for information from wherever they were located because users can gain access through the Internet and process all correspondence and pieces of information in the system.

Both demand-pull and technology-push forces have triggered the adoption of ICT. Users may seek solutions to particular problems (demand pulling supply) or senior management or ICT suppliers may sell a technology to solve a generic problem (technology pushing demand). Objectives for ICT adoption in all three cases were similar but their adoption processes were quite different.

CA’s quality assurance policy in early 1990 initially drove its ICT adoption when Internet technology was in a nascent development stage. To obtain the potential for competitive advantage in applying ICT, CA started to explore ICT applications in the market but it found that off-the-shelf software packages did not fulfil or support its organisational needs. Thus, CA decided to develop its own ICT application rather than wait till later to adopt suitable off-the-shelf software packages. The analysis of ICT adoption in CA could be classified as following a proactive ICT adoption strategy. This is because CA elected to be a first mover by investing in EDMS. Regional senior managers and quality managers supported the adoption decision with the IT department—this ICT adoption strategy can be classified as being ‘top-down’ and driven by a business imperative.

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

CC demonstrated a reactive ICT adoption strategy because it chose to adopt a web-based document management host service instead of developing its own system. The main reasons for choosing an off the shelf product were the ICT immaturity for this application and fear of risks associated with being an early adopter. It should be noted that CC had previously tried to adopt a similar ICT platform on two pilot projects, the rationale being that a simpler ICT application is more likely to be successfully adopted by users than a complex ICT one. Thus, it could be interpreted that complex ICT applications can present a high risk of adoption to organisations. One difference in the ICT adoption strategy of CC from CA and CB is that CC adopted a current web-based ICT host service for a pilot project to prepare the organisation to adopt an emerging ICT platform standard in the near future. In terms of senior management support, an e-business unit that consists of business representatives, senior project management, and IT people, supports the ICT application's adoption. This group has the essential role of exploring and initiating ICT adoption. In CC, an IT internal consultant was allocated to facilitate the adoption and diffusion of this ICT initiative. Adoption could be interpreted here as both top-down complemented by COPs. The e-business unit encourages the support of ICT adoption by suggesting and analysing suitable ICT applications for project use with the decision to adopt being decentralised, made by project managers. In addition, the degree of adoption is influenced by technology-push rather than demand-pull. CC provides two reasons for its latter adoption decision. First, it believes that current ICT for this application is not mature at the time of this study. Second, CC plans to pilot a commercial ICT application (a simple one) to create and build staff competency.

From the case studies, ICT diffusion at initial stage can be summarised as follows:

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

7.5 Analysis of ICT diffusion process at actual implementation

Although the nature of ICT adoption in the 3 cases reflects both a proactive and reactive strategic adoption, the implementation of ICT in the three cases was quite similar in terms of the support provided to management, technology, and individual users. Most of ICT users in the three cases believed that collegial help and knowledge-sharing ICT environments are the main factors influencing actual implementation. However, these two factors were informally managed within the organisations, which in turn can lead to the inefficient ICT implementation. As a result, these informal collegial and knowledge sharing environments should be incorporated into an ICT diffusion model to better capture the potential benefits of a people-infrastructure that supports ICT diffusion can offer. (See the proposed model of ICT diffusion in Chapter 8.)

In CA, the actual implementation focused on: IT people providing training and technical support; technology fit; and senior management support. Most respondents received 3-4 hours training on the applications but had strong support from an internal help desk. Also, CA top management were interested in developing suitable ICT applications for enhancing their work-processes. One quality manager mentioned that ICT functionality and simplicity were essential factors required for encouraging users' acceptance. Finally, senior project managers also supported the diffusion of ICT by encouraging users, trying to help them solve problems of ICT use and feeding comments to the ICT developer for improvement. Most ICT users in CA had strong computer skills, clear ideas of the benefits of using ICT applications, and self-confidence in using them. Most of them adopted and used ICT for their daily work. In CA, there was also a sharing and learning environment, in an informal way that supported ICT diffusion for its users. For example, a senior manager often shared and exchanged his technical experience with IT staff. This sharing environment helps both ICT supporters and users to understand and continuously improve ICT initiatives. One project manager informally set up regular morning meetings to create a learning environment within his team to help users learn how to use ICT applications for specific tasks and support cross-team learning—this illustrates another example of creating a sharing environment. However, this project manager sometimes found that it was too difficult in practice to continuously do this because ICT users were too busy and they had to travel to other construction sites.

CB's ICT implementation is focused on supporting training and help desk as well as providing substantial senior management support. Before any projects began, all respondents received 3-4 hours of training from an ICT implementer. Users appeared to have felt that this is adequate for introductory training. The implementer mentioned that he also provided specific training upon request. The implementer also undertook an additional role in helping ICT use though his offer of participating in help desk support. He and other interviewees considered immediate support on demand as a key success factor for users' ICT learning. However, a help desk facility supported via phone and email access seemed to be less satisfactory to ICT users. Some users mentioned that it was hard to contact the help desk by phone and get a quick response so in general they attempted to personally contact the ICT implementer. This reinforced the perceived need for one-to-one expert assistance where 'show-how' tacit knowledge could be more effectively transferred. Organisations also support each user by providing them with a computer, an Internet connection, and a user account. Thus, the provision of a computer and user account is a basic resource requirement for staff to use ICT. Senior management support in CB is on a project-by-project and staff's job responsibility basis. Two construction project managers provided a role model through encouraging their team by sending information to them about using ICT applications. On the other hand, a design project manager argued that ICT applications have not supported his project. In addition, potential users (from external organisations) complained about issues related to the implementation process. They were satisfied with the concept of ICT use, but some of them felt that ICT application needs to be improved e.g. cost control. In addition, current remote-site users complained about barriers to their use of technology: *'ICT application is based on 56k Internet connection, but there are several terminals in office use that share that Internet connection. It takes a long time for downloading drawing files'*. Although respondents in CB were satisfied with the content of training, some had different backgrounds and skills that affected individual learning outcomes. For example, one potential user in a training session asked an implementer: *'What is Netscape software?'* In addition, as each user may have a different role on a construction project, the implementation process should better define related modules that assist their job to enhance clarity of potential benefits of ICT use. Unclear benefits of ICT use may result in wasting time learning modules that are not essential to the user. This problem can also be solved in many applications by customising menu options to only contain those options or functions that are needed by particular groups. CB's learning environment demonstrated that at least one example of a construction project with a high number of experienced ICT users in place that could influence new users' acceptance of ICT. The transfer of ICT knowledge from experienced users to novices is another key ICT diffusion factor. Training provides a basic set of competencies, but users need to practice what they learn to gain continued benefits of ICT use on their projects. Thus, if users experience any difficulty in using ICT applications, then effective adoption and use of ICT often depends upon continued collegial support.

Actual ICT application implementation in CC was affected by both training and implementer support. As CC's ICT application was relatively simple, training to explain how to use the ICT application took approximately one and a half hours. Most participants were satisfied with the level of training and were able to develop an initial understanding of the application. The implementer used trial projects as a simulation exercise to help them familiarise themselves with the application before starting to use it on a real project. The implementer also had a prime role in helping users on construction sites because he was specifically allocated to support ICT users. Thus, users felt confident to ask for help from him. This important resource enhanced the supportive workplace environment and encouraged a learning environment.

CC's top management supported ICT use and provided suitable infrastructure such as computer and Internet networks as well as a project manager who had an enthusiastic personal interest in ICT innovation and use. At the project level, the project manager encouraged subordinates to use the ICT system. When he had time he would sit down and help users solve their problems. He sometimes found himself limited by his knowledge to help with specific problems but he would ask the implementer to help solve these. The characteristics of CC's ICT systems were quite simple—the main concept support of project communication and coordination within and between project teams. Application functions included daily work lists, drawing register, and correspondence. Most participants felt that these functions provided an adequate document management system for the construction project. Some interviewees mentioned that the use of ICT was reliable and provided a good response rate, but they noted that access was governed by the Internet connection speed. In terms of personal characteristics, ICT users from CC believed that they had enough computer background and clear benefits of using ICT. They also mentioned that ICT is quite simple and provide suitable benefits for them.

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

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

7.6 Summary of chapter

The analysis of research Phase 2 highlights important issues related to the five research questions: (1) What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations? (2) To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations? (3) How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations? (4) How has ICT knowledge been diffused by users within large Australian construction organisations? (5) What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?.

First, research results of the Phase 2 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 these issues and concerns are potentially generalisable as they accord with the literature. Many of these issues highlighted from this study relate to workplace culture and a supportive management that ensures that adequate technical resources are made available.

The extensive discussions and implications of issues raised in this section of this chapter highlights the centrality of human relations issues such as training needs analysis, training and professional development delivery, and creating a supportive workplace. It is clear that people who diffuse ICT innovation must feel motivated and be provided with adequate resources 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 must feel safe to ask for help, and their colleagues must be 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 chapter.

Second, this chapter presented the results of the empirical research on the diffusion of ICT within three large Australian global construction organisations with particular reference to the way in which COPs play an important role in ICT diffusion. In addition, the chapter presents three types of COPs that may represent a sound business practice in ICT diffusion: an institutional COP that help set the strategic direction for ICT development and validating; an implementer or technical support COP that links users with ICT support staff through gatekeepers that can help with the process of interpretation and re-framing problems and difficulties; a supporting work group COP that provides the gatekeepers referred in the technical support COPs; and a project manager/engineer network and collegial support COP that provides much of the necessary one-to-one or small group support. Finally, this chapter's relevance and contribution lies with its connection of the concepts of a COP and the exploration of the nature of the social networks that it generates, as well as its relevance to the domain of ICT diffusion.

Third, this chapter also found the issues that help to increase the understanding of early and later ICT adoption and to identify associated risks. The data from three case studies of large construction contractors show that construction contractors should be aware of the risks of being an ICT early adopter, especially if it requires commitment and participation of external project team members. This paper also discusses issues that organisations should be aware of in their strategic ICT adoption. As the case studies are focused upon leading construction organisations, further research on strategic adoption should be undertaken to compare this group with small to medium construction organisations.

Last, this chapter highlighted that leading construction contactors' current ICT diffusion practices can be categorised by initial adoption and actual implementation. Although the nature of ICT adoption in the 3 cases reflects both proactive and reactive strategic adoptions, the actual implementation of ICT applications in the three cases was quite similar in terms of the support provided to management, technology, and individual users. Most case study organisation ICT users believed that collegial and knowledge-sharing ICT environments are the main factors influencing actual ICT implementation. However, these two factors were informally managed within the case study organisations, which, in turn, can lead to inefficiency in ICT implementation. As a result, these informal, collegial and knowledge-sharing environments should be incorporated into the ICT diffusion model. (See the propose model of ICT diffusion in Chapter 8.)

Chapter 8
Developing and improving the understanding of ICT diffusion

This chapter develops conceptual models that provide an understanding of the ICT diffusion process taking place within a construction organisation. These models, based on research findings from the case study of three construction contractors, can be divided into two categories: *a supportive model* of ICT diffusion and *a constraining model* of ICT diffusion. The supportive model is focused on essential factors that positively influence ICT diffusion by describing the relationships between the factors and the processes of ICT diffusion. Therefore, this model may be used to guide a construction organisation's plans to adopt and diffuse an ICT system. The second model is focused on ICT diffusion constraints in which the adoption and diffusion of ICT may take longer than expected. This model can help us better understand limitations that may restrict and decelerate the adoption and diffusion of ICT innovation. Both the models supplement each other by explaining the facilitating and constraining factors influencing ICT diffusion.

8.1 Supportive ICT diffusion model

The supportive model of ICT diffusion that can be used to help guide the management of technology adoption is based on quantitative data reported in Chapter 5 and further refined and influenced by qualitative data derived from interviews conducted with the three Australian construction case study organisations reported upon in Chapter 6 and Chapter 7. Case study data indicate that similar actors and processes can explain and support our understanding of ICT application diffusion within these construction organisations. The model has extended traditional innovation diffusion theory (Cooper & Zmud 1990, Rogers 1995) by integrating factors and processes that explain ICT diffusion within these construction organisations at two diffusion process levels: initial adoption and actual implementation.

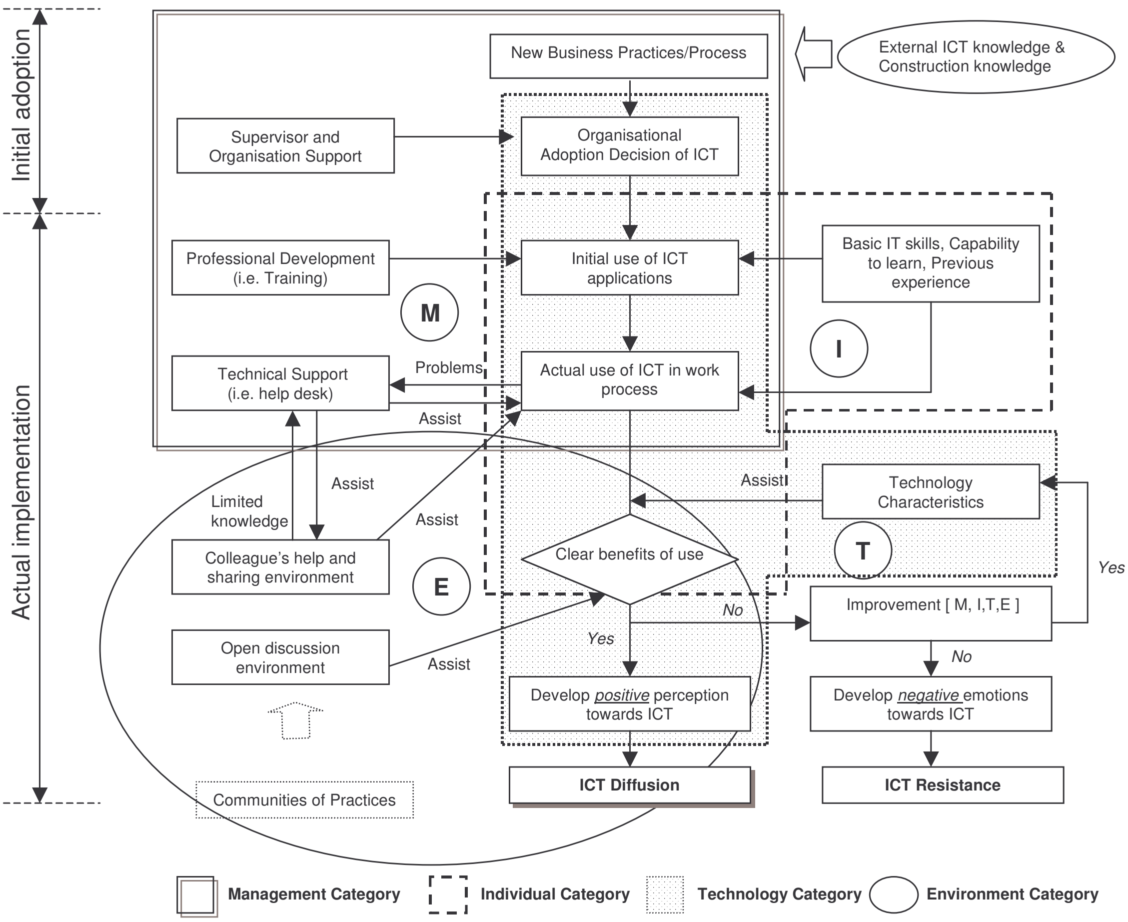


Figure 8.1 The supportive model of ICT innovation diffusion within an organisation

Figure 8.1 presents the model that consists of processes and factors influencing ICT diffusion. The overall model can be described in two stages: initial adoption and actual implementation. In the middle of the diagram, the figure shows the detailed processes of ICT diffusion within an organisation. Firstly, the model indicates how ICT diffusion takes place from initial adoption to actual implementation within a construction organisation. Figure 8.1 also illustrates six key processes of ICT diffusion throughout an organisation: (1) development of new business practices/processes, (2) organisational decision for adoption of ICT, (3) the initial use of ICT applications, (4) the actual use of the ICT applications, (5) clear benefits of their use, (6) development of a positive perception towards ICT and ICT diffusion throughout an organisation.

Secondly, the model shows the relationships of the key categories—management (M), individual (I), technology (T) and environment (E) —that influence the Figure 8.1

diffusion processes. Different shaded areas illustrate the influence of each category of the innovation process. The first category (**M-**management) focuses on the influence of management and organisational support, IT professional development, and technical help desk support. The second category (**I**-individual) focuses on the influence of personal/individual characteristics such as IT skill, capability to learn, and pervious experience of IT. The third category (**T**-technology) focuses on the influence of technology characteristics such as functionality, speed, and accessibility. The final category (**E**-environment) focuses on the influence of the workplace environment such as open discussion and sharing knowledge about ICT.

By using the 3 case studies, the analysis of adoption and diffusion of ICT applications can be demonstrated at an organisational level, individual level and group level. First, at the organisational level, there are two main stages: initiation and adoption (as illustrated in Figure 8.1). These two stages involve IT executives, champions and ICT developer teams. Second, after the organisation decides to invest in ICT applications, the actual implementation is triggered to deliver the ICT application to match user and business functionality requirements of the ICT innovation. Figure 8.1, top left quadrant, illustrates the M-category issues that ICT diffusers/implementers should consider (such as ICT application development and configuration, infrastructure support and training and technical support) at the initial adoption phase. Details of the ICT diffusion process at both the initial adoption and actual implementation phases are further described below.

8.1.1 *Stage 1: Development of new business practices/processes*

Development of new business practices/processes starts when an organisation tries to improve its own internal processes to gain a competitive advantage. This process comprises two sub-processes: knowledge awareness and persuasion. At the ICT innovation knowledge awareness stage, senior managers begin to recognise that the potential ICT application may provide the strategic and essential means to improve core business competence. The business advantage of using ICT may be grouped under two strategies: cost leadership and differentiation (Björnsson & Lundegård 1993, Porter 1985a). From the three case studies, the benefits of ICT were recognised as cost leadership and differentiation. For example, the use of ICT can improve productivity by reducing time and cost to transfer, store and search for information. As a result, the competitive advantage of using ICT may lie in a cost leadership strategy. The advantage of using ICT may also deliver a differentiation competitive advantage over other construction companies that do not have that technology. For example, the way that CA used ICT as a part of that organisation's knowledge management system differentiated it from the way that CB or CC approached this issue.

ICT innovation persuasion occurs when a champion attempts to convince senior executives and managers that adopting a potential ICT application is of strategic importance to the organisation. During this period, the champion proposes several scenarios and benefits of adopting a potential ICT application. After the champion receives support from senior executives and managers, the next step involves exploration of the way that the ICT application could be applied to support business requirements. Champions with strong background knowledge of construction processes, procedures, and the ICT application have a distinct advantage in persuading others to adopt a particular ICT innovation because they can develop a clear relationship between benefits of ICT use and the construction business needs. Once the champion receives the authorisation to continue, the process of persuasion will be repeated through the ICT implementation committee's meetings. In each of the three case studies these implementation vehicles for diffusion were evident. The case studies indicated that such committees consist of the champion and representatives of a group of senior executives, managers, and IT managers, along with the IT development teams involved in the ICT adoption decision. Therefore, the initiation of ICT diffusion at the organisational level depends upon a champion who has sound ICT knowledge, a good background in construction procedures and processes, and involvement in a management role. The first two characteristics of a champion are based on his/her innovation resources and knowledge, whereas the management role appears to be an important element that helps the management group to be convinced to adopt the innovative idea.

8.1.2 *Stage 2: Organisational adoption decision of ICT*

After senior management have been persuaded that the benefits of ICT innovation are real and sufficiently valuable, the adoption decision stage proceeds. This stage consists of exploring the way that the primary adoption of suitable ICT applications can be matched to existing business processes. Therefore existing ICT software in the market that delivers the identified benefits might influence the selection process of a particular ICT product or application system. In the early stages of ICT evolution, the application in the market might be designed for general purposes rather than specific construction work processes. This presents two approaches to ICT adoption. The first is to develop an in-house ICT application if there is no suitable available application whereas the second choice is to adopt an external ICT innovation process that provides a best fit for the organisation's needs.

Generally, the adoption decision is mainly based on matching an available ICT application to construction processes after undertaking a cost/benefit analysis. This is especially true when the organisation wants to gain a competitive advantage by adopting ICT. The benefits of adopting ICT is not, however, limited to financial value but can also be assessed on the basis of non-financial value such as having a single document repository or by generally enhancing communication. At this stage, the adoption decision is made by a group of people including executive managers, the champion, and IT staff.

The initial adoption of the ICT application at the organisational level is followed by the actual implementation of the ICT application through the target individuals or professional users within the organisation. Actual implementation requires more time to develop a positive perception about the ICT application's benefit and to ensure that the ICT application will be adopted and diffused throughout the organisation.

8.1.3 *Stage 3: Initial use of ICT application*

The initial use of the ICT application refers to the process that prepares expected users to learn and understand the ICT application at the group/individual level. First, the organisation should facilitate groups and individuals to develop a background understanding of the ICT application's key features and how these might benefit them. Facilitating that ICT background understanding requires additional staff that would help the champion. This staff member is called an *implementer*. The implementation activity may be similar to promoting knowledge awareness but it is more focused on issues revolving around capability and benefits of ICT use. The objectives of knowledge awareness at the individual/group level are to (1) develop an understanding in expected users within the organisation of how to use the ICT application and its benefits and (2) to get initial feedback from them on the introduction of the ICT application. From this perspective, knowledge awareness may be understood as a two-way process in which knowledge is transferred from the initiating group to targeted users within the organisation that are implementing the ICT application, and targeted users provide feedback for possible improved preparation of and ideas on the ICT application used.

One way to achieve this awareness is to present a '*road show*'. This communicates an overview outline of ICT application benefits and is aimed at persuading the targeted construction project staff and senior project managers who may be interested in adopting ICT at the construction project level. As the construction organisation structure is project based, use of the ICT applications also needs the senior project manager's support for project completion. The case studies indicate that some project managers do not feel inclined to take a risk of adopting ICT on their projects and may block ICT adoption at the project level. This may happen even though the ICT application has been adopted by the organisation on other projects. Therefore, commitment by project managers and engineering managers to initially use ICT applications is essential for the potential success of ICT diffusion at the project level.

Another aspect of knowledge awareness involves training. This develops understanding of the use of the ICT application to actual work processes. In the case studies reported upon earlier in this thesis, most participants received training before starting to use the ICT application. Training should to be conducted by a trainer who has a clear and practical understanding of the ICT application's use. Most participants in organisations surveyed in Phase 1 and the case study participants in Phase 2 of this research thesis agreed that training is valuable for them because it enables them to effectively and immediately use the ICT application instead of learning by trial and error. Users in all three case studies stated that they had a high level of satisfaction in training provided. However, they also made some suggestions for improvement in training, which included:

- A provision for more practical examples
- Use of skills assessment
- Allowing users to trial the application
- A provision of materials and manuals for reference

This suggests that training needs analysis should focus upon basic software/hardware requirements, main functions of ICT applications and examples of using ICT to support the users' work processes. Implementation is taking place at this stage through a process of adaptation where the initial benefits of use prompts continued and additional application of the ICT in ways that might not have been expected at the outset.

The case study data also indicated that group and individual users' experience plays a key role in the user group's understanding of how to best use an ICT application. Users with basic computer skills usually develop an understanding of the ICT application quicker than those who lack the skills because this helps them to increase their absorptive capacity (Cohen & Levinthal 1990). Thus, the characteristics of users probably influence the effectiveness of training provided. A skills assessment would allow groups of users to be classified by their capacity to learn so that training can be provided at an appropriate knowledge level. In summary, a supportive manager, training, and users' computer skills background appear to influence an ICT application's use.

8.1.4 *Stage 4: Actual continued use of an ICT application*

Actual continued ICT application use occurs at the stage in which users routinely accept and engage the ICT innovation in performing their job. Further adaptation also takes place to allow it to suit the needs of their work processes. This happens when organisations provide training and a supporting infrastructure such as computers, user accounts, and Internet connections. Staff in turn, may need to adjust their behaviour and procedures to accommodate ICT use. This may require overcoming problems with ICT functions, resources, and other technical problems. Therefore, the actual-use phase requires active communication and feedback between users and ICT initiative developers. This helps to minimise possible gaps between users' planned and actual ICT use. Transition to this stage involves support at four levels: management, the individuals, technology and the environment. The detailed influence of each the category is described below.

Technical support such as an IT help desk is most important at the management level in assisting potential ICT adopters when they have problems in using the ICT application. In addition, an IT help desk can be used as a tool to receive user feedback. Feedback is important to improve the ICT application's fit with the organisational management needs. In CB and CC, IT staff that are involved with the ICT development teams also operate the IT help desk. Thus they are in a good position to quickly assess problems as they arise. Some participants in CB mentioned that IT-help desk staff take a long time to respond to their problems and some help desk staff did not understand the nature of the construction process well enough to address problems they were trying to resolve. CB's IT help desk staff responded to problems via phone and email. Interestingly, CA uses the electronic web board and allows potential adopters to enter their concerns on their Intranet and use this forum to discuss problems of using ICT applications. This electronic web board can reduce an IT help desk workload by providing a community help facility forum for a community of linked users to answering basic problems of using the ICT application. This type of electronic web-board is one example of knowledge sharing and learning among ICT adopters within a construction organisation using a community of practice (Wenger, McDermott & Snyder 2002, p.24).

Apart from a technical help desk, management should provide an implementer who has the capability of solving common ICT application problems and who can assist during the initial use and implementation of the application at the construction project level. In CB and CC, an implementer is employed to help new potential ICT adopters on construction sites. The implementer has the role of assisting, helping and encouraging ICT adopters at several sites. Most participants agreed that the implementer was a key ICT diffusion resource. However, some project managers argued that the allocation of an implementer to each construction project might not provide the right ICT implementation support mechanism. They argue that it depends on the size of the construction project and the number and ICT-sophistication levels of adopters on the project. If staff have experience and a sufficient capability in using the ICT application then an implementer may be needed at the beginning of the project but then experienced adopters could take over this role to help each other on basic ICT use problems. This may be described as a 'collegial environment'.

Figure 8.1 model's group factor 'individual category' indicates that personal learning capability has a strong influence on the actual use of an ICT application. Two participants from the case study mentioned that they could readily learn how to use ICT applications by themselves without any training. A respondent provided another example of the significance of learning capabilities. She had little background in computers but agreed that her learning from other ICT Internet use helped her to learn and use the particularities of the groupware ICT application. Most of the engineers agreed that when they encountered problems they sometimes tried to learn how to solve the ICT application problems by themselves—as long as they had time to do so. Thus, personal learning could be a key characteristic of ICT adoption.

During the actual ICT application use, characteristics of an ICT application such as its functionality, easy of use, accessibility and connection speed may facilitate or hinder adopters' ICT application diffusion. Potential adopters usually focus on the functions of an ICT application that enhance their performance of traditional work tasks. Thus, the ICT application functions can also influence an individual's adoption decisions. Also, the ease of use of an ICT application can help users because it can reduce their use time. One senior IT manager who is involved in implementing user interfaces mentioned that ease of use is one of the key factors that reinforce an ICT adopter's use. He gave the example of how a reduction in unnecessary access windows in navigating through an ICT application can save time for users and also reduce its complexity. The easier it is to use an ICT application, the more users will adopt it.

8.1.5 *Stage 5: Clear benefit of use*

Clear benefit of use refers to the process by which members have understood the positive outcome of using a technological innovation such as ICT and have accepted it to the extent that they embed its use into their work routines. Clear benefit of use also includes understanding limitations that they may face during the ICT application's implementation. As this stage is reached the organisation's staff will use the ICT application as part of their normal activities. In order to support this condition, managers should also have a clear understanding of how the ICT application assists or inhibits their work. Project managers may become involved in encouraging ICT users to use and adopt ICT applications such as sending e-correspondence to staff instead of communicating on paper. Senior managers, in providing resources and infrastructure, should continuously support this clear benefit of use. They should monitor and receive users' feedback to understand problems and facilitate them to be solved as quickly as possible. This requires two-way communication between ICT users and senior managers/project managers where problems can be openly discussed without fear of reprisal.

From an individual standpoint, adopters may initially feel that it is difficult to apply an ICT application to their work processes. The ICT users' commitment may be an essential factor in their use of the ICT application in their work processes because users have to change procedures and this may cause them temporary discomfort and inconvenience.

After the ICT members within the construction organisation accept an ICT application, the next process is to make sure that work groups and teams embed the application in their normal work processes. The ICT application's characteristics should support and maintain system reliability. Also, the system should be designed to cater for increased numbers of users. Therefore, the organisation should make sure that the ICT application performance retains its functionality, reliability and speed so that it is not degraded.

A sharing and collegial environment was found to be a key factor in enhancing actual use of the ICT application for work processes. Adopters need to understand the important outcome of sharing their experience by explaining how they use the application to achieve a more practical result than previous approaches used for doing their work. The workplace environment needs to be free of recriminations or any sense of failure for not understanding how to use the ICT applications so that when difficulties arise such as data-line access or transfer speed, or if a user interface is perceived as confusing or difficult to use, that such problems are addressed. Also, there needs to be support in terms of benefits being derived from colleagues supporting each other and being rewarded for doing so. This may be structured with explicit tangible rewards or with implied intangible rewards such as career advancement or peer respect for expertise freely shared.

8.1.6 *Stage 6: Positive perception towards ICT and diffusion throughout users*

Positive perception towards ICT and its diffusion reaches a stage where potential users who have adopted the use of the ICT application as a part of their work, continue to contribute to its improvement. Routinisation of the ICT application into their work practices moves to a stage of infusion whereby a continual cycle of fine-tuning, improvement and evaluation takes place. In addition, adopters attempt to convince others of their positive experience. This is where ICT users may become what von Krogh, Ichijo & Nonaka (2000) call a 'knowledge activist'. These people not only effective transfer knowledge about an innovation but they also motivate others, often through using their behaviour as an example of adopting and adapting the knowledge in question.

At this stage, management support should focus facilitating the creation and maintenance of conditions that enhance the ICT users' experience of benefits of the ICT application's use. In addition, top management should create channels through which experienced adopters can share their knowledge with others. Although individual characteristics may reinforce users to start learning and improving their use of an ICT application, the case study findings suggests that a sharing and learning culture is essential to enhance ICT application use. During ICT implementation, the level of ICT use may be limited by an individual's knowledge of how to use it. Improvement in using ICT applications can be increased through people in groups exchanging, learning and combining knowledge. Thus, sharing and learning knowledge in relation to ICT use may be a key factor in innovation diffusion.

Therefore, the ICT application need to be: (1) continually improved through application upgrades; (2) continually improved in the way it is used in conjunction with other processes and ICT applications. This is because a continued experience of improvement can influence ICT diffusion, with adopters finding novel ideas of how to make their ICT use more effective.

In summary, the supportive model of ICT diffusion can help to explain how at different stages the innovation diffusion process takes place leading to complete infusion as the preferred way of working. Senior management has been shown to be in a pivotal position to strongly influence the initiation and implementation stages of ICT diffusion. First, senior managers mould the initial organisational adoption phase by making resources available and demonstrating their high level of commitment. The next stage is to encourage potential users to adopt and use ICT in their daily job through adaptation of the application and its acceptance, routinisation and infusion into normal workplace practices. This actual implementation stage requires a supporting management, technology, individuals, and a collegial environment. Figure 8.1 indicates that at the decision point where clear benefits of use are questioned two situations can arise. If the benefits of ICT use are accepted and routinised, then infusion of the ICT application can take place. However, if the benefits of ICT use are unclear or rejected then improvement in the management, technology or workplace environment needs to be instigated. To better understand how that might take place ICT constraints diffusion models have been developed from case study data and is explained in more detail in the next section.

8.2 Constraint models of ICT diffusion

The above analysis has identified various factors influencing the success of ICT implementation and the importance of IT project managers and senior managers understanding the particular constraints acting upon the diffusion of ICT. The three case studies provided a useful means to explore how this occurs. Improving positive perceptions of the use of ICT and reducing negative perceptions can best be understood by focusing upon how this occurs at the organisation, work group and individual levels. It requires understanding the drivers and constrains that govern acceptance and commitment to change behaviours that influence users to either adopt and internalise changes to new ways of working, or why they may reject changing to a new system. The literature suggested that Peter Senge’s change models (1999, p.14) might offer a useful starting point for this purpose. Figure 8.2, Figure 8.3 and Figure 8.4 illustrate in detail these driving and constraining forces based upon the three case studies described earlier.

The context of the constraint models is developed from two of the case studies focused upon a web-based document management system and one case study that focused on an Intranet document management system. The results show that, at the organisational level, constraints include limited budget for ICT investment, commitment from other project participants, issues of ICT standardisation, and security problems. At the personal level, constraints include levels of basic computer experience, time available to learn, and the identification of clear benefits of ICT use. Finally, constraints at the group level include time available to share information, quality of personal contact, and geographical distance. These three constraints model also help to provide further ICT diffusion process explanation. This enables us to better understand the supportive model in term of barriers that may occur during the ICT diffusion processes. For example, the organisational constraints will affect the initial adoption (Phases 1 and 2) while the individual and group constraints influence actual ICT implementation (Phases 3 to 6).

Thus, understanding these constraints may help us become more aware of possible ICT implementation delays and how best to overcome to these constraints.

8.2.1 *ICT diffusion constraints at the organisational level*

Figure 8.2 illustrates the driver 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 inside 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 on how 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.

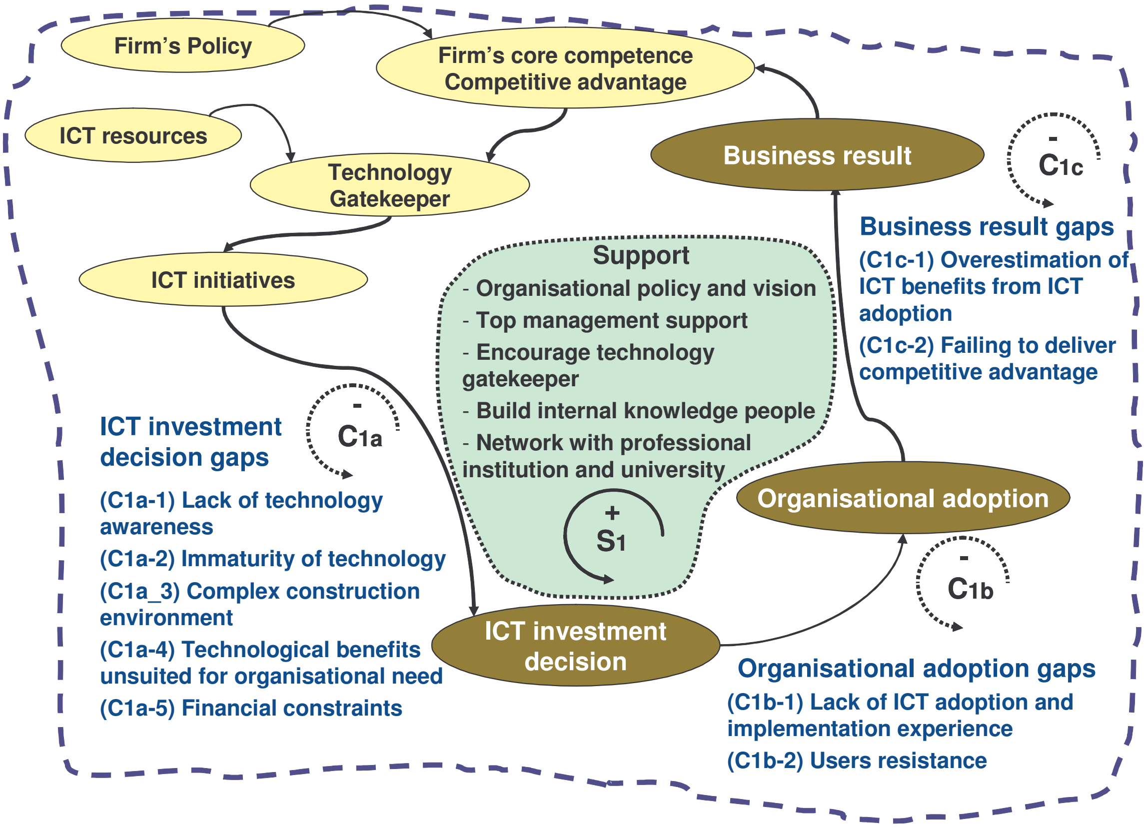


Figure 8.2 Constraints of ICT diffusion within a construction organisation (organisational loop, C1a, C1b, C1c)

Each driver has its own function in influencing ICT diffusion within a construction organisation. The results from the three case studies support the survey findings' conclusions. Figure 8.2 illustrates the supportive cycle S1 that summarises the influence drivers of the model. First, 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. Second, 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, allocate financial expenditure. Thus, to obtain adequate funding, it is necessary to provide clear potential benefits of the

ICT investment to gain the commitment of senior management. Third, 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. Fourth, 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 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, constraining barriers that inhibit the driving cycle's momentum 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.

The loops C1a, C1b and C1c 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 constraints at the individual and group levels. For example, the organisational constraints involve issues relating to an organisational adoption decision 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.

8.2.1.1 C1a) ICT investment decision gaps, C1a

The first constraint loop (C1a) of Figure 8.2 illustrates the 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.

C1a-1) Lack of technology awareness

Lack of technology awareness could be one constraint affecting ICT investment decisions. For example, senior IT managers 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 in different and innovative ways.

C1a-2) Immaturity of technology

Immaturity of technology may cause reluctance to invest. For example, the IT senior manager in CC 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 applications might lead to incompatibility with any future systems that may become an industry standard. Thus, immature technology may require a lot of resources for integration with legacy systems that in turn might demand high ICT development investment including technical specialists and hardware and software development. This may help to explain why many small to medium construction organisations seem slow to adopt ICT innovation. Immaturity of technology, therefore, may be seen as an investment risk because of potential high costs and possible incompatibility. This risk becomes an innovation barrier.

C1a-3) Complex construction environment

The complex nature of the construction environment may influence the ICT investment decision. For example, the IT developer in CB mentioned that the construction industry is slow to adopt most new technologies. Many construction people are very conservative in their thinking. Similarly, the IT senior manager in CA said that the general 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 complex process of construction requires many different supply chain partners of different organisational size and sophistication, each often using their own documentation processing standards. ICT investment decisions could benefit from an industrial standard. However, as noted by the IT manager in CC, 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 existing context of construction environment constraints.

C1a-4) Technological benefits unsuited for organisation needs

In both CA and CB 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 bandwidth 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 appear to be uneconomical.

C1a-5) Financial constraint
Senior IT managers agreed that financial considerations are a major ICT investment decision 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 funding resources and recruiting people with highly specialised skills. The ICT investment needs commitment from senior management to provide the necessary budget and support. Where there are financial constraints, the investment decision for an 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.

8.2.1.2 C1b) Organisational adoption gap, C1b

Figure 8.2 illustrates the second constraint loop (C1b), the organisational level adoption gap. Senior managers' lack of ICT adoption implementation experience in 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.

C1b-1) Lack of ICT adoption and implementation experience
The data suggest that adoption of an ICT application might not be a success because of an organisation's inexperience in ICT adoption and implementation, which may cause several difficulties for 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 CC mentioned that previous adoption of a 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 for users to feel comfortable with it for the organisation to absorb. The precise reasons for this complexity were unclear and the IT implementer could not be drawn further to explicate the nature of this complexity. Thus, inexperience in ICT adoption and implementation may lead to the development of a gap in ICT adoption between what is expected and is what experienced.

C1b-2) ICT user resistance
The uncertain complexity discussed above relating to ICT users' lack of confidence in the application's value may have led to user resistance. It seems reasonable to surmise that users could resist this risk exposure and reject ICT adoption when they feel exposed and placed in an 'unsafe zone' where they are expected to deliver normal or better productivity while trying to master an innovation of dubious benefit.

8.2.1.3 C1c) Business result gap, C1c

In Figure 8.2, the third constraint loop (C1c) at the organisational level is the business results gap. A business result delivers beneficial tangible outcomes from the ICT investment though intangible results may also be recognised as being of value. However, the actual result experienced may not match the identified expected organisational needs and thus be devalued. A perceived lack of value of business results may be hindered by an overestimation (overselling) of expected ICT benefits by innovation champions.

C1c-1) Overestimation of ICT benefits
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, Zammuto & Aiman-Smith 1999). This evaluation may be based on a software vendor or consultant recommendation. An unexpected business result gap 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 may be difficult to estimate all benefits from the ICT investment, especially if the organisation has had no prior significant ICT experience. When the only source of ICT benefits comes from a software vendor or an IT consultant, this information should be used only as guide for evaluation and healthy scepticism should be applied.

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, Young & Davis 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.

C1c-2) Failing to deliver competitive advantage

An ICT application that should in theory deliver benefit may not do so for a number of reasons despite there being a 'reasonable' or conservative expectation of benefits that may be realised. These can include: (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, which is particularly prevalent in the turbulent ICT industry where rapid advances and application redundancy can happen quicker than the organisation's decision making and implementation processes can keep pace with; and (3) A potential competitive advantage cost or through differentiation of services, may not be effectively capitalised upon by the organisation due to mismanagement of this potential advantage.

8.2.2 *ICT diffusion constraints at the individual level*

Figure 8.3 displays constraints of ICT diffusion at the individual level categorised as: a personal learning and support gap, a technology characteristics gap, and an individual use and adoption gap. The dashed line in the diagram shows the people boundary within an organisation. It should be pointed out that, generally, after an organisation has decided to adopt ICT, the focus of staff members within the organisation is moved to the development of a suitable ICT application and to an encouragement of its use—ICT innovation is diffused to expected users within the organisation. This is similar to the process of actual ICT implementation, but from a diffusion perspective. To understand the barriers that may occur at an individual level, this section will explain the constraints of ICT during actual implementation.

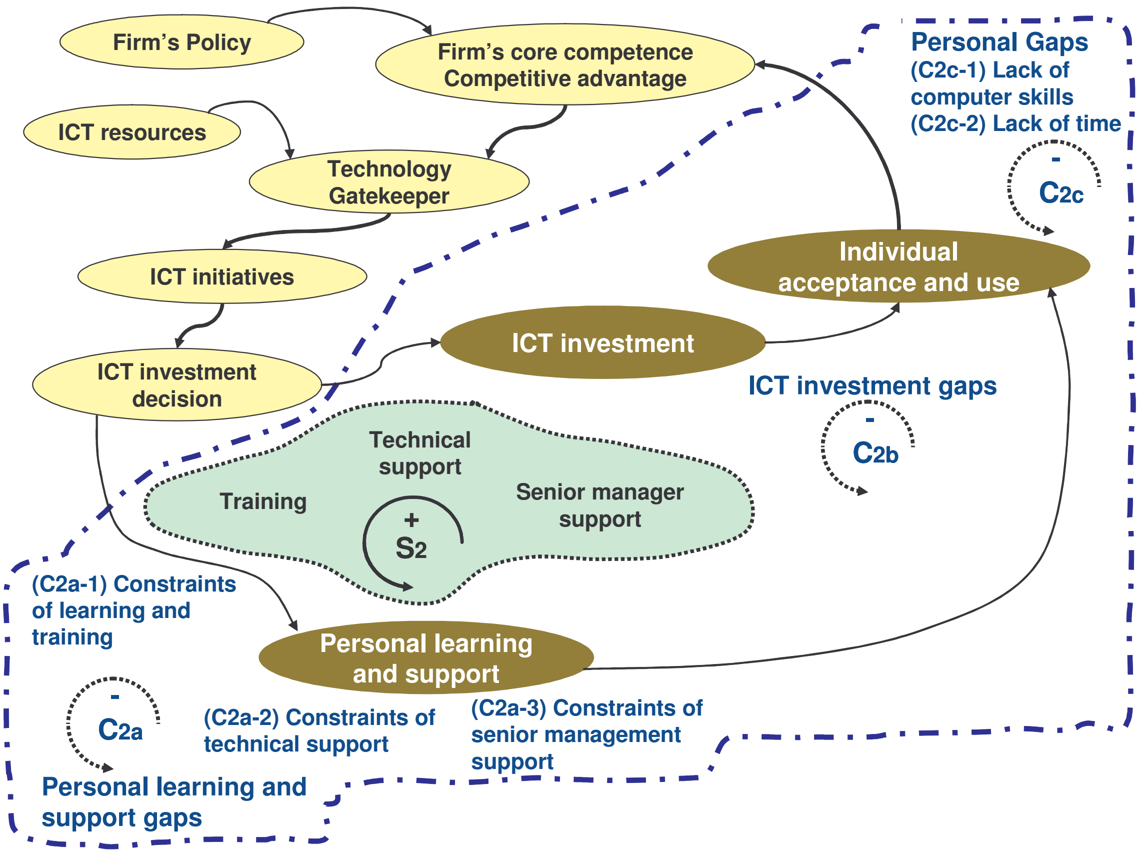


Figure 8.3 Constraints of ICT diffusion within a construction organisation (individual loop, C2a, C2b, C2c)

The key driving cycle S2 at the individual level as indicated earlier is training, adequate technical support and senior management support. A key finding from the case studies is that factors in the categories of management, technology, individuals, and environment all have an influence on actual ICT implementation. But the factors influencing ICT diffusion may be subject to limitations when applied to staff within the organisational setting. For example, it is known that training is one of the key factors in ICT diffusion, yet training may be limited by some constraints such as an unwillingness to learn or the quality of training provided. These constraints may delay the adoption of ICT by users. Based on the supportive factors, constraints on ICT diffusion may be described in terms of: (C2a) personal learning and support gaps (management); (C2b) ICT development gaps (technology); and (C2c) individual adoption gaps (individuals).

In summary, the constraint loops (C2a, C2b, C2c) explain the limitations that may occur at the individual level. In addition, these constraints have negative relationships with support group factors such as management, individuals/people, and technology.

8.2.2.1 C2a) Personal learning and support gaps

From the management support aspect, organisational attempts to provide encouragement to staff will include training, technical help desk, and senior management support. This support may be defined as the main driver of ICT diffusion at the individual level but it has some constraints as described in Figure 8.3. At the individual level, the first constraint loop (C2a) is personal learning and support gap. This gap may result from several constraints such as

- Lack of practical training content
- Limited time of training
- Remote geographical distance
- Response rate of the technical help desk
- Senior project manager's limited time to help and
- Senior project manager's lack of commitment.

These constraints may be grouped into: (1) learning and training constraints; (2) technology support constraints; and (3) senior manager support constraints.

C2a-1) Constraints of learning and training

In relation to constraints of learning and training content, the quality of delivery may be one of the main issues as the training provides only for the basic understanding of the ICT concept, benefits, and know-how. The IT trainer may lack a construction practice perspective. This can lead to gaps as the IT trainer focuses only on the technical context (such as menus, functions, interfaces) but leaves the staff little time to learn how to apply it in their work process. An overemphasis on technical aspects of an ICT application may mean that potential users of that application get lost in their training session and leave with a negative experience and perception of the benefits to be derived. Further, the training approach may provide little time for reflection and making sense of the ICT application. This can inhibit the ICT user's motivation to perceive value in the application. Management pressure for ICT users to simultaneously carry out their normal work and absorb new ways of doing it without expectations of any drop in effectiveness while new patterns of working are mastered can also inhibit ICT adoption.

C2a-2) Constraints of technical support

As most construction staff have little technical background in computer technology technical support constraints arise, as users need an effective support system to help them solve any technical problems. This lack of support may develop into personal learning gaps, as users fail to find a clear guideline on their use of ICT in their work. Eventually users may give up using ICT and may develop a negative perception toward its use. The constraints of technical support also include remote distances and the response rate of the help desk. The latter issue was identified by users as the case when '*help desk sometimes take long time to respond*'. Thus, a low rate of help desk response naturally creates a barrier to ICT use.

Also, inadequate technical support extends to ICT users' helping each other through personal contact in one-to-one coaching (being both technical support and work content support agents) as well as an ICT-support person for ICT users in a one-to-one setting. This may be inhibited by location, access, and time to engage.

As the help desk normally operates via phone or electronic mail, problems of remote distance may be limited to a few cases. However, some users prefer to have 'hands on' assistance to solve an ICT application problem rather than get advice via the phone or by email. In addition, some participants mentioned that users who work on construction sites might get hardly any help compared to those who work in close proximity to the IT department. The problem of remote distance will probably tend to diminish in the near future as the development of remote administrators or virtual networks increases because IT people can login to a user's computer from a remote site just as if they were sitting down with the user.

C2a-3) Constraints of senior management support

This occurs when the project manager, a key person in the construction workplace in supporting users, fails to give active and positive managerial support. There are several reasons for this constraint. First, some project managers may be too involved in their own work routines and provide little spare time to mentor and encourage ICT users. Second, experienced project managers may generally have limited ICT knowledge themselves because their experience profile has been shaped before ICT became so integral to current management practice, hence they may be not be confident in getting involved in somewhat unfamiliar areas of expertise. Evidence from the case studies indicated that some project managers did not put a significant effort into promoting ICT use because they may have perceived this as an unproven project risk. Third, technology investment may be constrained by senior management's lack of confidence in real benefits being realisable resulting in a lack of senior management support. This in turn may lead to difficulties with ICT diffusion within an organisation. Finally, senior managers can impose great pressure on ICT users to 'get on with their job' and either inadvertently or deliberately makes it difficult for users to find time to help each other. Senior managers have a leadership obligation to set an example and recognise the time lag between experimenting with new ways of doing things and regaining lost productivity rates while adapting to innovation. The case study data illustrate examples of this constraint as isolated pockets of management reaction to ICT change.

8.2.2.2 C2b) ICT investment gaps

The characteristics of ICT investment may influence users' adoption outcomes because the reality of actual level of investment delivered may present technical limitations during implementation. For example, ICT hardware performance may be limited by the connection speed. Groupware ICT applications such as email were originally designed to be used with a 56 kilobytes per second (kbps) connection. This transfer rate during normal dialup networking may be slowed down to the hardware limitation of the modem supplied for users. Additionally, there are ICT integration limitations. Also, because there is often an interoperability problem with information exchange protocols, ICT may not be effectively integrated with an enterprise-wide system so that time and energy is wasted with transferring and translating data from one form to another. An example of this is where one project group uses a planning and scheduling software package that is poorly translatable to the package used by others in a project team. ICT investment should include careful consideration of such aspects as speed of transmission, interoperability even between versions of identical software applications (where it is impossible for version 5 being read by version 6 for example) and reliability of both hardware and software. Inadequate ICT investment can deliver poor ICT experiences.

8.2.2.3 C2c) Personal/individual adoption gaps

The last constraint discussed here is the personal/individual constraint that may occur due to (1) personal characteristics that could limit ICT implementation such as lack of computer skills or (2) lack of time to learn new ICT skills.

C2c-1) Lack of computer skills

This could present a significant limitation in ICT application use. Computer skill relates to basic computer hardware and software knowledge rather than that of being an IT programmer. At times, such lack of basic knowledge may lead to the development of a negative perception of ICT use. For example, a few users in the case studies complained that the ICT application was not reliable because it would log them out when they stopped using it for a while. They had to login again. In fact, this problem was associated with security issues that protected them against unauthorised usage of the ICT system. A second example cited in the case studies was that some staff had no basic operating system computer skills or even how to logon to the computer. Clearly, this background knowledge should have been provided to users in order for them to increase their basic computer skills competency. In addition, this knowledge should have been updated to ensure that people are familiar with technology advances. Although young staff would have received basic computer skills as a part of their university or school education, this knowledge can become rapidly outdated because of the swift pace of ICT development.

C2c-2) Lack of time

There is also a lack of time to learn how to resolve potential problems, given that construction workers are usually very busy with site management work and generally have little or no time relief for professional development to learn new skills. It was evident from the case studies that many 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-level staff had experienced. This was a significant problem where only basic computer use-training was provided to ICT-inexperienced staff and ICT users were then expected to learn how to use complex ICT applications by themselves. Limited learning time may thus lead to a gap in individual adoption and use.

8.2.3 *ICT diffusion constraints at the group level*

This section provides an understanding, based upon the case studies, of how groups of individuals within an organisation experience barriers to ICT diffusion of groupware applications. Figure 8.4 provides a model of these group constraints. People are social animals and naturally turn to each other to get help when needed. Thus, while barriers exist as identified at the organisational and individual level, discrete ICT application diffusion barriers also exist for groups. As learning and sharing is also primarily involved at a group level as well as the one-to-one relationship, it is necessary to explore possible constraints at this level.

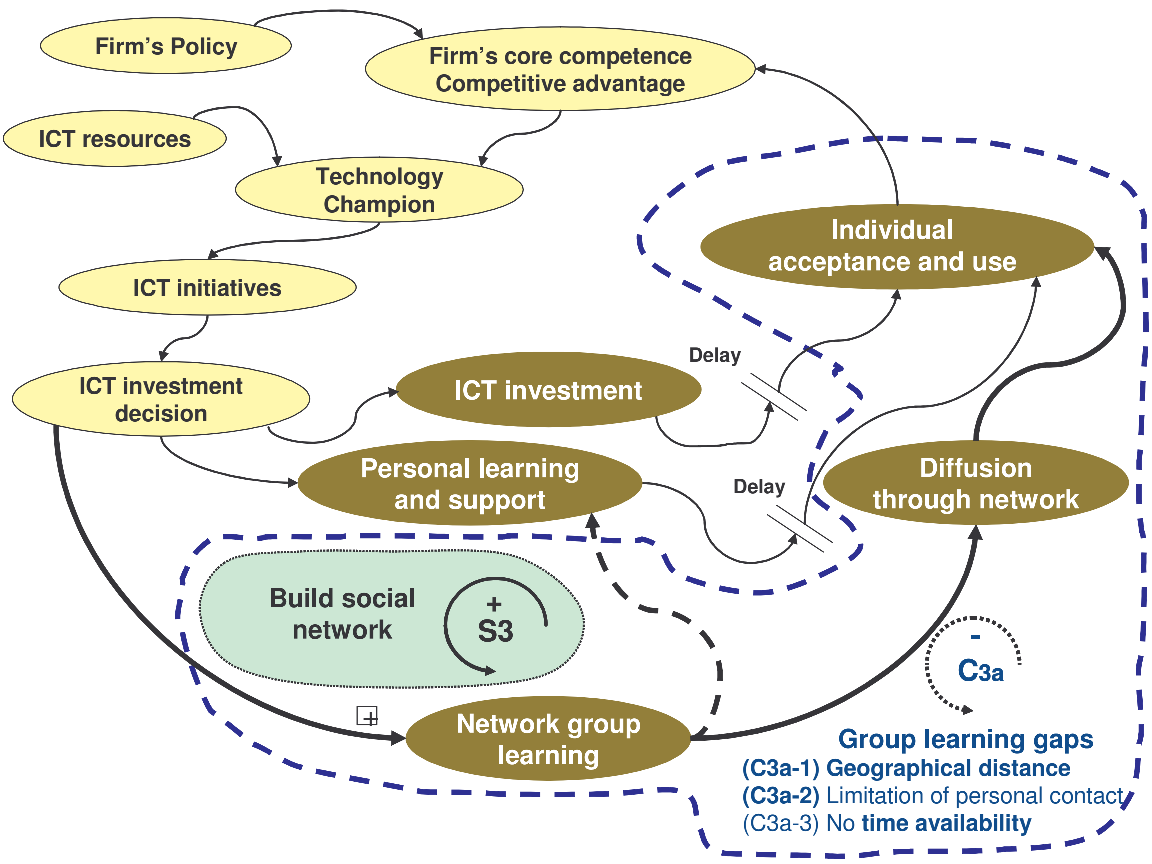


Figure 8.4 Constraints of ICT diffusion within a construction organisation (network loop, C3a)

Figure 8.4 indicates that the support of a group network can be introduced to encourage group learning and sharing and thus provide a driver for ICT innovation at the group level. This has been identified in the literature as being a strategy adopted across many industries and over many centuries for innovations through the ages (Wenger, McDermott & Snyder 2002, p.27). However, there are some constraints that may be barriers put in place to hinder ICT diffusion through a knowledge network such as a community of practice. These constraints are described below. One barrier has been identified to this process, a group-learning gap between how groups could realistically be achieved versus what is achieved.

8.2.3.1 C3a) Group learning gaps

Three aspects of this barrier reflect organisational and individual level constraints discussed earlier in this chapter. These can be categorised as (1) geographical distance, (2) personal contact and (3) time sharing.

C3a-1) Geographical distance

One barrier to group learning is their lack of proximity. Learning by observation was the stated preference because it is easy to understand and very helpful to be able to not only watch and learn but pause, reflect, question and receive responses that help users to link cause and effect. This strengthens the absorptive capacity of ICT users as this cause and effect connection has been cited as one of the key elements of knowledge transfer of what is called 'sticky knowledge' (Szulanski 2003). In particular, many users are familiar with the learning approach of 'show me how' rather than only 'tell me how'. In this circumstance, physical distance may cause problems in relation to experts or colleagues sharing their experiences. On the other hand, some participants who were physically close to colleagues they sought help from received this help very easily. Sometimes they stated that they just called in or walked into the IT department (or a knowledgeable colleague) and asked for help and received it. They mentioned that construction people who worked on site could get help but it may be hard to get a quick and satisfactory response. 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) and this has been reported to occur in the UK on construction projects using a COP management system (Jewell 2005).

C3a-2) Limitation of personal contact

Most participants revealed that they would request help from a person whom they knew and felt close to. In fact, personal contact is not limited by physical distance as some contact people who were previous colleagues got help via the phone. In such cases, the personal contact may get a quick response from past colleagues or others in their network of knowledge contacts because of their relationship with them. ICT users usually from the case studies stated that they request help or learn from their colleagues as a principal source of knowledge. Thus, the more users have strong personal contacts, the more knowledge sharing and learning would likely occur.

C3a-3) No time availability
Most construction people have a lack of time to regularly or methodically share ICT experience with a community of colleagues as they operate under severe time pressures. In CA, the project manager who has experience with ICT mentioned that while he always offered the benefit of his ICT experience it is difficult for him to be constantly available to do so because he is always very busy. A project manager in CB mentioned that people in her construction site are often too busy to share their ICT experience even though they are motivated and would like to do so.

This last barrier to group learning is due to the time that individuals have available to share knowledge. This aspect has pervaded the above discussion. Clearly, without some slack time available in people's lives to be able to respond to calls for help, the delivery of help will be sub-optimal. It is unfortunate that in all case studies and other observations in general throughout the construction industry, anecdotal 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).

8.3 Summary of chapter

In summary, this chapter aims to explain how a range of factors influences the ICT diffusion process in different stages and at different levels. It can be confirmed that the support from management strongly influences ICT diffusion at the initiation and adoption stages. The reason for this is that organisations need investment in ICT to better facilitate knowledge transfer and general management communication and coordination. After the initial organisational adoption decision has been made, the next process is to encourage users to adopt and embed ICT use as part of their job. This actual implementation stage requires a lot of support from senior management, technology, individuals and networks of people working in a supportive workplace environment. To achieve successful ICT innovation diffusion, a framework/model of ICT diffusion was proposed. It aims to help the manager to understand the nature of ICT diffusion, and how the various factors may affect the diffusion process.

Supplementary to the supportive model, this research also provides three constraints models at organisational level, personal level, and group level. The results show that at the organisational level, the constraints are a limited budget for ICT investment, commitment from other project participants, issues of ICT standardisation, and security problems. At the personal level, the constraints are levels of basic computer experience, time available to learn, and clear benefits of ICT use. Finally, the constraints at the group level are time available to share information, qualities of personal contact, and geographical distance. An understanding of these constraints may help the IT project manager to become more aware of the possible delays of ICT implementation through construction firm.

The frameworks illustrated by the models presented have been validated by two means. Research findings were presented to many of the case study participants to seek feedback and reflective comments. The findings were also presented at two industry seminars and several academic conferences. (See list of publications resulting from this research in Appendix E.) Feedback indicates that these models provide a fair and understandable representation of what appears to be taking place in terms of ICT diffusion.

The objectives of this chapter were to provide a means to better understand the ICT diffusion process. Presenting the supportive and constraint models and describing these in detail have delivered this chapter objective.

Chapter 9
Conclusions and recommendations

This chapter draws a conclusion to the thesis by discussing findings from Chapter 5, Chapter 6, Chapter 7 and Chapter 8 that answer the research questions posed in Chapter 1, and discusses these findings in the light of the previous research from the literature review carried out in Chapter 2 and Chapter 3. The chapter begins by summarising the research findings related to the research questions. Then it discusses the potential contribution that this study makes to the construction management discipline. Finally, the chapter ends with a discussion of limitations of the study, implications of the supportive model, and recommendations for future research.

9.1 Main research findings

The main research premise was stated in Chapter 1 as:

Current construction IT management literature does not adequately explain actual ICT implementation from an intra-organisational perspective, and this may contribute to the failure and/or a slow diffusion of technology within construction organisations.

The core research is aimed at addressing five main research questions:

1. *What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations?*
2. *To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations?*
3. *How do ICT diffusion factors influence the diffusion processes within large Australian construction organisations?*
4. *How has ICT knowledge been diffused by users within large Australian construction organisations?*
5. *What current ICT diffusion processes (adoption strategy and actual implementation process) are practiced within large Australian construction organisations?*

9.1.1 *What are the essential factors that influence ICT diffusion at the actual ICT implementation stage within large Australian construction organisations?*

The findings from both quantitative and qualitative data indicate that 11 factors influence ICT diffusion during implementation within Australian construction organisations. The analysis of a survey questionnaire addressing ICT experienced users identified eleven factors that are grouped from 46 variables. These factors are:

- F1 Professional development and technical support
- F2 Clear benefits of use
- F3 Supporting individual/personal characteristics
- F4 Supporting technological characteristics
- F5 Supervisor and organisational support
- F6 Supporting an open discussion environment
- F7 Supporting tangible and intangible rewards
- F8 Collegial help
- F9 Positive feeling towards ICT use
- F10 Negative emotions towards ICT use
- F11 Frustration with ICT use

These eleven factors were also confirmed by the case studies of three leading Australian construction contractors in which one participated in the quantitative survey. The results confirmed that these eleven factors influence ICT diffusion at the actual implementation stage.

While factor 9 has an opposite relationship to factor 10 and factor 11, these factors may be grouped together to explain a composite feeling towards a personal perception of ICT. Another aspect of these factors is that they can be classified as internal and external factors that facilitate intra-organisational ICT diffusion during implementation to determine its success. The external factors highlighted during interviews were data ownership and ICT standards, information overload, commitment for ICT use, intellectual property and associated legal issues. These factors are consistent with current ICT implementation studies at an industrial level

(Alshawi & Ingirige 2002, Gyampoh-Vidogah, Moreton & Proverbs 2003, Laage-Hellman & Gadde 1996, Love *et al.* 2001, Nitithamyong & Skibniewski 2003).

9.1.2 *To what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations?*

After the factors were identified, it was interesting to find out 'to what extent have the ICT diffusion factors been experienced by ICT users within large Australian construction organisations'. Based on results of quantitative data in Table 5.8, ICT users experienced high levels of individual/personal factors including 'supporting individual/personal characteristics' (F3) and 'clear benefits of ICT use' (F2). The results show that ICT users perceived these factors influencing the ICT diffusion during implementation. In a similar vein in the qualitative results from interviews, these two factors were also experienced highly by ICT users in cases A and C and moderately by ICT users in case B (see Table 7.5). Therefore, this suggests that ICT diffusion is more likely to succeed if the factors related to individual/personal characteristics and clear benefits of ICT use are perceived as being of high value by expected users.

Supporting environmental factors including 'supporting an open discussion environment' (F6) and 'Collegial help' (F8) were experienced by ICT users at a fairly high level (see Table 5.8). This can be interpreted to mean that ICT users felt positive about their open discussion environment when they felt that they were having a high level of support from their colleagues. The fairly positive experiences about an open discussion environment were also supported by interview case study results presented in Table 7.5. Most respondents felt free to openly discuss their problems with IT implementers and their colleagues. However, some respondents mentioned that they have their own work responsibilities and it is often difficult for them to get sufficient time to create an open environment for discussion on ICT improvement. Consequently, it could be inferred that ICT diffusion is more likely to succeed if expected users perceive the factors related to 'supporting an open discussion environment' and 'collegial help' as scoring a high value—this support extends to providing time to reflect and exchange knowledge.

Based on quantitative data, ICT users indicated a relatively high perception of 'supervisor and organisational support' (F5). This means that users received a relatively high level of supervisor support, which in turn facilitates ICT diffusion such as provision of computers, a user account and Internet access. This is especially so where most of the senior managers and project managers are committed to the use of ICT. Similarly in the findings from interviews, users in Case A and Case C perceived high levels of supervisor and organisational support while those in Case B perceived a medium level of support. Most users agreed that support from the supervisor and the organisation is one of key factors that influence ICT diffusion within an organisation.

However, users perceived that they only had a moderate level experience of the factor, 'professional development and technical support' (F1). This could be interpreted as the users' feelings of misgivings about their level of professional development and technical support, rating them only at the average/medium level. In addition, it was also evident that organisations leave their employees with insufficient time to reflect and think upon and learn from their experiences and to consolidate lessons learned. The comments and results suggest that most users did not have time to learn how to adequately use ICT applications or get the opportunity to trial and experiment them. While users in all cases were satisfied that the potential for 'professional development and technical support' motivated them to use ICT, they perceived a need for improvement and for provision for re-training in future if an ICT system is to be expanded and upgraded.

Based on quantitative findings, the results of the factor 'supporting tangible and intangible rewards' (F7) clearly indicated a perceived low level of organisational support in terms of rewards for sharing knowledge and for assisting in the development of a learning environment for ICT users. It was found that intangible rewards (respect, admiration, self-fulfilment, feel good about myself) have been ranked more highly than tangible rewards (advancement, additional pay, security, or better job prospects). This indicates that intangible rewards may slightly influence the ICT use. Interestingly, the respondents perceived that they obtained rewards from their ICT use rather than from sharing knowledge about their ICT use. Similarly in the qualitative findings, the users in all the three cases indicated a similar pattern of 'supporting tangible and intangible rewards'. Most of the users indicated that this factor might not be an important factor influencing the diffusion of ICT. They perceived ICT use as a tool that enhances their work productivity. This can link back to intangible rewards such as self-fulfilment.

ICT users experienced that 'supporting technology characteristics' (F4) have a moderate influence on their use of ICT. This could be interpreted that ICT applications in these three organisations somehow needed to be improved in terms of speed, reliability, and accessibility. This finding was also supported by additional comments in the questionnaire. Some had perceived a need for computers and/or increased access (i.e. line speed to be upgraded). In addition, users expressed a need to have more Internet workstations at the construction sites. However, users felt that the existing ICT applications had high functionality and ease of use. These findings are also supported by the interview case studies, in which it was found that users registered a moderate level of response for the factors of technological characteristics (F4).

Factors F9 (positive feeling towards ICT use), F10 (negative emotions towards ICT use) and F11 (frustration with ICT use) involve the interaction between the individuals and ICT technology. However, factor F9 has the opposite relationship to factors F10 and F11. For example, if users showed highly positive feelings towards ICT, it implies low negative emotions and frustration with ICT use. Therefore, these factors may be grouped together to explain a composite perception of ICT use. Based on F9, a positive feeling towards ICT use, most users fare moderately well with regard to this factor. This finding corresponds to the users' experience of technology characteristics.

9.1.3 *How do factors influence the diffusion processes within large Australian construction organisations?*

Findings from the ICT diffusion case studies within three construction organisations can be categorised into two factors groups: intra- and inter-organisational factors.

Based on the case study, intra-organisational factors can be grouped into four main categories: management, individual, technical, and environmental. These categories could then form an ICT diffusion framework within construction organisations. This framework details factors under four main categories. Intra-organisational factors are focused on issues *within* the organisation such as management, individual, technical and workplace environment. On the other hand, inter-organisational factors are focused on the ICT use issues of dealing with externally linked project team supply chain members: consultants, subcontractors, and suppliers. These issues are concerned with ICT ownership and standards, information overload and team commitment to ICT use.

9.1.3.1 Management factors (F1, F5, F7)

Three main management factor groups affecting ICT diffusion were: professional and/or technical development support; supervisor and organisation support; and reward systems.

- The first factor revolves around 'professional development and technical support' (F1) that helps ICT users to understand the basic advantages and operational features of an application to get them to start using it effectively. This will start diffusion throughout the organisation, especially for users who have a low-level of background knowledge of the ICT application and might otherwise feel lost, anxious or fearful.
- The second management factor is 'supervisor and organisational support' (F5). The findings suggest that an ICT application's diffusion is strongly influenced by the supervisor and organisational support behaviours. The mediating factor, benefits of ICT use, becomes clearer and triggers motivation to support the budgeting and application of support resources.
- The third factor, management involvement, is an issue of 'supporting tangible and intangible rewards' (F7). The interview results suggest that tangible rewards were believed to be unnecessary for ICT diffusion, whereas intangible rewards through self-fulfilment may have only a minor influence on ICT diffusion. Evidence from interviews suggests that developing tangible reward systems has been considered too difficult to tackle and thus is poorly considered by senior management.

9.1.3.2 Individual factors (F2, F3, F9)

- ‘Supporting individual/personal characteristics’ (F3) is a core element of ICT diffusion because it is the individual ICT user who bears the ultimate responsibility for enhancing the work processes through the application of ICT tools. Without the users’ adoption of the ICT application, diffusion within the organisation cannot occur. An individual’s skill is their personal capacity to apply and transfer general ICT skills to their personal work. People have various requirements at different times for using a range of ICT applications in their work. Those who are capable of applying it to their work processes may be computer literate and have had an experience of similar technologies.
- ‘Clear benefit of use’ (F2) however, might also be dependent on an individual’s characteristics such as experience and ICT skill. Individuals’ initial experience of an ICT application is important because they may not immediately recognise benefits they are gaining from its continual use.
- ‘Positive feeling towards ICT use (F9) has an influence on ICT diffusion because it reflects upon the quality of the ICT users’ experience. It also impacts on future perceptions towards any new systems that may be introduced in the future. However, if the ICT users feel frustrated with ICT use (F11), they will instead develop a negative perception (F10) towards ICT use.

9.1.3.3 Technology factors (F4)

The influence of ‘supporting technology characteristics’ (F4) on ICT diffusion could be addressed at three levels: individual, management, and environment. 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). 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, which is essential because ICT is designed to deliver immediate interactive communication and, therefore, transfer rates must be adequately fast; and
- User accessibility, this relates to ICT applications being readily available through web-based Internet access with user-friendly standard browsers or other user-interfaces.

9.1.3.4 Workplace environmental factors (F6, F8)

The workplace environment defines the context of ICT diffusion. The term 'environment' in this study refers to the level of 'open discussion environment' (F6) and 'collegial help' (F8) in the workplace—which can be based on physical facilities or on virtual communities. This environment provides an important support to the novice user and also increases the diffusion within workgroups using an ICT application.

- The *open discussion* environment and a *collegial help* environment have a slightly different support role to ICT diffusion. Generally, an open discussion environment would encourage the users to discuss their problems free from recrimination. This allows the users to ask for an opinion on how to use or to improve the use of the ICT application and for a dialogue to take place among colleagues to jointly solve problems. In addition, an open discussion environment helps the ICT diffusion by providing a feedback channel for ICT improvement.
- While *collegial help* will facilitate ICT diffusion by sharing and transferring ICT knowledge among experienced and inexperienced users. This collegial help is also critical for users to learn to adopt and adapt ICT at the actual implementation stage. This was claimed as a significant and pivotal source of support that ICT users seek to further their ICT knowledge. However, collegial help may be limited by the users' knowledge to know what to ask for and of course colleagues' knowledge of how to respond. Thus, organisations should provide an ICT implementer to build up ICT users' capability and self-confidence to

advance ICT diffusion. Once a critical mass of ICT users have self-confidence and ICT experience, this group can develop a sharing and learning culture to facilitate ICT diffusion throughout an organisation.

Additional findings indicate four inter-organisational factors: ownership and ICT standards; information overload; commitment of ICT use; and intellectual property and legal issues. It was found that the diffusion of ICT within an organisation is also influenced by these external factors. Thus, earlier ICT adopters in leading construction organisations should concern themselves with these issues if external users (within their supply chain or engaged in their projects) are required to make full benefit of their ICT systems.

9.1.3.5 Ownership and ICT standards

From a supply chain 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.

9.1.3.6 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 are only partially interested in the issues contained in a transmitted message. The data suggests that information overload was a problem that featured in communication between companies using ICT.

9.1.3.7 Commitment of ICT use

Conceptually, ICT was designed to help communication and coordination within and between project teams. The effective use of ICT needs a commitment from all the project participants. Otherwise organizations that communicate electronically through

ICT would need to send the documents on paper as well to those organisations that did not use ICT.

9.1.3.8 Intellectual property and legal issues

The ICT implementer and senior project manager in one case study raised the issues of legal and intellectual property. They mentioned that sending electronic document such as construction drawings or document files to other project participants raised legal validity problems that was of concern to them and inhibited their full support for the ICT application.

Also, in Chapter 8 three models were developed from the above four main categories that described and illustrated drivers and barriers to ICT diffusion at the actual implementation stage. Figure 8.2 illustrated drivers and barriers at the organisational level. Important barriers were identified associated with gaps in the optimal situation versus the generally experienced conditions that relate to the ICT investment decision; organisational adoption, and the impact of business results. Figure 8.3 illustrated drivers and barriers at the individual ICT user level. Important barriers were identified associated with gaps in the optimal situation versus the generally experienced conditions that relate to personal learning support, the ICT investment, and individual acceptance and use. Figure 8.4 illustrated drivers and barriers at the ICT group user level. Important barriers were identified associated with gaps in the optimal situation versus the generally experienced conditions above those noted at the individual level that relate to developing group learning networks. All factors concurred with, and related to, these three levels drawn from the framework of the fundamental four categories of ICT diffusion factors.

9.1.4 *How has ICT knowledge been diffused by users within large Australian construction organisations?*

The result of the qualitative survey in Section 5.6 shows that most ICT users obtained their ICT knowledge with their colleagues' help. The qualitative results also confirmed this and provide deep understanding of how ICT knowledge has been diffused throughout the users within large Australian construction organisations. From the analysis of the cases of qualitative interviews, the three main actors involved in disseminating ICT knowledge are: IT executives, IT implementers or IT staff, and project managers and experienced users. Each actor provides a significant and slightly different support to the users. The analysis from Section 7.2 highlights three kinds of COPs within-organisations that can facilitate the ICT diffusion from strategic to operational levels. 'Institutional' COPs provide the strategic direction for ICT initiative and development. It transfers ICT knowledge to senior managers. 'Implementer or technical support' COPs support users by providing the technical ICT knowledge, encouraging the use of ICT throughout users, and solving problems with the actual use of ICT at operational level. 'Project manager/engineer network and collegial support' COPs play the essential role of supporting users and developing a sharing culture of ICT experience among experienced and non-experienced users. Furthermore, the results show external organisational COPs may effectively harness such resources as past colleagues, friends, and members of professional institutions.

9.1.5 *What ICT diffusion processes (adoption strategy and actual implementation process) are currently practiced within large Australian construction organisations?*

The current practices of ICT diffusion could be categorised into initial adoption strategy and implementation processes. From the case studies, ICT diffusion at the initial stage can be summarised as follows:

- CA and CB chose to embrace a proactive strategy of ICT adoption whereas CC selected a reactive strategy of ICT adoption;
- ICT adoption in CA and CB was influenced by both demand-pull and technology-push while CC was more influenced by technology-push than demand-pull;
- The adoption decision in CA and CB was centralised (top-down) whereas the adoption decision in CC was decentralised (top-down as well as a bottom-up COP);
- The adoption of ICT in all three cases is supported by groups of top business managers and senior IT managers;

- The adoption approach in CA is defined as in-house development, CB's approach is based on in-house development plus IT consultancy, and CC relied on outsourcing (external web-based service); and
- In the three cases described, it is difficult to measure ICT adoption benefits and use in quantifiable terms but in all cases, users expected to gain benefits from ICT adoption by improving team communication, information exchange, having an accessible document repository, and a developing a project register of past events (a project history repository).

Although the ICT adoption in the three cases reflects both a proactive and reactive strategic adoption, the implementation of ICT applications within the three cases was quite similar in terms of the support provided by the management to technology and individual users. Most ICT users in the three cases believed that collegial help and knowledge-sharing ICT environments were the main factors influencing the implementation. However, these two factors were informally managed within the organisations—this can lead to inefficient ICT implementation. Realistically, these informal collegial and knowledge sharing environments should be incorporated into an ICT diffusion model to better capture the potential benefits that people-infrastructure can offer. It could be concluded from these case studies and the quantitative study that the main process of implementation is focused on training and technical support, senior management support, user characteristics, and ICT characteristics. Training and technical support, and ICT characteristics were *formally* managed, but support from senior management or project managers, characteristics of users, and a sharing and open discussion environment were *informally* managed.

9.2 Contribution of the research

As outlined in Chapter 1, this thesis aims to achieve four main objectives. The first is to identify factors that influence ICT diffusion during actual ICT implementation within large Australian construction organisations. The second is to explore current ICT diffusion factors and processes that have been experienced by ICT users within large Australian construction organisations. The third is to investigate how these factors influence ICT diffusion processes within large Australian construction organisations. The fourth is to identify how ICT knowledge has been diffused by users within Australian construction organisations.

This research contributes to the body of knowledge in at least four areas. The first contribution concerns the study of ICT diffusion during actual implementation. It helps us to understand the nature and extent of intra-organisational factors influencing ICT diffusion within large construction organisations. In addition, the integration of three main concepts can assist our understanding of both static and dynamic factors that influence ICT diffusion at actual implementation. This study highlights the eleven main factors influencing ICT diffusion, which can be further categorised into management issues, individual issues, technology issues and work place environment issues.

The second contribution is to knowledge management theory by illustrating how ICT knowledge has been diffused throughout users within construction organisations. It is focused on explaining the roles of communities of practice (COPs) that support the diffusion of ICT innovation within construction organisations. From the three cases, several types of COP networks emerge: institutional, implementer or technical support; project manager/engineer focused; and collegial support. These three types of within-organisation COPs can be developed to positively contribute to ICT diffusion.

The third contribution is to IT management in construction theory by introducing and explaining the processes that occur during actual ICT implementation. The research highlighted the different stages of ICT diffusion as initial adoption and actual implementation. Importantly, the initial adoption process was shown to involve development of new business practices/processes for organisational ICT adoption. Both stages involve key personnel such as IT executives, champions, and ICT development teams. On completion of the organisational adoption stage, the actual implementation stage begins with the transition of ICT adoption and its adaptation to expected users throughout the organisation. These stages are embedded within four main transformation levels of ICT use: (1) initial use of an ICT application; (2) actual continued use of an ICT application; (3) recognition of clear benefit of use, and positive perception towards ICT leading to confidence in its use; and (4) adaptation for individual needs and widespread diffusion of its use throughout the organisation as an embedded feature of the workplace culture. These four stages will be supported by management factors, individual/personal factors, technology factors, and workplace environment factors.

The last contribution is the proposed supportive and constraint models that describe the way that factors influence ICT diffusion during the actual implementation phase and the understanding that this brings of the barriers that may occur during actual implementation of ICT initiatives. The supportive model is focused on essential factors that positively influence ICT diffusion by describing the relationship between these factors and the processes of ICT diffusion. Therefore this model can be used as a practical guide for construction organisations to plan to adopt and diffuse ICT use. The second model describing the dynamics of ICT innovation diffusion at the organisation, individual and group level is focused on ICT diffusion constraints. This model helps to explain the limitations that may hinder the adoption and diffusion of ICT during the actual implementation phase. Thus, both supportive and constraint models help us to explain how ICT diffusion is influenced by internal and external agents and forces.

9.3 Recommendations

The result offers both management and theoretical recommendations that provide a contribution to relevant theory and construction management practice in linking change management, knowledge management and innovation diffusion.

9.3.1 *Management recommendations*

The findings of this study indicate that major Australian construction organisations are currently adopting ICT to improve their management processes. However, their implementation in practice still lacks a full understanding of the actual ICT implementation process that can enable them to rapidly adopt ICT and adapt it quickly for their needs. Thus, this study provides several management recommendations from an intra-organisational diffusion perspective.

First, management should focus on this study's identified key ICT diffusion factors such as management factors, individual/personal factors, technology factors, and workplace factors. Management issues require the organisational and managerial support to ensure that ICT users received enough technological infrastructure and encouragement to begin to use ICT applications. The role of project managers on construction sites in supporting ICT use is also important to inspire ICT users' commitment.

Management should ensure that training and technical IT support should be adequately resourced. This helps to increase the level of ICT skills and self-confidence of users to facilitate its initial use. In addition, technical IT support assists ICT users by continuously solving their problems with using ICT. However, before providing ICT training, needs analysis should be undertaken to evaluate IT users' background in order to provide suitable training programs that suit their skill level and requirements. In addition, these research findings indicate that organisations leave their employees with insufficient time to reflect and think to be able to learn from their experiences and consolidate lessons learned.

In terms of supporting rewards, tangible rewards (such as advancement, additional pay, security, or better job prospects) may not be necessary because users currently feel that ICT is a useful tool to support their work processes. Users are more focused on intangible rewards (such as respect, admiration, self-fulfilment, feeling good about themselves). Therefore, the management should provide recognition and encouragement to users while they use ICT. However, management may also consider ways of establishing measurement instruments of the impact of ICT use and mentoring others to effectively use ICT with associated rewards related to tangible organisational benefits.

Individual/personal factors help ICT diffusion at the actual implementation stage as the users gain a positive experience and so a positive attitude can facilitate their self-motivation to adopt ICT. This study found that ICT users' experience during their tertiary education, personal computer use, or previous work experience helps them to develop a basic understanding of ICT technology. However, not all users have a strong computer background, especially many senior managers and foremen. In addition, some users may not fully understand the benefits of ICT use. As a result, the success of ICT diffusion requires awareness training to develop their background skills and show how the ICT will benefit them (O'Brien 2000).

ICT characteristics are essential factors that influence user perceptions of ICT use. Basic ICT characteristics include advantage of ICT use, ease of use, speed and reliability, availability etc. If these characteristics are not met to a user's satisfaction, then organisations should improve ICT hardware, software and network operational characteristics to suit users' requirements. Otherwise, users may develop a negative perception of ICT and avoid using it. However, it should be recognised that ICT applications may not suit all users. Therefore, the organisation should define the scope of ICT use and the role of staff to create a people-ICT alignment. This would help define what main ICT application functions are best suited to any individual's role.

To ensure the success of ICT diffusion, organisations should ensure the development of open discussion and collegial help within their work place environment. Open discussion provide an opportunity for users to share their experience of ICT use. Due to the limitation of geographical distance, users may develop a web-based COP that allows them to put forward suggestions or seek answers to questions and obtain feedback. In addition, collegial help often occurs at construction projects or within the main construction office. It was clear that personal contact underlines collegial help; therefore organisations should create social activities that bring individuals together to get to know each other. One such type of development of sharing ICT knowledge is a COP. COPs should be encouraged, developed, and supported by management.

The above highlighted internal factors are not the only driving and limiting factors for ICT diffusion. This research has highlighted external factors drivers and barriers to ICT diffusion such as ownership and ICT standards, information overload, commitment of ICT use, and intellectual property and legal issues. These issues should be adequately addressed and their limitations to ICT users better understood.

A further recommendation relates to management processes of actual ICT implementation. This study's results highlight the five stages of ICT diffusion during actual implementation. These processes provide a framework or guide of how to best diffuse ICT into large construction organisations. In addition, the understanding of the

ICT diffusion stages helps managers to focus on ICT diffusion factors that relate to specific stages as they arise. For example, heavy investment in training support may be required at the initial adoption stage for awareness, identification of benefits and showing people how to use ICT applications, while technical help desk support may be needed at actual implementation to provide trouble shooting advice and advanced training to improve the use of features that may be available but rarely used.

9.3.2 *Theoretical recommendations*

This research has discovered some different findings to those reported in other studies because this study focuses on both factors and processes. In addition, the research highlights the relationships between factors and processes that lead to an improved understanding of ICT diffusion at actual implementation more than was evident from the current literature (see Figure 3.2). This research found similar factors influencing ICT adoption at the industrial and organisational level categorised into management, individual, and technology issues. However, this study's findings illustrated the dynamic of these same factors during the actual implementation phase (see in Figures 8.2, 8.3 and 8.4). The dynamic of these factors' interaction at the actual implementation illustrates the challenges facing ICT users throughout and within organisations when adopting ICT. Therefore, this study has contributed to a more holistic appreciation of what is happening at both the adoption decision phase of ICT as well as during actual implementation.

This research also integrates change management and knowledge sharing and learning theory to DoI theory, which helps to better explain ICT diffusion at the actual implementation stage. These dynamic factors help researchers to better understand how organisations manage change and develop a sharing and learning culture that overcome the limited focus on static factors that influenced initial ICT adoption.

9.4 Recommendation for future research

This research is focused on ICT diffusion within large construction organisations at the actual implementation stage. Thus, it will be useful to explore and compare the factors and processes of ICT diffusion within the small and medium construction enterprises. This future research will be useful to understand the main driver and barriers that influence small and medium enterprises (SMEs) because they lack the resources and expertise that is available in large construction organisations such as those studied in this thesis. In addition, the practice of ICT diffusion processes within construction SMEs will help large construction organisations that can be categorised as the early adopters of ICT innovation. Therefore, the understanding of the nature of ICT diffusion within construction SMEs will help the early adopters plan and manage their diffusion at intra-organisation level properly. Further, study of ICT diffusion among members of a supply chain that includes both large companies and SMEs would be useful to highlight how to overcome problems identified in this research relating to double-handling information using both paper and electronic exchange of data/information.

This research is limited to one type of ICT application—an electronic document management system (EDMS) that helps to communicate and coordinate both construction information and documents within construction organisations and projects. Therefore, it will be interesting to explore the diffusion of other ICT applications such as personal digital assistant (PDA), other advanced web-based project management systems, and electronic commerce portals. A future study of this kind could compare the nature of ICT diffusion at actual implementation from both factor and process perspectives.

Leadership and policy is also found as key factors that determined the organisational adoption and implementation. Thus, it should be interesting to study the impact of leadership style and policy that influenced the diffusion of ICT within construction organisations. As leadership has a strong influence on the organisational vision related to ICT diffusion, the nature of this influence on the direction of organisational strategy such as being an early adopter or late adopter could be a further useful topic of study.

Finally, it may be interesting to compare organisational culture factors that influence ICT diffusion at the actual implementation stage. Such a study could explore ICT diffusion within the same organisation but focus on offices or sites in different countries. This future research could help global construction enterprises with branches around the world.

9.5 Summary of chapter

This chapter provides a summary of research findings and draws the research findings together to answer the research questions identified in Chapter 1. The findings provide answers to research questions and specifically contributed to the body of knowledge of ICT diffusion at the actual implementation stage. It integrates ICT diffusion factors derived from innovation diffusion, change management, and knowledge sharing and learning theory and provides an holistic understanding of factors that influence ICT diffusion at the actual ICT implementation stage. In addition, the case study findings also provide a deep insight into ICT diffusion processes. This research extends and modifies DoI theory to help us understand ICT diffusion processes. Furthermore, the constraints models also develop a useful understanding of barriers and limitations that may occur during ICT diffusion processes. Although the research provides the understanding of ICT diffusion at actual implementation, the research still faces limitations inherent in case study research and future research needs were highlighted.

References

ABS 1999, *Business use of information technology, Australia, 1997-98, preliminary*, Commonwealth of Australia, viewed July 11,2002 <http://www.abs.gov.au/>.

ABS 2001, *Business use of information technology, Australia, 1999-2000*, Commonwealth of Australia, viewed July 11,2002 <http://www.abs.gov.au/>.

ABS 2002, *Business use of information technology, Australia, 2000-01*, Commonwealth of Australia, viewed April 11,2002 <http://www.abs.gov.au/>.

ABS 2003, *Business use of information technology, Australia, 2001-02*, Commonwealth of Australia, viewed April 11,2002 <http://www.abs.gov.au/>.

Abudayyeh, O. 1998, 'Intranet-based project control systems for the construction industry', paper presented to Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA.

Abudayyeh, O., Temel, B., Al-Tabtabai, H. and Hurley, B. 2001, 'An intranet-based cost control system', *Advances in Engineering Software*, vol. 32, no. 2, pp. 87-94.

ACIF 2002, *Innovation in the Australian building and construction industry - survey report*, Australian Construction Industry Forum, viewed July 11, 2002, <http://www.acif.com.au/>.

Agarwal, R., Tanniru, M. and Wilemon, D. 1997, 'Assimilating information technology innovations: Strategies and moderating influences.' *Engineering Management, IEEE Transactions on*, vol. 44, no. 4, pp. 347-58.

Ahmad, I., Azhar, S. and Ahmed, S. 2002, 'Web-based construction project management: Scope, potential and trends.' paper presented to Proceedings of the CIB-W65/W55 International Conference "Construction Innovation and Global Competitiveness", Cincinnati, Ohio, USA, 6-10 September.

Akins, M. L. and Griffin, J. R. 1999, 'Keys to successful systems administration', *Computers in Libraries*, vol. 19, no. 3, pp. 66-8.

Akinsola, A., Dawood, N. and Hobbs, B. 2000, 'Development of an automated communication system using internet technology for managing construction projects', paper presented to Proceedings of the 1st Conference on Implementing IT to Obtain a Competitive Advantage in the 21st Century, Hong Kong.

Alp, N., Alp, B. and Omurtag, Y. 1997, 'The influence of decision makers for new technology acquisition', *Computers and Industrial Engineering*, vol. 33, no. 1-2, pp. 3-5.

Alshawi, M. and Ingirige, B. 2002, *Web-based project management: A report on web-enabled project management*, School of Construction and Property Management, University of Salford, UK.

Alshawi, M. and Ingirige, B. 2003, 'Web-enabled project management: An emerging paradigm in construction', *Automation in Construction*, vol. 12, no. 4, pp. 349-64.

Amor, R., Betts, M., Coetzee, G. and Sexton, M. 2002, 'Information technology for construction: Recent work and future directions', *ITcon*, vol. 7, pp. 245-58.

Anderson, A. A. 1996, 'Predictors of computer anxiety and performance in information systems', *Computers in Human Behavior*, vol. 12, no. 1, pp. 61-77.

Anderson, C. J., Glassman, M., McAfee, R. B. and Pinelli, T. 2001, 'An investigation of factors affecting how engineers and scientists seek information', *Journal of Engineering and Technology Management*, vol. 18, no. 2, pp. 131-55.
Andresen, J., Baldwin, A., Betts, M., Carter, C., Hamilton, A., Stokes, E. and Thorpe, T. 2000, 'A framework for measuring IT innovation benefits', *Electronic Journal of Information Technology in Construction*, vol. 5, pp. 57-72.
Anumba, C. J. 2000, 'Integrated systems for construction: Challenges for the millennium', paper presented to Proceedings of the INCITE 2000 Conference on Implementing IT To Obtain a Competitive Advantage in the 21st Century, The Hong Kong Polytechnic University, Hong Kong.
Anumba, C. J. and Duke, A. 1997, 'Internet and intranet usage in a communications infrastructure for virtual construction project teams', paper presented to Proceedings of the Sixth IEEE workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises, Massachusetts, USA.
Anumba, C. J. and Ruikar, K. 2002, 'Electronic commerce in construction-trends and prospects', *Automation in Construction*, vol. 11, no. 3, pp. 265-75.
Aouad, G., Kagioglou, M., Cooper, R., Hinks, J. and Sexton, M. 1999, 'Technology management of IT in construction: A driver or an enabler?' *Logistics Information Management*, vol. 12, no. 1/2, pp. 130-7.
Aouad, G., Hinks, J., Cooper, R., Sheath, D. M., Kagioglou, M. and Sexton, M. 1998, 'An IT map for a generic design and construction process protocol', *Journal of Construction Procurement*, vol. 4, no. 1, pp. 132-51.
Armstrong, C. P. and Sambamurthy, V. 1999, 'Information technology assimilation in firms: The influence of senior leadership and IT infrastructures', *Information Systems Research*, vol. 10, no. 4, pp. 304-27.
Astebro, T. 1995, 'The effect of management and social interaction on the intra-firm diffusion of electronic mail systems', *IEEE Transactions on Engineering Management*, vol. 42, no. 4, pp. 319-31.
Attaran, M. 2000, 'Why does reengineering fail? A practical guide for successful implementation', *The Journal of Management Development*, vol. 19, no. 9, pp. 794-801.
Attewell, P. 1992, 'Technology diffusion and organizational learning: The case of business computing.' *Organization Science*, vol. 3, no. 1, pp. 1-19.
Baldwin, A., Betts, M., Blundell, D., Hansen, K. L. and Thorpe, T. 1999, 'Measuring the benefits of IT innovation', in M Betts (ed.), *Strategic management of IT in construction*, Blackwell Science, Oxford, pp. 288-310.
Behrman, W. 2002, *Best practices for the development and use of XML data interchange standards*, Center for Integrated Facility Engineering, Stanford University, Stanford, CA.
Benjamin, R. I. 1993, 'A framework for managing IT-enabled change', *Sloan Management Review*, vol. 34, no. 4, pp. 23-33.
Betts, M. 1999, *Strategic management of IT in construction*, Blackwell Science, Oxford.
Betts, M., Cher, L., Mathur, K. and Ofori, G. 1991, 'Strategies for the construction sector in the information technology era', *Construction Management and Economics*, vol. 9, no. 6, pp. 509-28.
Bhandari, N. 1977, 'Computer applications in construction management', *Journal of the Construction Division*, vol. 103, no. 3, pp. 343-56.

Bikson, T. K. 1987, 'Understanding the implementation of office technology', in RE Kraut. (ed.), *Technology and the transformation of white-collar work*, L. Erlbaum Associates, Hillsdale, N.J., pp. 155-76.

Björk, B. C. 1999, 'Information technology in construction: Domain definition and research issues', *International Journal of Computer Integrated Design and Construction*, vol. 1, no. 1, pp. 3-16.

Björk, B. C. 2002, 'The impact of electronic document management on construction information management', paper presented to Proceedings of the International Council for Research and Innovation in Building and Construction, CIB w78 conference 2002, 12 – 14 June, Aarhus School of Architecture.

Björnsson, H. and Lundegård, R. 1993, 'Strategic use of IT in some european construction firms', in KS Mathur, MP Betts & KW Tham (eds), *Management of information technology for construction*, World Scientific Publishing Co. Pty. Ltd., Singapore, pp. 17-33.

Borton, J. M. and Brancheau, J. C. 1994, 'Does an effective information technology implementation process guarantee success?' in L Levine (ed.), *Diffusion, transfer and implementation of information technology, proceedings of the IFIP TC8 working conference on diffusion, transfer and implementation of information technology*, Elsevier Science B.V. (North-Holland), Pittsburgh, PA, USA, 11-13 October 1993.

Bourne, L. 2003, *Knowledge management reflective learning*, RMIT University, Doctor of Project Management Program, Melbourne.

Brancheau, J. C. and Wetherbe, J. C. 1990, 'The adoption of spreadsheet software: Testing innovation diffusion theory in the context of end-user computing', *Information Systems Research*, vol. 1, no. 2, pp. 115-43.

Bresnen, M. and Marshall, N. 2001, 'Understanding the diffusion and application of new management ideas in construction', *Engineering, Construction and Architectural Management*, vol. 8, no. 5/6, pp. 335-45.

BRW 2001, 'Top 500 private companies list', *Business Review Weekly*, vol. August 3, 2001, pp. 52-76.

Brynjolfsson, E. and Hitt, L. M. 1998, 'Beyond the productivity paradox', *Communication of the ACM*, vol. 41, no. 8, pp. 49-55.

Burkhardt, M. E. and Brass, D. J. 1990, 'Changing patterns of patterns of change: The effects of a change in technology on social network structure and power', *Administrative Science Quarterly*, vol. 35, no. 1, pp. 104-27.

Cannon, J. A. 1994, 'Why IT applications succeed or fail.' *Industrial & Commercial Training*, vol. 26, no. 1-3, pp. 10-5.

Carlopio, J. R. 1998, *Implementation: Making workplace innovation and technology change happen*, McGraw-Hill Book Company Australia Pty Limited, NSW, Australia.

Carrillo, P. 1994, 'Technology transfer: A survey of international construction companies.' *Construction Management & Economics*, vol. 12, no. 1, pp. 45-51.

Clemmens, J. P. and Willenbrock, J. H. 1978, 'The scrapesim computer simulation', *Journal of the Construction Division*, vol. 104, no. 4, pp. 419-35.

Coakes, S. J., Steed, L. G. and Kopanidis, F. 2001, *SPSS: Analysis without anguish: Version 10.0 for windows*, John Wiley, Brisbane.

Coffin, R. J. and MacIntyre, P. D. 1999, 'Motivational influences on computer-related affective states', *Computers in Human Behavior*, vol. 15, no. 5, pp. 549-69.

Cohen, W. M. and Levinthal, D. A. 1990, 'Absorptive capacity: A new perspective on learning and innovation', *Administrative Science Quarterly*, vol. 35, no. 1, pp. 128-52.

Compeau, D. R. and Higgins, C. A. 1995, 'Computer self-efficacy: Development of a measure and initial test.' *MIS Quarterly*, vol. 19, no. 2, pp. 189-211.

Cooper, R. B. and Zmud, R. W. 1990, 'Information technology implementation research: A technological diffusion approach', *Management Science*, vol. 36, no. 2, pp. 123-39.

CSIRO 1996, *Perspectives of construction contractors communication and performance practices*, CSIRO Building, Construction and Engineering, Victoria.

Daft, R. L. 1978, 'A dual-core model of organizational innovation', *Academy of Management Journal*, vol. 21, no. 2, p. 193.

Damanpour, F. 1992, 'Organizational size and innovation', *Organization Studies*, vol. 13, no. 3, p. 375.

Damanpour, F. 1996, 'Organizational complexity and innovation: Developing and testing multiple contingency models.' *Management Science*, vol. 42, no. 5, pp. 693-716.

Damanpour, F. and Evan, W. M. 1984, 'Organizational innovation and performance: The problem of 'organizational lag'', *Administrative Science Quarterly*, vol. 29, no. 3, p. 392.

Damsgaard, J. and Scheepers, R. 2000, 'Managing the crises in intranet implementation: A stage model', *Information Systems Journal*, vol. 10, no. 2, pp. 131-49.

Davenport, T. H. and Prusak, L. 1998, *Working knowledge: How organizations manage what they know*, Harvard Business School Press, Boston, Mass.

Davis, F. D. 1989, 'Perceived usefulness, perceived ease of use, and user acceptance of information technology.' *MIS Quarterly*, vol. 13, no. 3, pp. 319-40.

Davis, F. D., Bagozzi, R. P. and Warshaw, P. R. 1989, 'User acceptance of computer technology: A comparison of two theoretical models', *Management Science*, vol. 35, no. 8, pp. 982-1003.

Davis, K. A. and Songer, A. D. 2002, 'Technological change in the AEC industry: A social architecture factor model of individuals' resistance', paper presented to Engineering Management Conference, 2002. IEMC '02. 2002 IEEE International.

Deng, Z. M., Li, H., Tam, C. M., Shen, Q. P. and Love, P. E. D. 2001, 'An application of the internet-based project management system', *Automation in Construction*, vol. 10, no. 2, pp. 239-46.

Devapriya, K. A. K. and Ganesan, S. 2002, 'Technology transfer subcontracting in developing countries through.' *Building Research & Information*, vol. 30, no. 3, pp. 171-82.

Doherty, J. M. 1997a, *A survey of computer use in the new zealand building and construction industry*, Jan, 2001, <http://www.itcon.org/1997/4/>.

Doherty, P. 1997b, *Cyberplaces : The internet guide for architects, engineers & contractors*, R.S. Means, Kingston, MA.

Doherty, P. 2004, *IFC and XML: What is the difference?*, Autodesk, August 7, 2004, <http://usa.autodesk.com/adsk/servlet/item?siteID=123112&id=2694038&linkID=2475912>.

Dulaimi, M. F., Ling, F. Y. Y. and Bajracharya, A. 2003, 'Organizational motivation and inter-organizational interaction in construction innovation in singapore.' *Construction Management & Economics*, vol. 21, no. 3, pp. 307-18.
Duyshart, B. 1997, *The digital document : A reference for architects, engineers, and design professionals*, Butterworth-Heinemann, Oxford.
Earl, M. J. 1993, 'Experiences in strategic information systems planning.' *MIS Quarterly*, vol. 17, no. 1, pp. 1-24.
Eason, K. 1988, *Information technology and organisational change*, Taylor & Francis, London ; New York.
Easterby-Smith, M., Thorpe, R. and Lowe, A. 2002, *Management research*, 2nd edn, Sage series in management research, Sage, London.
Egan, J. S. 1998, *Rethinking construction*, DETR, London.
Egbu, C., Gaskell, C. and Howes, J. 2001, 'The role of organizational culture and motivation in the effective utilization of information technology for teamworking in construction', paper presented to Proceedings of the ARCOM 17th Annual Conference, University of Salford, 5-7 September.
Fichman, R. G. 1992, 'Information technology diffusion: A review of empirical research', paper presented to Proceedings of the Thirteenth International Conference on Information Systems, Dallas, Texas, December.
Fichman, R. G. and Moses, S. A. 1999, 'An incremental process for software implementation', *Sloan Management Review*, vol. 40, no. 2, pp. 39-52.
Fichman, R. G. and Kemerer, C. F. 1999, 'The illusory diffusion of innovation: An examination of assimilation gaps.' *Information Systems Research*, vol. 10, no. 3, pp. 255-75.
Fishbein, M. and Ajzen, I. 1975, *Belief, attitude, intention, and behaviour: An introduction to theory and research*, Addison-Wesley, Reading.
Futcher, K. G. and Rowlinson, S. 1998, 'Information technology used by hong kong contractors', paper presented to Proceedings of the CIB-W78 Conference The Life-Cycle of Construction IT Innovation - Technology transfer from research to practice, Royal Institute of Technology, Stockholm, Sweden.
Futcher, K. G. and Rowlinson, S. 1999, 'IT survey within the construction industry of hong kong', paper presented to Proceedings of the 8th International Conference on Durability of Building Materials and Components CIB W78 Workshop, National Research Council of Canada, Ottawa, Canada.
Galbraith, J. 2002, *Designing organizations: An executive guide to strategy, structure, and process*, Jossey-Bass, San Francisco.
Gallivan, M. J. 2000, 'Examining workgroup influence on technology usage: A community of practice perspective', paper presented to Proceedings of the 2000 ACM SIGCPR Conference on Computer Personnel Research, Chicago, Illinois, United States.
Gallivan, M. J. 2001, 'Organizational adoption and assimilation of complex technological innovations: Development and application of a new framework', *Data Base for Advances in Information Systems*, vol. 32, no. 3, pp. 51-85.
Gann, D. 2001, 'Putting academic ideas into practice: Technological progress and the absorptive capacity of construction organizations.' *Construction Management & Economics*, vol. 19, no. 3, pp. 321-30.
Garcia, C., Garcia, G., Sarria, F. and Echeverry, D. 1998, 'Internet-based solutions to the fragmentation of the construction process', paper presented to Proceedings of the Congress on Computing in Civil Engineering, Reston, VA, USA.

Gibson, D. V. and Smilor, R. W. 1991, 'Key variables in technology transfer: A field-study based empirical analysis', *Journal of Engineering and Technology Management*, vol. 8, no. 3-4, pp. 287-312.
Ginzberg, M. J. 1981a, 'Key recurrent issues in the MIS implementation process', *MIS Quarterly*, vol. 5, no. 2, pp. 47-59.
Ginzberg, M. J. 1981b, 'Early diagnosis of MIS implementation failure: Promising results and unanswered questions', *Management Science*, vol. 27, no. 4, pp. 459-78.
Goodhue, D. L. and Thompson, R. L. 1995, 'Task-technology fit and individual performance.' *MIS Quarterly*, vol. 19, no. 2, pp. 213-36.
Goodman, P. S. and Griffith, T. L. 1991, 'A process approach to the implementation of new technology', *Journal of Engineering and Technology Management*, vol. 8, no. 3-4, pp. 261-85.
Gottschalk, P. 1999, 'Implementation predictors of strategic information systems plans.' *Information & Management*, vol. 36, no. 2, pp. 77-91.
Grantham, C. E. and Nichols, L. D. 1993, *The digital workplace: Designing groupware platforms*, Vnr computer library, Van Nostrand Reinhold, New York.
Gray, L. 1998, 'Why coaches are needed in software process improvement', *CROSSTALK: The journal of defence software engineering*, vol. 11, no. 9, pp. 17-9.
Green, G. C. and Hevner, A. R. 2000, 'The successful diffusion of innovations: Guidance for software development organizations', *IEEE Software*, vol. 17, no. 6, pp. 96-103.
Griffith, T. L., Zammuto, R. F. and Aiman-Smith, L. 1999, 'Why new technologies fail', *Industrial Management*, vol. 41, no. 3, pp. 29-34.
Gyampoh-Vidogah, R., Moreton, R. and Proverbs, D. 2003, 'Implementing information management in construction: Establishing problems, concepts and practice', *Construction Innovation*, vol. 3, pp. 157-73.
Hair, J. F. 1998, *Multivariate data analysis*, Prentice Hall, Upper Saddle River, N.J.
Hajjar, D. and AbouRizk, S. M. 2000, 'Integrating document management with project and company data', *Journal of Computing in Civil Engineering*, vol. 14, no. 1, pp. 70-7.
Halpin, D. W. 1977, 'Cyclone - method for modeling job site processes', *Journal of the Construction Division*, vol. 103, no. 3, pp. 489-99.
Hampson, K. and Tatum, C. B. 1997, 'Technology strategy and competitive performance in bridge construction', *Journal of Construction Engineering and Management*, vol. 123, no. 2, pp. 153-61.
Hampson, K. D. and Tatum, C. B. 1994, 'Strategies for appropriate technology and competitive performance in infrastructure construction', paper presented to Proceedings of the National Construction Management Conference, Sydney, Australia.
Harrison, D. A., Mykytyn Jr., P. P. and Riemenschneider, C. K. 1997, 'Executive decisions about adoption of information technology in small business: Theory and empirical tests.' *Information Systems Research*, vol. 8, no. 2, pp. 171-95.
Hartono, E., Lederer, A. L., Sethi, V. and Zhuang, Y. 2003, 'Key predictor of the implementation of strategic information systems plans', *Data Base for Advances in Information Systems*, vol. 34, no. 3, pp. 41-53.
Hedderson, J. 1991, *SPSS/PC+ made simple*, Wadsworth Pub. Co., Belmont, Calif.

Ho, S. P. and Liu, L. Y. 2003, 'How to evaluate and invest in emerging A/E/C technologies under uncertainty', *Journal of Construction Engineering and Management*, vol. 129, no. 1, pp. 16-24.

Howard, H. C., Levitt, R. E., Paulson, B. C., Pohl, J. G. and Tatum, C. B. 1989, 'Computer integration: Reducing fragmentation in AEC industry', *Journal of Computing in Civil Engineering*, vol. 3, no. 1, pp. 18-32.

Howard, R. 1998, *Computing in construction : Pioneers and the future*, Butterworth-Heinemann, Boston.

Howard, R. and Samuelsson, O. 1998, 'IT barometer - international comparison of IT in building.' paper presented to Proceedings of the CIB-W78 Conference "The Life-Cycle of Construction IT Innovation - Technology transfer from research to practice", Royal Institute of Technology, Stockholm, Saweden.

Howard, R., Kviniemi, A. and Samuelsson, O. 1998, *Surveys of IT in the construction industry and experience of the IT barometer in Scandinavia*, viewed Jan, 2001 <http://www.itcon.org/1998/4/>.

Huang, C., Fisher, N., Spreadborough, A. and Suchocki, M. 2003, 'Identify in the critical factors of IT innovation adoption and implementation within the construction industry', paper presented to Proceedings of the Second International Conference on Construction in the 21st Century (CITC-II), Sustainablity and Innovation in Management and Technology, Hong Kong, 10-12 December.

Huff, S. L. and Munro, M. C. 1985, 'Information technology assessment and adoption: A field study.' *MIS Quarterly*, vol. 9, no. 4, pp. 327-40.

Humphrey, W. S. 1989, *Managing the software process*, Addison-Wesley, Reading, Mass.

Huysman, M. H., Fischer, S. J. and Heng, M. S. 1994, 'An organizational learning perspective on information systems planning', *The Journal of Strategic Information Systems*, vol. 3, no. 3, pp. 165-77.

IBIS 1999, *Technology transfer: An overview*, Integrated Business Information Systems (IBIS) Ltd, 15 July 2003, <http://www.ibisl.com/13.htm>.

Igbaria, M. and Parasuraman, S. 1989, 'A path analytic study of individual characteristics, computer anxiety and attitudes toward microcomputers', *Journal of Management*, vol. 15, no. 3, pp. 373-88.

Igbaria, M. and Chakrabarti, A. 1990, 'Computer anxiety and attitudes towards microcomputer use', *Behavior and Information Technology*, vol. 9, no. 3, pp. 229-41.

Igbaria, M. and Tan, M. 1997, 'The consequences of information technology acceptance on subsequent individual performance', *Information & Management*, vol. 32, no. 3, pp. 113-21.

Igbaria, M., Iivari, J. and Maragahh, H. 1995, 'Why do individuals use computer technology? A Finnish case study', *Information & Management*, vol. 29, no. 5, pp. 227-38.

Igbaria, M., Parasuraman, S. and Baroudi, J. J. 1996, 'A motivational model of microcomputer usage', *Journal of Management Information Systems*, vol. 13, no. 1, pp. 127-43.

Iivari, J. 1993, 'From a macro innovation theory of IS diffusion to a micro innovation theory of IS adoption: An application of case adoption', in D Avision, JE Kendall & JI DeGross (eds), *Human, organizational, and social dimensions of information systems development (a-24)*, Elsevier Science Publishers B.V., North-Holland, pp. 295-320.

Irani, Z. 1999, 'IT/IS investment justification: An interpretivist case study', paper presented to Proceedings of the 32nd Annual Hawaii International Conference on System Sciences (HICSS-32).
Irani, Z., Ezingeard, J.-N. and Grieve, R. J. 1997, 'Integrating the costs of a manufacturing IT/IS infrastructure into the investment decision-making process', *Technovation*, vol. 17, no. 11-12, pp. 695-706.
Irani, Z., Ezingeard, J.-N. and Grieve, R. J. 1998, 'Costing the true costs of IT/IS investments in manufacturing: A focus during management decision making', *Logistics Information Management*, vol. 11, no. 1, pp. 38-43.
Johnson, J. 1995, 'Chaos: The dollar drain of IT project failures', *Application development trends*, vol. 2, no. 1, pp. 41-7.
Jung, Y. and Gibson, G. E. 1999, 'Planning for computer integrated construction', *Journal of Computing in Civil Engineering*, vol. 13, no. 4, pp. 217-25.
Kappelman, L. A. 1995, 'Measuring user involvement: A diffusion of innovation perspective', *Data Base for Advances in Information Systems*, vol. 26, no. 2-3, pp. 65-86.
Katzenbach, J. R. and Smith, D. K. 1993, 'The discipline of teams', *Harvard Business Review*, no. March-April, pp. 111-20.
Keen, P. G. W. 1981, 'Information systems and organizational change', *Communications of the ACM*, vol. 24, no. 1, pp. 24-33.
Kirveennummi, M., Hirvo, H. and Eriksson, I. 1998, 'Framework for barriers to IS-related change: Development and evaluation of a theoretical model', paper presented to Proceedings of IFIP WG8.2 & WG8.6 Joint Working Conference on Information Systems: Current Issues and Future Changes, Helsinki, Finland, December 10-13.
Klein, H. K. and Hirschheim, R. 1987, 'Social change and the future of information systems development', in RJ Boland & RA Hirschheim (eds), *Critical issues in information systems research*, John Wiley & Sons Ltd., Chichester [Sussex] ; New York, pp. 275-305.
Kong, S. C. W., Li, H. and Shen, L. Y. 2001, 'An internet-based electronic product catalogue of construction materials.' *Construction Innovation*, vol. 1, no. 4, pp. 245-57.
Kong, S. C. W., Li, H. and Love, P. E. D. 2001, 'An e-commerce system for construction material procurement.' *Construction Innovation*, vol. 1, no. 1, pp. 43-54.
Kong, S. C. W., Li, H., Hung, T. P. L., Shi, J. W. Z., Castro-Lacouture, D. and Skibniewski, M. 2004, 'Enabling information sharing between e-commerce systems for construction material procurement', *Automation in Construction*, vol. 13, no. 2, pp. 261-76.
Koo, B. and Fischer, M. 2000, 'Feasibility study of 4D cad in commercial construction', *Journal of Construction Engineering and Management*, vol. 126, no. 4, pp. 251-60.
Korunka, C., Weiss, A. and Zauchner, S. 1997, 'An interview study of 'continuous' implementations of information technology', *Behaviour & Information Technology*, vol. 16, no. 1, pp. 3-16.
Koskela, L. and Kazi, A. S. 2003, 'Information technology in construction: How to realise the benefits?' in S Clarke, E Coakes, GM Hunter & A Wenn (eds), *Socio-technical and human cognition elements of information systems*, Idea Group Publishing, Hershey, PA, pp. 60-75.

Kosovac, B., Froese, T. M. and Vanier, D. J. 2000, 'Integrating heterogeneous data representations in model-based AEC/FM systems', paper presented to Proceedings of Construction Information Technology CIT 2000, Reykjavik, Iceland, June 28-30.
Kueppers, S. and Schilingno, M. 1999, 'Getting our act together: Human and technological factors in establishing an on-line knowledge base', paper presented to Proceedings of the 27th annual ACM SIGUCCS conference on Mile high expectations, Denver, Colorado, United States.
Kwon, T. H. 1990, 'A diffusion of innovation approach to MIS infusion: Conceptualization, methodology and management studies', paper presented to Proceedings of the eleventh International Conference on Information Systems, Copenhagen, Denmark, December 16 - 19.
Kwon, T. H. and Zmud, R. W. 1987, 'Unifying the fragmented models of information systems implementation', in BR J. & HR A. (eds), *Critical issues in information systems research*, John Wiley & Sons Ltd., New York, pp. 227-51.
Laage-Hellman, J. and Gadde, L.-E. 1996, 'Information technology and the efficiency of materials supply: The implementation of EDI in the swedish construction industry', *European Journal of purchasing & supply management*, vol. 2, no. 4, pp. 221-8.
Lai, V. S. G., J.L. 1997, 'An assessment of the influence of organizational characteristics on information technology adoption decision: A discriminative approach', *Engineering Management, IEEE Transactions on*, vol. 44, no. 2, pp. 146-57.
Latham, S. M. 1994, *Constructing the team*, Her Majesty Stationary Office (HMSO), London.
Lave, J. and Wenger, E. 1991, *Situated learning: Legitimate peripheral participation*, Learning in doing, Cambridge University Press, Cambridge [England] ; New York.
Lawrence, N. W. 1997, *Social research methods: Qualitative and quantitative approaches*, 3rd Ed. edn, Allyn and Bacon, MA.
Leavitt, H. J. 1965, 'Applied organizational change in industry: Structural technological, and humanistic approach', in JG March & D Cartwright (eds), *Handbook of organizations*, Rand McNally, Chicago, pp. 1144-70.
Lederer, A. L. and Sethi, V. 1996, 'Key prescriptions for strategic information systems planning.' *Journal of Management Information Systems*, vol. 13, no. 1, pp. 35-62.
Lederer, A. L., Maupin, D. J., Sena, M. P. and Zhuang, Y. 2000, 'The technology acceptance model and the world wide web', *Decision Support Systems*, vol. 29, no. 3, pp. 269-82.
Lenard, D. J. and Bowen-James, A. 1996, *Innovation: The key to competitive advantage. A report to the construction industry institute, Australia*, Research Report no. 9, Innovation and Organisation Task Force, Adelaide.
Lenoard-Barton, D. and Sviokla, J. J. 1988, 'Putting expert systems to work', *Harvard Business Review*, March-April, pp. 91-8.
Leonard-Barton, D. 1988, 'Implementation characteristics of organizational innovations', *Communication Research*, vol. 15, no. 5, pp. 603-31.
Leonard-Barton, D. and Kraus, W. A. 1985, 'Implementing new technology', *Harvard Business Review*, vol. 63, no. 6, 1985/11//Nov/Dec85, p. 102.

Lester, J. L. 1984, 'Project documentation and management using jobsite microcomputers', in WC Moore (ed.), *Applications of small computers in construction*, American Society of Civil Engineers, New York, pp. 1-7.
Lewin, K. 1958, 'Group decision and social change', in EE Maccoby, TM Newcomb & EL Hartley (eds), *Readings in social psychology*, 3d ed. / edn, Henry Holt, New York, pp. 459-73.
Li, H. 1996, 'Towards quantitatively measuring the performance of construction IT systems', *Building Research and Information*, vol. 24, no. 6, pp. 379-82.
Liston, K. M., Fischer, M. A. and Kunz, J. C. 2000, 'Designing and evaluating visualization techniques for construction planning', paper presented to Eighth International Conference on Computing in Civil and Building Engineering (ICCCBE-VIII), Stanford University.
Love, P. E. D., MacSporran, C. and Tucker, S. N. 2000, *The application of information technology by Australian contractors: Toward process re-engineering*, Commonwealth Scientific and Industrial Research Organisation (CSIRO), viewed 19/05 2001, <http://sun7.bham.ac.uk/d.j.crook/lean/iglc4/tucker/tucker.htm>.
Love, P. E. D., Irani, Z., Li, H., Tse, R. Y. C. and Cheng, E. W. L. 2000, 'An empirical analysis of IT/IS evaluation in construction', *The International Journal of Construction Information Technology*, vol. 8, no. 2, pp. 21-38.
Love, P. E. D., Irahi, Z., Li, H., Cheng, E. W. L. and Tse, R. Y. C. 2001, 'An empirical analysis of the barriers to implementing e-commerce in small-medium sized construction contractors in the state of victoria, Australia', *Construction Innovation*, vol. 1, no. 1, pp. 31-41.
Mahajan, V. and Muller, E. 1979, 'Innovation diffusion and new product growth models in marketing.' *Journal of Marketing*, vol. 43, no. 4, pp. 55-68.
Mahajan, V. and Muller, E. 1990, 'New product diffusion models in marketing: A review and directions for research', *Journal of Marketing*, vol. 54, no. 1, p. 1.
Mahmood, M. A., Burn, J. M., Gemoets, L. A. and Jacquez, C. 2000, 'Variables affecting information technology end-user satisfaction: A meta-analysis of the empirical literature', *International Journal of Human-Computer Studies*, vol. 52, no. 4, pp. 751-71.
Markus, M. L. 1983, 'Power, politics, and MIS implementation', *Communications of the ACM*, vol. 26, no. 6, pp. 430-44.
Markus, M. L. 1987, 'Toward a 'critical mass' theory of interactive media: Universal access, interdependence and diffusion', *Communication Research*, vol. 14, no. 5, pp. 491-511.
Markus, M. L. and Keil, M. 1994, 'If we build it, they will come: Designing information systems that people want to use', *Sloan Management Review*, vol. 35, no. 4, pp. 11-25.
Markus, M. L. and Benjamin, R. I. 1997, 'The magic bullet theory in IT-enabled transformation', *Sloan Management Review*, vol. Vol. 38, no. 2, pp. 55-68.
Marosszeky, M., Sauer, C., Johnson, K., Karim, K. and Yetton, P. 2000, 'Information technology in the building and construction industry: The Australian experience', paper presented to Proceedings of the INCITE 2000 Conference, Implementing IT To Obtain a Competitive Advantage in the 21st Century, The Hong Kong Polytechnic University, Hong Kong.
Marsh, L. and Finch, E. 1998, 'Attitudes towards auto-id technologies within the uk construction industry.' *Construction Management & Economics*, vol. 16, no. 4, pp. 383-8.

Marsh, L. and Flanagan, R. 2000, 'Measuring the costs and benefits of information technology in construction', *Engineering, Construction and Architectural Management*, vol. 7, no. 4, pp. 423-35.

Martinko, M. J., Henry, J. W. and Zmud, R. W. 1996, 'An attributional explanation of individual resistance to the introduction of information technologies in the workplace', *Behaviour & Information Technology*, vol. 15, no. 5, pp. 313-30.

Martocchio, J. J. 1994, 'Effects of conceptions of ability on anxiety, self-efficacy, and learning in training.' *Journal of Applied Psychology*, vol. 79, no. 6, pp. 819-25.

Mathieson, K. and Keil, M. 1998, 'Beyond the interface: Ease of use and task/technology fit', *Information & Management*, vol. 34, no. 4, pp. 221-30.

Mckersie, R. B. and Walton, R. E. 1991, 'Organization change', in MS Scott Morton (ed.), *The corporation of the 1990s: Information technology and organizational transformation*, Oxford Univeristy Press, New York, pp. 244-77.

McShane, S. L., Travaglione, A. and Marshall, S. 2003, *Organisational behaviour on the pacific rim*, McGraw-Hill, Sydney.

Meyers, P. W., Sivakumar, K. and Nakata, C. 1999, 'Implementation of industrial process innovations: Factors, effects, and marketing implications', *Journal of Product Innovation Management*, vol. 16, pp. 295-311.

Miles, M. B. and Huberman, A. M. 1994, *Qualitative data analysis : An expanded sourcebook*, 2nd edn, Sage Publications, Thousand Oaks.

Miller, R. G. 1986, *Beyond anova, basics of applied statistics*, Wiley series in probability and mathematical statistics. Applied probability and statistics, Wiley, New York.

Milliken, G. A. and Johnson, D. E. 1984, *Analysis of messy data*, Lifetime Learning Publications, Belmont, Calif.

Mintzberg, H. 1994, *The rise and fall of strategic planning*, Prentice Hall, New York.

Mitev, N. N., Wilson, F. A. and Wood-Harper, A. T. 1996, 'An information systems model for concurrent construction project partnership environments', in DA Langford & A Retik (eds), *The organization and management of construction: Shaping theory and practice*, vol. 3, pp. 226-35.

Mitropoulos, P. and Tatum, C. B. 1999, 'Technology adoption decisions in construction organizations', *Journal of Construction Engineering and Management*, vol. 125, no. 5, pp. 330-8.

Mitropoulos, P. and Tatum, C. B. 2000, 'Forces driving adoption of new information technologies', *Journal of Construction Engineering and Management*, vol. 126, no. 5, pp. 340-8.

Mohamed, S. and Stewart, R. A. 2003, 'An empirical investigation of users' perceptions of web-based communication on a construction project', *Automation in Construction*, vol. 12, no. 1, pp. 43-53.

Moore, G. C. and Benbasat, I. 1991, 'Development of an instrument to measure the perceptions of adopting an information technology innovation', *Information Systems Management*, vol. 2, no. 3, pp. 192-222.

Mowery, D. and Rosenberg, N. 1979, 'The influence of market demand upon innovation: A critical review of some recent empirical studies', *Research Policy*, vol. 8, no. 2, pp. 102-53.

Munkvold, B. E. 1999, 'Challenges of IT implementation for supporting collaboration in distributed organizations', *European Journal of Information Systems*, vol. 8, no. 4, pp. 260-72.

Murphy, C. A., Coover, D. and Owen, S. V. 1989, 'Development and validation of the computer self-efficacy scale', *Educational & Psychological Measurement*, vol. 49, no. 4, pp. 893-9.

Murray, M. and Mavrokefalos, D. 2000, 'The use of e-mail and dedicated web-sites in the management of engineering projects', paper presented to Proceedings of the 22nd Symposium on Computers in Engineering, South African Institute of Civil Engineering.

Nahapiet, J. and Ghoshal, S. 1998, 'Social capital, intellectual capital, and the organizational advantage', *Academy of Management Review*, vol. 23, no. 2, pp. 242-66.

Nam, C. H. and Tatum, C. B. 1992, 'Strategies for technology push - lessons from construction innovations', *Journal of Construction Engineering and Management*, vol. 118, no. 3, pp. 507-24.

Nelson, R. R. 1991, 'Educational needs as perceived by is and end-user personnel - a survey of knowledge and skill requirements', *MIS Quarterly*, vol. 15, no. 4, pp. 503-21.

Nelson, R. R. and Cheney, P. H. 1987, 'Training end users - an exploratory study', *MIS Quarterly*, vol. 11, no. 4, pp. 547-59.

Nelson, R. R., Whitener, E. M. and Philcox, H. H. 1995, 'The assessment of end-user training needs', *Communications of the ACM*, vol. 38, no. 7, pp. 27-39.

Neuman, W. L. 1997, *Social research methods: Qualitative and quantitative approaches*, 3rd edn, Allyn & Bacon, Needham Hights, MA.

Newman, M. and Sabherwal, R. 1996, 'Determinants of commitment to information systems development: A longitudinal investigation', *MIS Quarterly*, vol. 20, no. 1, pp. 23-54.

Ng, S. T., Palaneeswaran, E. and Kumaraswamy, M. M. 2003, 'Web-based centralized multiclient cooperative contractor registration system', *Journal of Computing in Civil Engineering*, vol. 17, no. 1, pp. 28-37.

Nilakanta, S. and Scamell, R. W. 1990a, 'The effect of information sources and communication channels on the diffusion of innovation in a data base development environment', *Management Science*, vol. 36, no. 1, pp. 24-40.

Nilakanta, S. and Scamell, R. W. 1990b, 'The effect of information sources and communication channels on the diffusion of innovation in a data base development environment', *Management Science*, vol. 36, no. 1, p. 24.

Nitithamyong, P. and Skibniewski, M. 2003, 'Critical success/failure factors in implementation of web-based construction project management systems', paper presented to Proceedings of the Construction Research Congress - Winds of Change: Integration and Innovation in Construction, Honolulu, Hawaii.

Nitithamyong, P. and Skibniewski, M. J. 2004, 'Web-based construction project management systems: How to make them successful?' *Automation in Construction*, vol. 13, no. 4, pp. 491-506.

NOIE 2001, *The current state of play*, Commonwealth of Australia, viewed May 11, 2002 <http://www.noie.gov.au/projects/information_economy/research&analysis/ie_stats/CSOP_June2001/CSOP_June01.pdf>.

Nonaka, I. 1995, 'The knowledge creation company', *Havard Business Review*, vol. November-December, pp. 96-104.

Nonaka, I. and Takeuchi, H. 1995a, *The knowledge-creating company*, Oxford University Press, Oxford.

Nonaka, I., Toyama, R. and Konno, N. 2001, 'SECI, ba and leadership: A unified model of dynamic knowledge creation', in I Nonaka & D Teece (eds), *Managing industrial knowledge - creation, transfer and utilization*, Sage, London, pp. 13-34.

Nonaka, I. o. and Takeuchi, H. 1995b, *The knowledge-creating company : How japanese companies create the dynamics of innovation*, Oxford University Press, Oxford.

Norusis, M. J. 1997, *SPSS 7.5 guide to data analysis*, Prentice Hall, Upper Saddle River, N.J.

Norušis, M. J. 1985, *SPSS-x advanced statistics guide*, McGraw-Hill, Chicago, IL.

O'Brien, M. J. and Al-Biqami, N. M. 1999, 'Survey of information technology and the structure of the saudi arabian construction industry', paper presented to Proceedings of 8th International Conference on Durability of Building Materials and Components CIB W78 Workshop, National Research Council of Canada, Ottawa, Canada.

O'Brien, W. J. 2000, 'Implementation issues in project web sites: A practitioner's viewpoint.' *Journal of Management in Engineering*, vol. 16, no. 3, pp. 34-9.

Opfer, N. D. 1997, 'Intranet internet applications for the construction industry', paper presented to Proceedings of the 33rd Annual ASC Conference, University of Washington, Washington.

Orlikowski, W. J. and Hofman, J. D. 1997, 'An improvisational model for change management: The case of groupware technologies', *Sloan Management Review*, vol. 38, no. 2, pp. 11-21.

Orth, D. L. 2000, 'The use of the internet, intranet, e-mail, and web-based project management software in construction industry', paper presented to Proceedings of the 36th Annual ASC Conference, Purdue University-West Lafayette, Indiana, March 29-April 1.

Pallant, J. 2001, *SPSS survival manual: A step-by-step guide to data analysis using SPSS for windows (version 10)*, Allen & Unwin, St Leonards, N.S.W.

Paulson, B. C. 1995, *Computer applications in construction*, International edn, McGraw-Hill, New York ; Singapore.

Peansupap, V., Walker, D. H. T., Goldsmith, P. W. and Wilson, A. 2003, 'Developing within-company information and communication technologies (ICT) innovation diffusion networks: A study of three Australian major contractors', paper presented to Proceedings of 19th ARCOM Conference, Brighton , UK, 3-5 September.

Peña-Mora, F. and Tanaka, S. 2002, 'Information technology planning framework for japanese general contractors.' *Journal of Management in Engineering*, vol. 18, no. 3, pp. 138-49.

Peña-Mora, F., Vadhavkar, S., Perkins, E. and Weber, T. 1999, 'Information technology planning framework for large-scale projects', *Journal of Computing in Civil Engineering*, vol. 13, no. 4, pp. 226-37.

Poon, J., Potts, K. and Cooper, P. 2001, 'Identification of success factors in the construction process', paper presented to COBRA.

Porter, M. E. 1980, *Competitive advantage: Techniques for analyzing industries and competitors*, The Free Press, New York.

Porter, M. E. 1985a, *Competitive advantage: Creating and sustaining superior performance*, The Free Press, New York.

Porter, M. E. 1985b, 'Technology and competitive advantage', *Journal of Business Strategy*, vol. 5, no. 3, p. 60.

Porter, M. E. 1985c, *Competitive advantage: Creating and sustaining superior performance*, The Free Press, New York.
Porter, M. E. and Miller, V. E. 1985, 'How information gives you competitive advantage', *Harvard Business Review*, vol. 63, no. 4, pp. 149-60.
Prescott, M. B. and Conger, S. A. 1995, 'Information technology innovations: A classification by IT locus of impact and research approach', *Data Base for Advances in Information Systems*, vol. 26, no. 2-3, pp. 20-41.
Rackoff, N., Wiseman, C. and Ullrich, W. A. 1985, 'Information systems for competitive advantage: Implementation of a planning process.' *MIS Quarterly*, vol. 9, no. 4, p. 285.
Ramamurthy, K. 1994, 'Moderating influences of organizational attitude and compatibility on implementation success from computer- integrated manufacturing technology', *International Journal of Production Research*, vol. 32, no. 10, pp. 2251-73.
Ramamurthy, K. and Premkumar, G. 1995, 'Determinants and outcomes of electronic data interchange diffusion', *IEEE Transactions on Engineering Management*, vol. 42, no. 4, pp. 332-51.
Regan, E. A. and O'Connor, B. N. 2000, *End-user information systems : Implementing individual and work group technologies*, 2nd ed. edn, Prentice Hall, Upper Saddle River, NJ.
Rivard, H. 2000, *A survey on the impact of information technology on the canadian architecture, engineering and construction industry*, Jan. 2001, <http://itcon.org/2000/3/>.
Robbins, S. P. 1998, *Organizational behavior : Concepts, controversies, applications*, 8th ed. edn, Prentice Hall, Upper Saddle River, N.J.
Rogers, D. M. A. 1996, 'The challenge of fifth generation r&d', *Research Technology Management*, vol. 39, no. 4, pp. 33-41.
Rogers, E. M. 1976, *Communication in organizations*, The Free Press, New York.
Rogers, E. M. 1983, *Diffusion of innovations*, 3rd edn, Free Press, New York.
Rogers, E. M. 1995, *Diffusion of innovations*, 4th edn, Free Press, New York.
Rojas, E. M. and Songer, A. D. 1999, 'Web-centric systems: A new paradigm for collaborative engineering', *Journal of Management in Engineering*, vol. 15, no. 1, pp. 39-45.
Sackton, F. 1999, 'The human factor in information technology', *Armed Forces Comptroller*, vol. 44, no. 1, pp. 39-43.
Sarker, S. 2000, 'Toward a methodology for managing information systems', *Informing Science*, vol. 3, no. 4, pp. 195-205.
Sarshar, M., Ridgway, M. and Betts, M. 1999, 'Strategic information systems planning techniques', in M Betts (ed.), *Strategic management of IT in construction*, Blackwell Science, Oxford, pp. 141-69.
Scheirer, M. A. 1983, 'Approaches to the study of implementation', *IEEE Transactions on Engineering Management*, vol. EM-30, no. 2, pp. 76-82.
Scott Morton, M. S. 1991, 'Introduction', in MS Scott Morton (ed.), *The corporation of the 1990s: Information technology and organizational transformation*, Oxford University Press, New York.
Senge, P., Kleiner, A., Roberts, C., Ross, R., Roth, G. and Smith, B. 1999, *The dance of change: The challenges of sustaining momentum in learning organizations*, Nicholas Brealey Publishing, London.
Senge, P. M. 1992, *The fifth discipline: The art and practice of the learning organization*, Random House Australia, Milsons Point, NSW.

Skibniewski, M. J. and Abduh, M. 2000, 'Web-based project management for construction: Search for utility assessment tools', paper presented to Proceedings of the INCITE 2000 Conference on Implementing IT to Obtain a Competitive Advantage in the 21st Century, The Hong Kong Polytechnic University, Hong Kong.
Skibniewski, M. J. and Nitithamyong, P. 2004, 'Web-based construction project management systems: Practical advantages and disadvantages', paper presented to Proceedings of the 4th International Conference on Construction Project Management (ICCPM), Singapore.
Slaughter, E. S. 1998, 'Models of construction innovation', *Journal of Construction Engineering and Management*, vol. 124, no. 3, pp. 226-31.
Slaughter, E. S. 2000, 'Implementation of construction innovations', *Building Research & Information*, vol. 28, no. 1, pp. 2-17.
Songer, A. D., Young, R. and Davis, K. 2001, 'Social architecture for sustainable IT implementation in AEC/EPC', paper presented to Proceedings of IT in Construction in Africa 2001, Mpumalunga, South Africa, 30 May - 1 June.
Sriprasert, E. and Dawood, N. 2002a, 'Next generation of construction planning and control system: The LEWIS approach', paper presented to Proceedings of the IGLC-10, Gramado, Brazil, 6-8 August.
Sriprasert, E. and Dawood, N. 2002b, 'Lean enterprise web-based information system for construction (LEWIS): A framework', paper presented to International Council for Research and Innovation in Building and Construction CIB W78 Conference, Aarhus School of Architecture, 12 – 14 June.
Sriprasert, E. and Dawood, N. 2002c, 'Requirements identification for 4D constraint-based construction planning and control system', paper presented to International Council for Research and Innovation in Building and Construction CIB W78 Conference, Aarhus School of Architecture, 12 – 14 June.
Stephenson, P. and Blaza, S. 2001, 'Implementing technological change in construction organisations', paper presented to Proceedings of the IT in Construction in Africa, Mpumalunga, South Africa, 30 May - 1 June.
Stewart, R. and Mohamed, S. 2002, 'Barriers to implementation information technology in developing countries', paper presented to Proceedings of the CIB-W107 1st International Conference Creating a sustainable construction industry in developing countries, Spier, Stellenbosch, South Africam, 11-13 November.
Stewart, R. A. and Mohammed, S. 2001, 'Utilizing the balanced scorecard for IT/IS performance evaluation in construction.' *Construction Innovation*, vol. 1, no. 3, pp. 147-63.
Stewart, R. A., Mohamed, S. and Daet, R. 2002, 'Strategic implementation of IT/IS projects in construction: A case study', *Automation in Construction*, vol. 11, no. 6, pp. 681-94.
Stewart, R. A., Mohamed, S. and Marosszeky, M. 2004, 'An empirical investigation into the link between information technology implementation barriers and coping strategies in the Australian construction industry.' *Construction Innovation*, vol. 4, no. 3, pp. 155-71.
Storck, J. and Hill, P. A. 2000a, 'Knowledge diffusion through "strategic communities"', *Sloan Management Review*, vol. 41, no. 2, pp. 63-74.
Storck, J. and Hill, P. A. 2000b, 'Knowledge diffusion through "strategic communities"', *Sloan Management Review*, vol. Winter, pp. 63-74.

Suckarieh, G. 1984, 'Construction management control with microcomputers', *Journal of Construction Engineering and Management*, vol. 110, no. 1, pp. 72-8.
Szulanski, G. 2003, *Sticky knowledge: Barriers to knowing in the firm*, Sage Publications, London;Thousand Oaks.
Tam, C. M. 1999, 'Use of the internet to enhance construction communication: Total information transfer system', *International Journal of Project Management*, vol. 17, no. 2, pp. 107-11.
Tan, R. R. 1996, 'Information technology and perceived competitive advantage: An empirical study of engineering consulting firms in taiwan', *Construction Management and Economics*, vol. 14, pp. 227-40.
Tatum, C. B. 1987, 'Process of innovation in construction firm', *Journal of Construction Engineering and Management*, vol. 113, no. 4, pp. 648-63.
Tatum, C. B. 1988, 'Technology and competitive advantage in construction engineering', *Journal of professional Issues in Engineering*, vol. 114, no. 3, pp. 256-64.
Taylor, S. and Todd, P. A. 1995, 'Understanding information technology usage: A test of competing models', *Information Systems Research*, vol. 6, no. 2, pp. 144-76.
Teng, J. T. C., Grover, V. and Guttler, W. 2002, 'Information technology innovations: General diffusion patterns and its relationships to innovation characteristics', *IEEE Transactions on Engineering Management*, vol. 49, no. 1, pp. 13-27.
Thomas, S. R. 1999, *Impacts of design/information technology on project outcomes*, NIST GCR 99-786, National Institute of Standards and Technology (NIST), Gaithersburg, MD.
Thompson, R. L., Higgins, C. A. and Howell, J. M. 1991, 'Personal computing: Toward a conceptual model of utilization', *MIS Quarterly*, vol. 15, no. 1, pp. 125-43.
Thorpe, D. 2003, 'Online remote construction management trials in queensland department of main roads: A participant's perspective.' *Construction Innovation*, vol. 3, no. 2, pp. 65-79.
Thorpe, T. and Mead, S. 2001, 'Project-specific web sites: Friend or foe?' *Journal of Construction Engineering and Management*, vol. 127, no. 5, pp. 406-13.
Toole, T. M. 1998, 'Uncertainty and home builders' adoption of technological innovations', *Journal of Construction Engineering and Management*, vol. 124, no. 4, pp. 323-32.
Tornatzky, L. G. and Klein, K. J. 1982, 'Innovation characteristics and innovation adoption implementation: A meta analysis of findings', *IEEE Transactions on Engineering Management*, vol. 29, no. 1, pp. 28-45.
Tornatzky, L. G. and Fleisher, M. 1990, *The processes of technological innovation*, Lexington Books, Lexington, MA.
Trevino, L. K. and Webster, J. 1992, 'Flow in computer-mediated communication: Electronic mail and voice mail evaluation and impacts', *Communication Research*, vol. 19, no. 5, pp. 539-73.
Tucker, S., Mohamed, S. and Ambrose, M. D. 1999, *Information technology analysis framework for action peninsula project*, Department of Industry, Science and Resources and CSIRO, Victoria.
Tucker, S., Mohamed, S. and Ambrose, M. D. 2001, *Information technology analysis framework for action peninsula project*, Department of Industry, Science and Resources and CSIRO, Victoria.

Underwood, J. and Watson, A. 2003, 'An XML metadata approach to seamless project information exchange between heterogeneous platforms', *Engineering, Construction and Architectural Management*, vol. 10, no. 2, pp. 128-45.
Veeramani, D., Tserng, H. P. and Russell, J. S. 1998, 'Computer-integrated collaborative design and operation in the construction industry', *Automation in Construction*, vol. 7, pp. 485-92.
Veshosky, D. 1998, 'Managing innovation information in engineering and construction firms', *Journal of Management in Engineering*, vol. 14, no. 1, pp. 58-66.
Villeneuve, C. E. and Fayek, A. R. 2003, 'Construction project websites: Design and implementation.' *Cost Engineering*, vol. 45, no. 1, pp. 26-31.
von Krogh, G., Ichijo, K. and Nonaka, I. 2000, *Enabling knowledge creation : How to unlock the mystery of tacit knowledge and release the power of innovation*, Oxford University Press, Oxford.
Voordijk, H., Leuven, A. V. and Laan, A. 2003, 'Enterprise resource planning in a large construction firm: Implementation analysis', *Construction Management and Economics*, vol. 21, no. 5, pp. 511-21.
Wager, D., Scoins, D. and Construction Industry Computing Association (Great Britain) 1984, *More computer programs for construction management: Comparative descriptions of computer programs for estimating, accounting, planning and valuing building projects*, Construction Industry Computing Association, Cambridge.
Walker, D. H. T. 2003, 'Implications of human capital issues', in DHT Walker & KD Hampson (eds), *Procurement strategies: A relationship based approach*, Blackwell Publishing, Oxford, pp. 258-95.
Walker, D. H. T. and Betts, M. 1997, 'Information technology foresight', paper presented to Proceedings of the Future Application of the W78 IT for Construction Process Reengineering World Wide Web in Construction, CIB, July, Cairns, Australia.
Walker, D. H. T. and Betts, M. 1998, 'Future application of the world wide web to the construction industry - two scenarios explored', paper presented to Proceedings of the CIB W78 Workshop, Information Technology Support for Construction Process Re-Engineering IT-CPR-97, James Cook University, Cairns, Queensland, 9 - 11 July.
Walker, D. H. T. and Lloyd-Walker, B. M. 1999, 'Organisational learning as a vehicle for improved building procurement', in S Rowlinson & P McDermott (eds), *Procurement systems a guide to best practice in construction*, E&FN Spon, London.
Ward, J. and Griffiths, P. M. 1996, *Strategic planning for information systems*, 2nd edn, Wiley, Chichester; New York.
Ward, J. and Peppard, J. 2002, *Strategic planning for information systems*, 3rd ed. edn, J. Wiley, Chichester; New York.
Weippert, A., Kajewski, S. L. and Tilley, P. A. 2002a, 'Online remote construction management (orcm)', paper presented to Proceedings of the International Council for Research and Innovation in Building and Construction CIB W78 Conference 2002, Aarhus Schooi of Architecture. 12-14 June 2002.
Weippert, A., Kajewski, S. L. and Tilley, P. A. 2002b, 'Internet-based information and communication systems on remote construction projects: A case study analysis.' *Construction Innovation*, vol. 2, no. 2, pp. 103-16.

Wenger, E., McDermott, R. A. and Snyder, W. 2002, *Cultivating communities of practice: A guide to managing knowledge*, Harvard Business School Press, Boston, MA.
Wenger, E. C. 1999, 'Communities of practice: The key to knowledge strategy', *The Journal of the Institute for Knowledge Management*, vol. 1, no. Fall, pp. 48-63.
Wenger, E. C. and Snyder, W. M. 2000, 'Communities of practice: The organisational frontier', *Harvard Business Review*, vol. 78, no. 1, pp. 139-45.
Whyte, J. and Bouchlaghem, D. 2001, 'IT innovation within the construction organisation', paper presented to Proceedings of the IT in Construction in Africa 2001, Mpumalunga South Africa, 30 May - 1 June.
Whyte, J. and Bouchlaghem, D. 2002, 'Implementation of VR systems: A comparison between the early adoption of cad and current uptake of VR.' *Construction Innovation*, vol. 2, no. 1, pp. 3-13.
Whyte, J., Bouchlaghem, D. and Thorpe, T. 2002, 'IT implementation in the construction organization', *Engineering Construction and Architectural Management*, vol. 9, no. 5-6, pp. 371-7.
Williams, A. 1999, *Creativity, invention and innovation : A guide to building your business future*, Allen & Unwin, St Leonards, NSW.
Wilson, D. E. 1997, 'Inspiring your users to learn', *Proceedings of the ACM SIGUCCS 1997 User Services Conference XXV. Are You Ready? 25th SIGUCCS '97 Conference*, pp. 341-7.
Wilson, T. D. 1989, 'The implementation of information system strategies in uk companies: Aims and barriers to success', *International journal of Information Management*, vol. 9, no. 4, pp. 245-58.
Wolek, F. W. 1975, 'Implementation and the process of adopting managerial technology', *Interfaces*, vol. 5, no. 3, pp. 38-46.
Wolfe, R. A. 1994, 'Organizational innovation: Review, critique and suggested research directions.' *Journal of Management Studies*, vol. 31, no. 3, pp. 405-31.
Yetton, P. W., Johnston, K. D. and Craig, J. F. 1994, 'Computer-aided architects: A case study of it and strategic change', *Sloan Management Review*, vol. 35, no. 4, pp. 57-67.
Yin, R. 1994, *Case study research: Design and methods*, 2nd edn, Sage Publications, Thousand Oaks.
Yin, R. K. 2003, *Case study research: Design and methods*, 3rd edn, Sage Publications, Thousand Oaks, Calif.
Zaltman, G., Duncan, R. and Holbek, J. 1973, *Innovations and organizations*, John Wiley & Sons, New York.
Zipf, P. J. 2000, 'Technology-enhanced project management', *Journal of Management in Engineering*, no. January-Febuary, pp. 34-9.

Appendix A – Development of online survey questionnaire

APPENDIX A – Development of online survey questionnaire

This section describes the development of online questionnaire. It contains three main parts: the web-page design, the web programming, and the context of the survey questionnaire.

A1 Web-page design

Normally, a Web page is developed in HyperText Markup Language (HTML) format. This language is one of the standard formats for accessing information by users via Internet. The advantage of using HTML is, the graphic user interface in which a web page can show not only a text file but also a graphic file. In addition, it also has the standard attribute of text and paragraph formatting with which we can adjust text size, colour or fonts.

One of the important features of HTML is the hyper link, as it can allow the linking of many web pages both within and between web pages. This looks like the section of a book that connects topics. This feature also helps to decrease access time to the web pages by separating one web page into several smaller web page files.

In addition, the user can interact with a web page by searching and putting data from the database, however this process requires a web programming language to gather data from the web page and then send them through to the database. The details of this will be described in part A2.

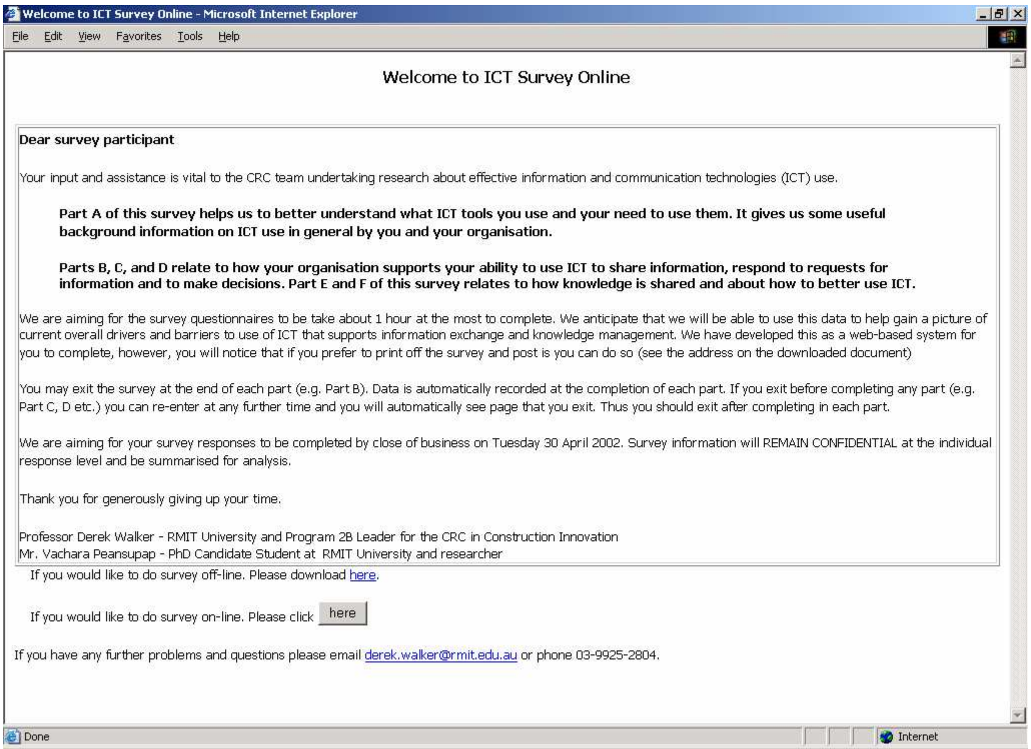


Figure A.1 The Welcome Survey Online Page

A web page that is developed by using a HTML format has some limitations. For example, HTML format files cannot check the user's authority to access the web page. Therefore, if the web page is designed to provide the information without validating the authority, the HTML format could be applied for developing web pages such as the welcome web page in Figure A-1.

Most of the online survey web pages in the current research were developed by using Active Server Page (ASP) format instead of HTML format. The reasons for using ASP are as follows: (1) ASP supports Microsoft Access Database, (2) ASP format is compatible with HTML format and (3) ASP supports Visual Basic script.

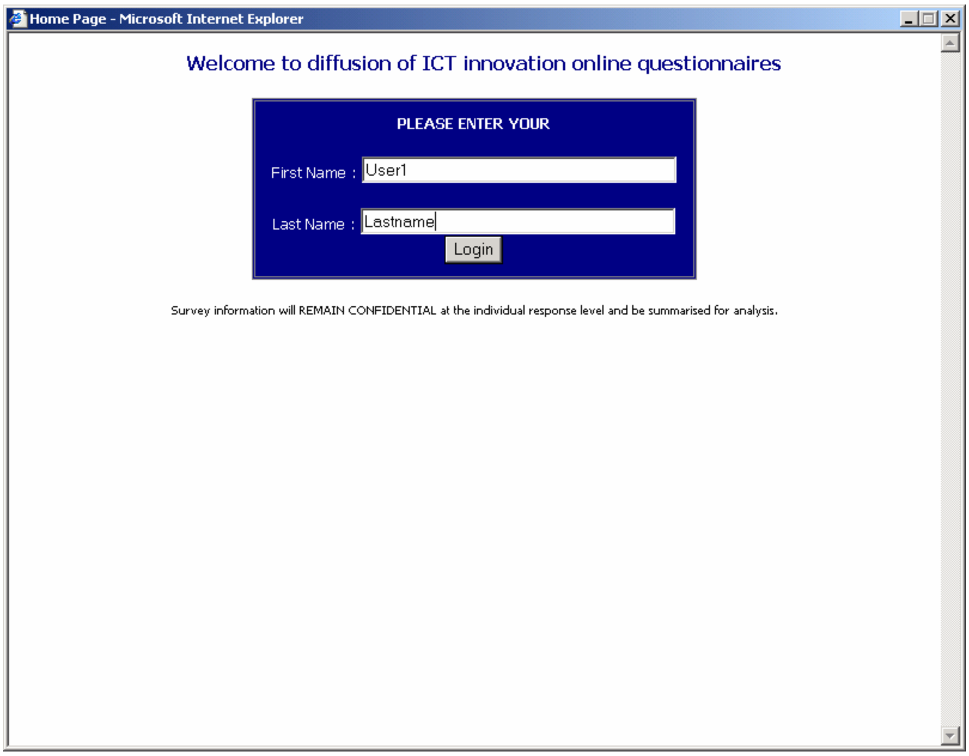


Figure A.2 The login web page

All web pages of the questionnaire were designed for participants who had registered themselves onto the database. Therefore, all participants would need to create their own profiles through a login at the web page in Figure A.2. To make the survey simple, the first name was used in the research and last name as a login and password. Therefore, participants who login for the first time will be asked to check the correct spelling of their first name and the last name before storing it into the database. In addition, participants needed to input their general information such as email and postal addresses, contact phone number during the first time, before responding to the questionnaire part. In the case of participants who had registered previously, after they login, the proper questionnaire part will be shown. The details of this task will be described in the next topic on the web programming.

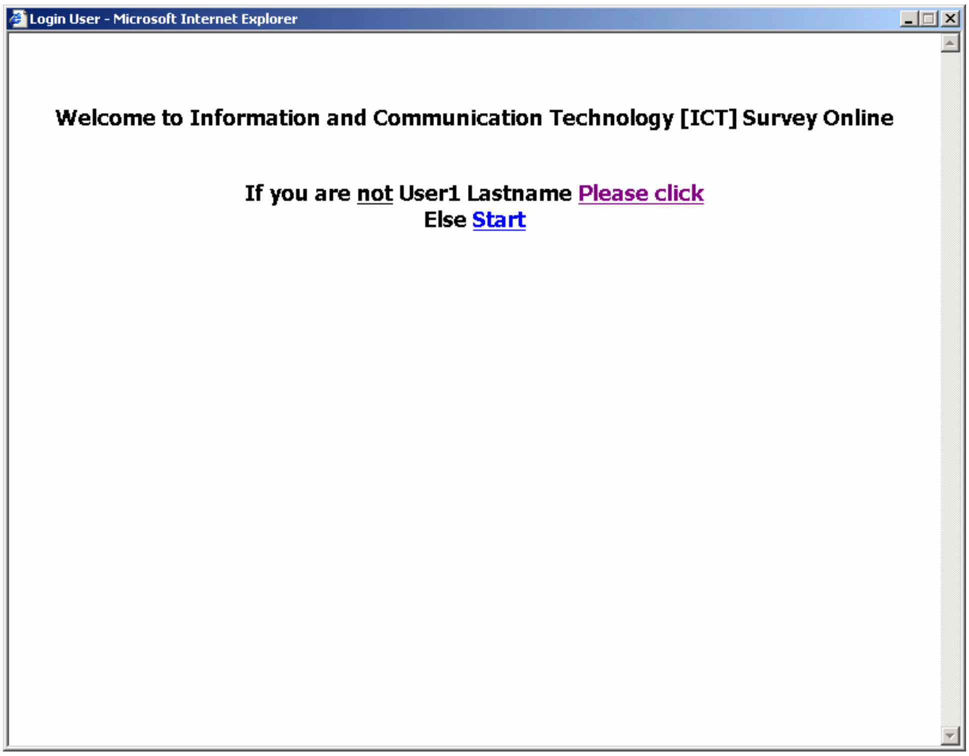


Figure A.3: The Confirmation of First Name and Last Name

To ensure that participants have not left any questions out, each web page also has a function to check for the completeness of data before storing it onto the database. The function was developed by JavaScript programming and embedded into the web page. For example, the questionnaire part ‘a’ in section 2 (qparta2.asp) demonstrates the JavaScript code for checking competed data entry before sending as can be seen in Figure A.4.

```
<HTML><HEAD>
<TITLE>1.2 Software Package Tools</TITLE>
<META http-equiv=Content-Type content="text/html; charset=windows-1252">

<SCRIPT LANGUAGE="JavaScript"><!--
function cForm() {

   for (var i=1;i<18;i++) {
      if ((eval("document.bForm.b" + i + "a" + "[0].checked") != true) &&
         (eval("document.bForm.b" + i + "a" + "[1].checked") != true) &&
         (eval("document.bForm.b" + i + "a" + "[2].checked") != true) &&
         (eval("document.bForm.b" + i + "a" + "[3].checked") != true) &&
         (eval("document.bForm.b" + i + "a" + "[4].checked") != true) &&
         (eval("document.bForm.b" + i + "a" + "[5].checked") != true)
        )
       {
        alert("Please answer the question 1.2." + i);
        return false;
       } // end if statement
…
…
```

Figure A.4: The JavaScript code for checking completed data entry in sparta2.asp

It is essential to describe how the web page refers to web programming code. To do this, the web page could create a link as follows:

```
…
<form NAME="bForm" onsubmit="return cForm()" method="POST"
action="sparta2.asp">      // link command between web page and web programming
…
…
   <TD vAlign=top align=left width=368 height=1>
         <FONT face=Tahoma size=1><INPUT type=radio value=1 name="b1a">1
                                   <INPUT type=radio value=2 name="b1a">2
                                   <INPUT type=radio value=3 name="b1a">3
                                   <INPUT type=radio value=4 name="b1a">4
                                   <INPUT type=radio value=5 name="b1a">5
                                   <INPUT type=radio value=x name="b1a">X
         </FONT>           // option button form in web page
   </TD>
…
…
</form>
…
```

Figure A.5 The Example Code of Form in Web Page

Within each web page, a form was developed to help the participants to answer their question in graphic mode and code the selected answer into a number. In standard HTML, the types of form could be textbox, checkbox, option button, dropdown, list box, and text area

For example, the option button in form name *"b1a"* was designed to have six options which has values as 1, 2... 5, and X as can be seen in Figure A.5. Therefore, if a participant selects one of the answers by a click at the option button, the value from the selected button will represent the answer to the question.

Before sending the data into database, each page has been added to the JavaScript command to check the data. If a participant has left out an answer, a reminder will show the number of question that participant did not provide the answer.

Figure A.6 The Reminder of the Unfilled Question

Thus the web page questionnaire was designed to be then transferred into HTML format to help participant answer the question via Internet. The design also enabled checking for completeness of data before storing data onto the database. Thus, the web page functions as an electronic paper that allows participants to fill and then transfer data to be manipulated by using web programming.

A2 Web Programming Language

The main function of web programming is to connect the data from the web page to the database file. The current research selected the use of ASP for web programming, principally because it is compatible with the web server used for gathering research data. Another important reason is ASP's compatibility with Microsoft Access database. There are four main steps of web programming in order to store the data from web page to database.

1. Check the authorisation of the user,
2. Read data from web page,
3. Connect to the database
4. Open database and store data into it

Each web page has its own programming to store the data because of the different numbers of questions and different types of variables in the forms. The examples of online survey questionnaire are illustrated in Figures A-7 to A-14. In addition, an example of the database is displayed in Figure A-15 and A-16.

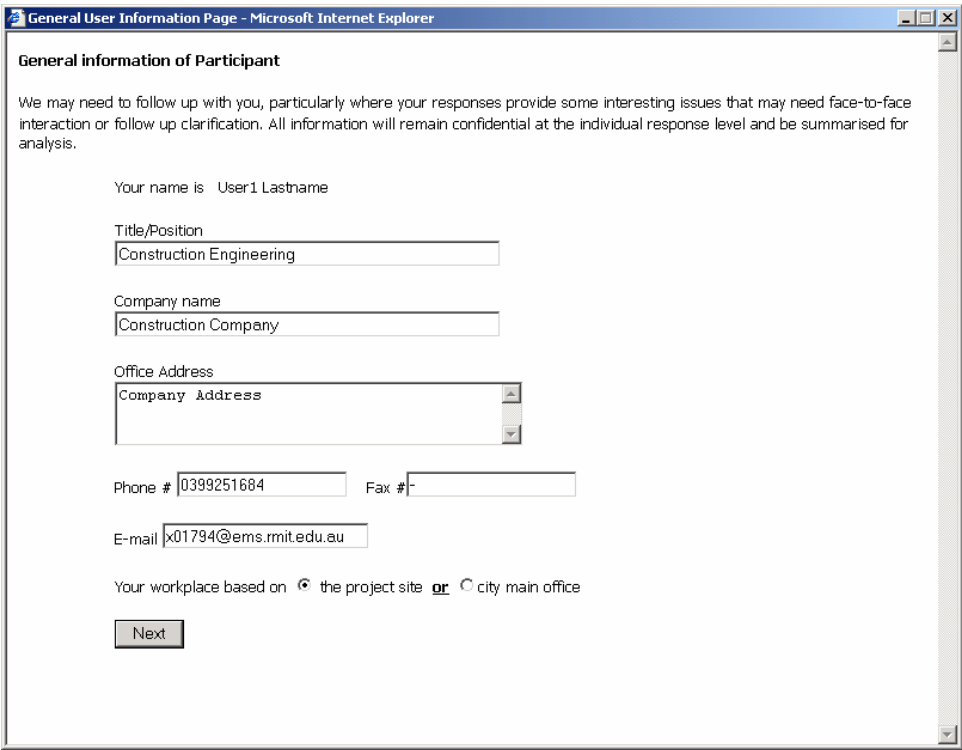


Figure A.7: The General information for participants

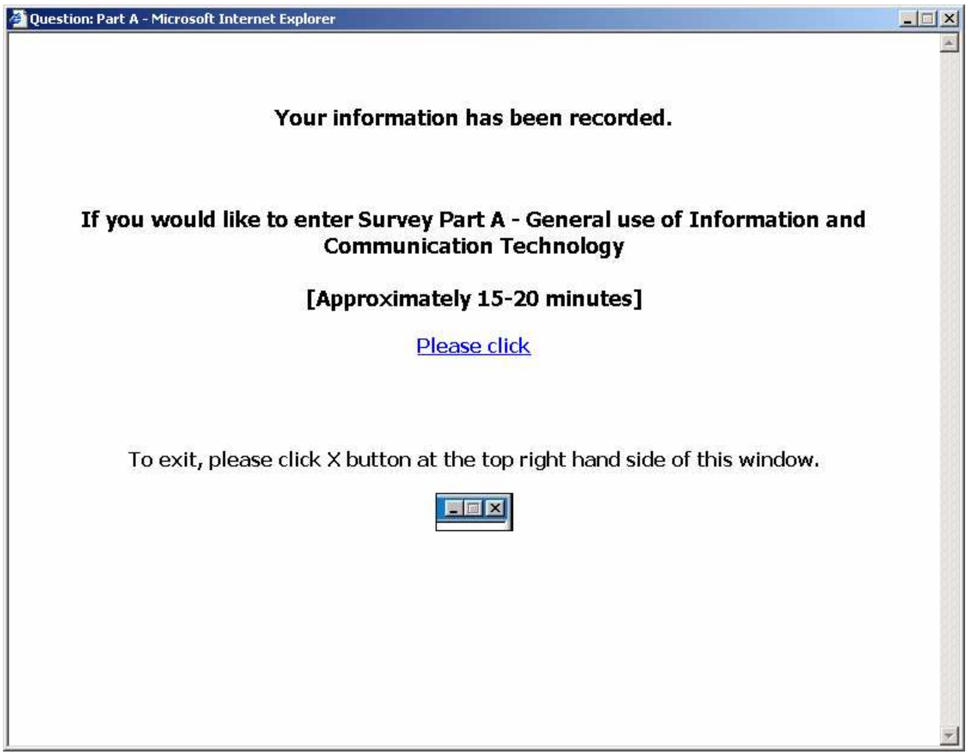


Figure A.8: The confirmation from the web-page to indicate the completion of Part A

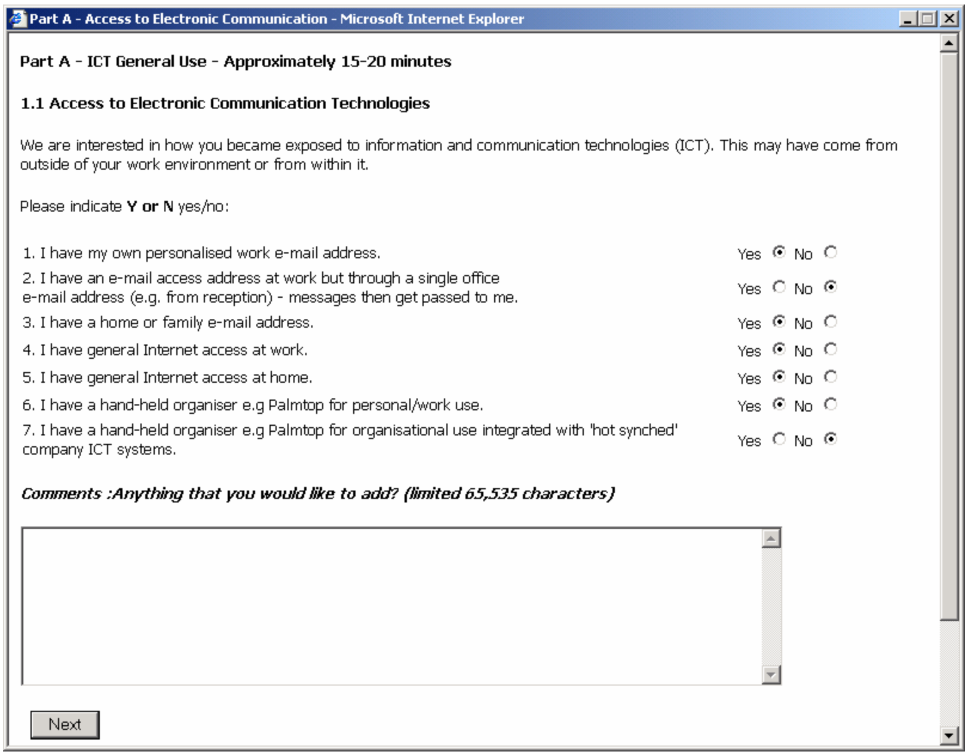
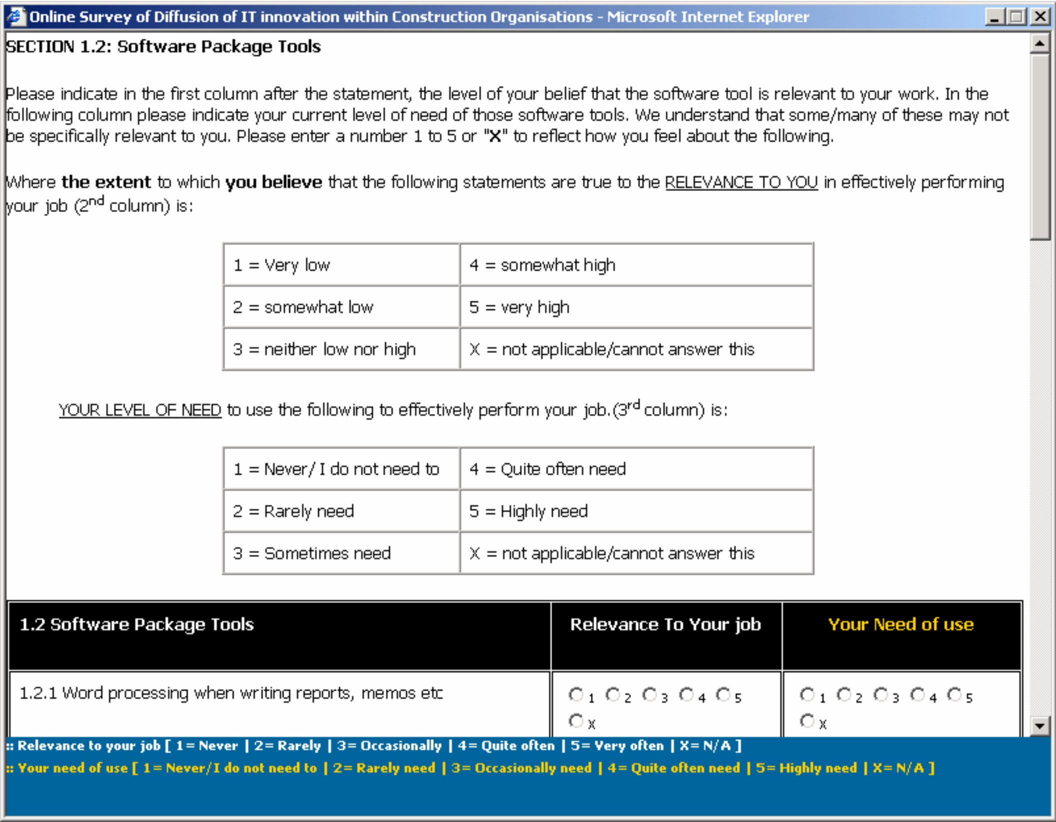


Figure A.9: The webpage of general ICT use, part A



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SECTION 1.2: Software Package Tools

Please indicate in the first column after the statement, the level of your belief that the software tool is relevant to your work. In the following column please indicate your current level of need of those software tools. We understand that some/many of these may not be specifically relevant to you. Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where **the extent** to which **you believe** that the following statements are true to the RELEVANCE TO YOU in effectively performing your job (2nd column) is:

1 = Very low	4 = somewhat high
2 = somewhat low	5 = very high
3 = neither low nor high	X = not applicable/cannot answer this

YOUR LEVEL OF NEED to use the following to effectively perform your job.(3rd column) is:

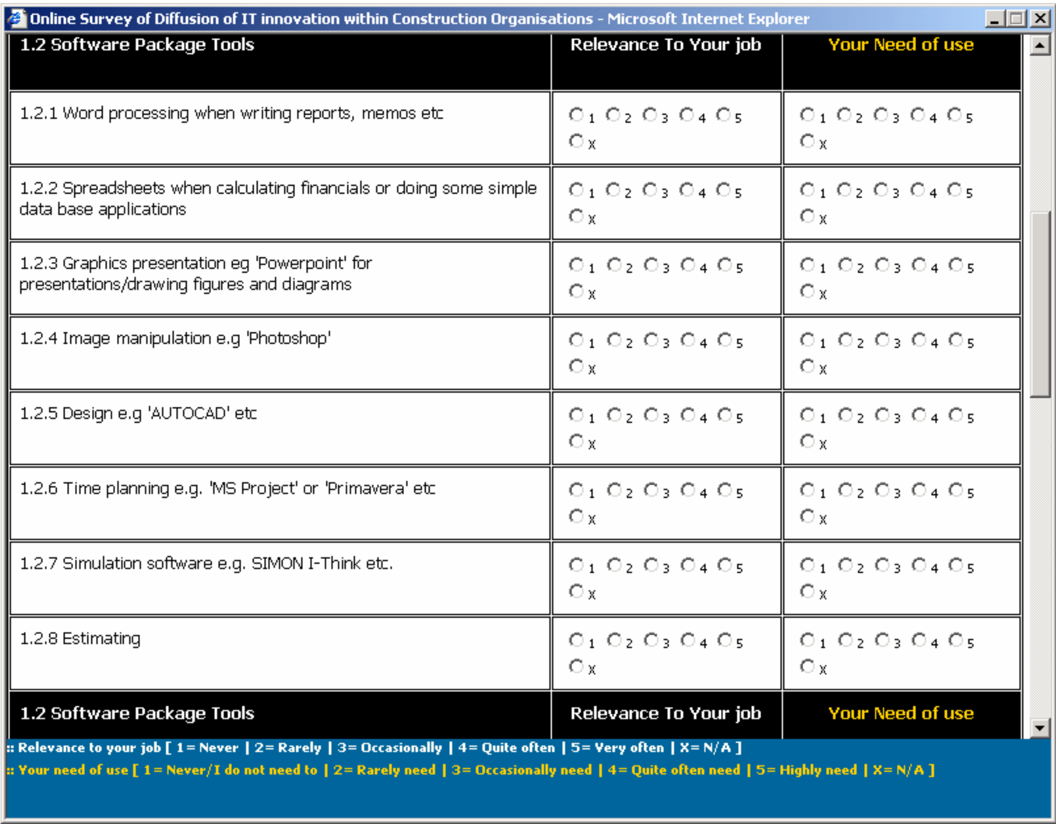
1 = Never/ I do not need to	4 = Quite often need
2 = Rarely need	5 = Highly need
3 = Sometimes need	X = not applicable/cannot answer this

1.2 Software Package Tools	Relevance To Your job	Your Need of use
1.2.1 Word processing when writing reports, memos etc	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x

:: Relevance to your job [1= Never \| 2= Rarely \| 3= Occasionally \| 4= Quite often \| 5= Very often \| X= N/A]

:: Your need of use [1= Never/I do not need to \| 2= Rarely need \| 3= Occasionally need \| 4= Quite often need \| 5= Highly need \| X= N/A]

Figure A.10: The webpage of general ICT use, part B



Online Survey of Diffusion of IT innovation within Construction Organisations - Microsoft Internet Explorer

1.2 Software Package Tools	Relevance To Your job	Your Need of use
1.2.1 Word processing when writing reports, memos etc	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.2 Spreadsheets when calculating financials or doing some simple data base applications	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.3 Graphics presentation eg 'Powerpoint' for presentations/drawing figures and diagrams	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.4 Image manipulation e.g 'Photoshop'	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.5 Design e.g 'AUTOCAD' etc	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.6 Time planning e.g. 'MS Project' or 'Primavera' etc	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.7 Simulation software e.g. SIMON I-Think etc.	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2.8 Estimating	○1 ○2 ○3 ○4 ○5 ○x	○1 ○2 ○3 ○4 ○5 ○x
1.2 Software Package Tools	Relevance To Your job	Your Need of use

:: Relevance to your job [1= Never \| 2= Rarely \| 3= Occasionally \| 4= Quite often \| 5= Very often \| X= N/A]

:: Your need of use [1= Never/I do not need to \| 2= Rarely need \| 3= Occasionally need \| 4= Quite often need \| 5= Highly need \| X= N/A]

Figure A.11: The webpage of general ICT use, Part B (cont.)

The page was designed to have a middle headline to decrease the potential for misleading answers the any question.

Before sending the information into the database, the data each page is checked by the JavaScript command. If the participants had left out an answer, a reminder will show the participant number of that question (see figure A-13).

Figure A.12: The popup of the reminder message indicating the missing answer

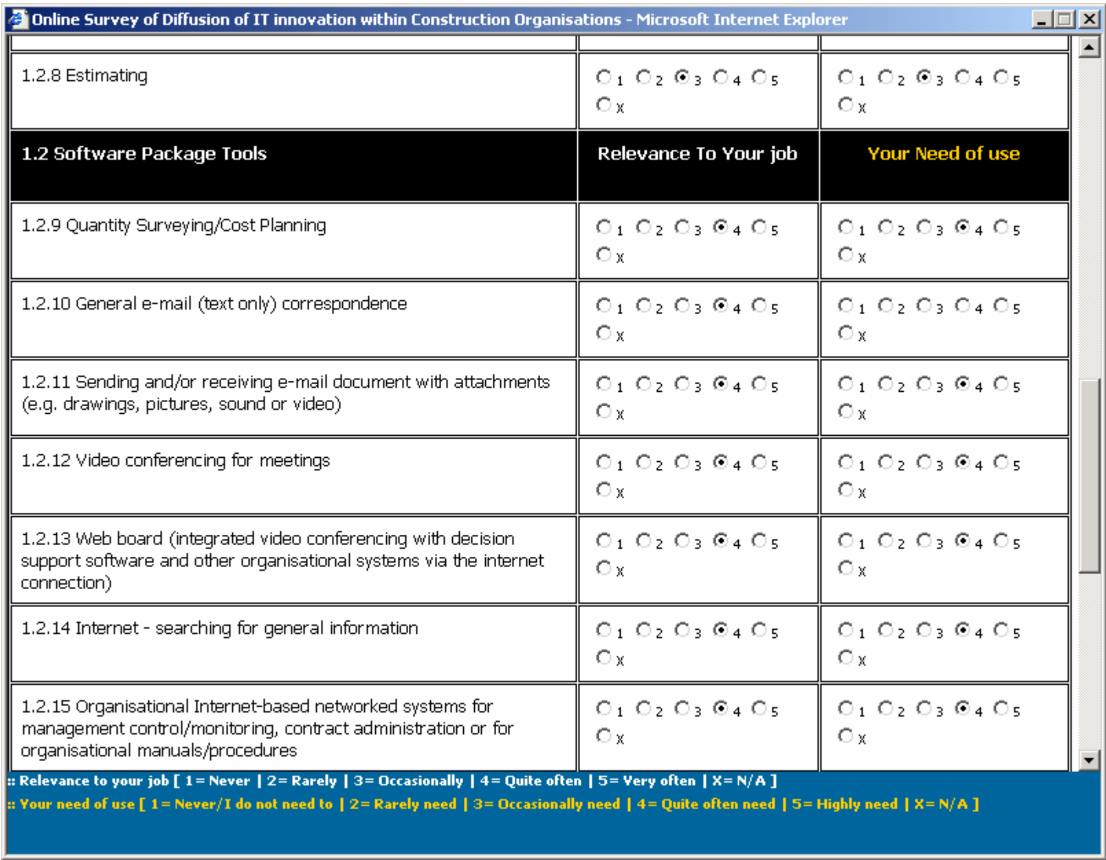


Figure A.13: The webpage of general ICT use, Part B (cont.)

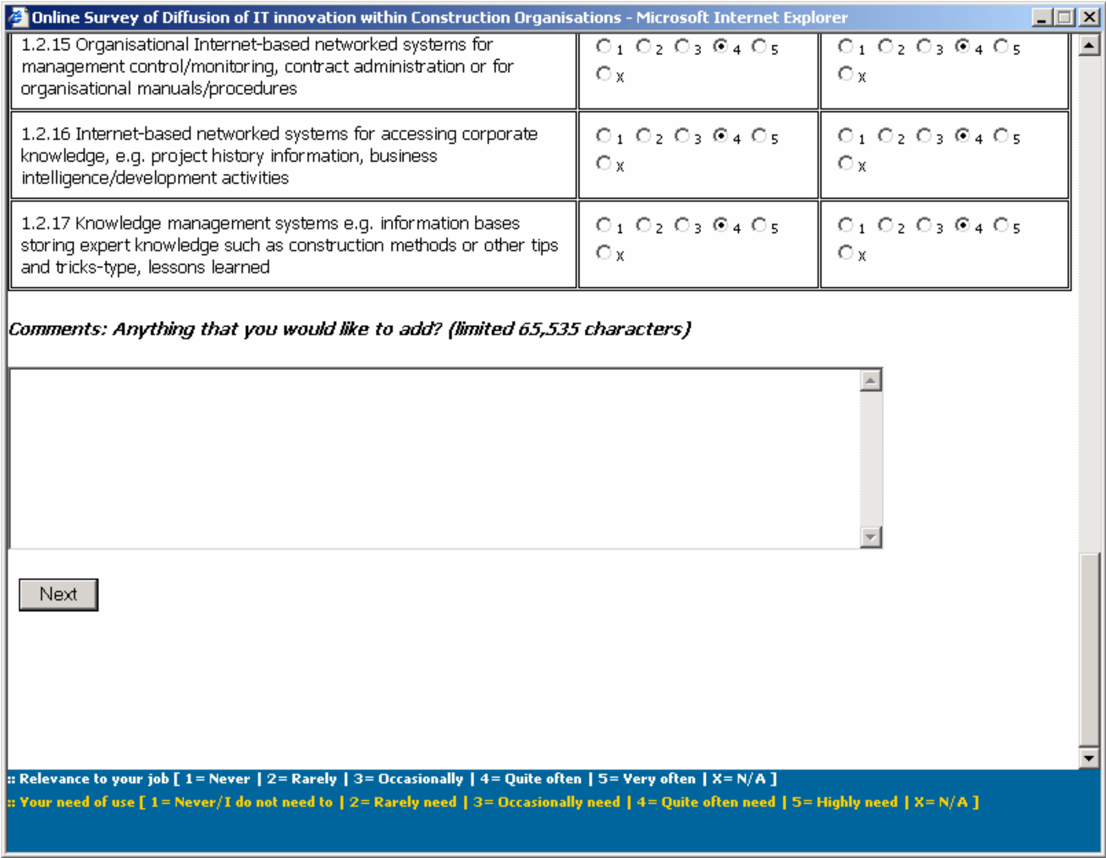


Figure A.14: The webpage of general ICT use, Part B (cont.)

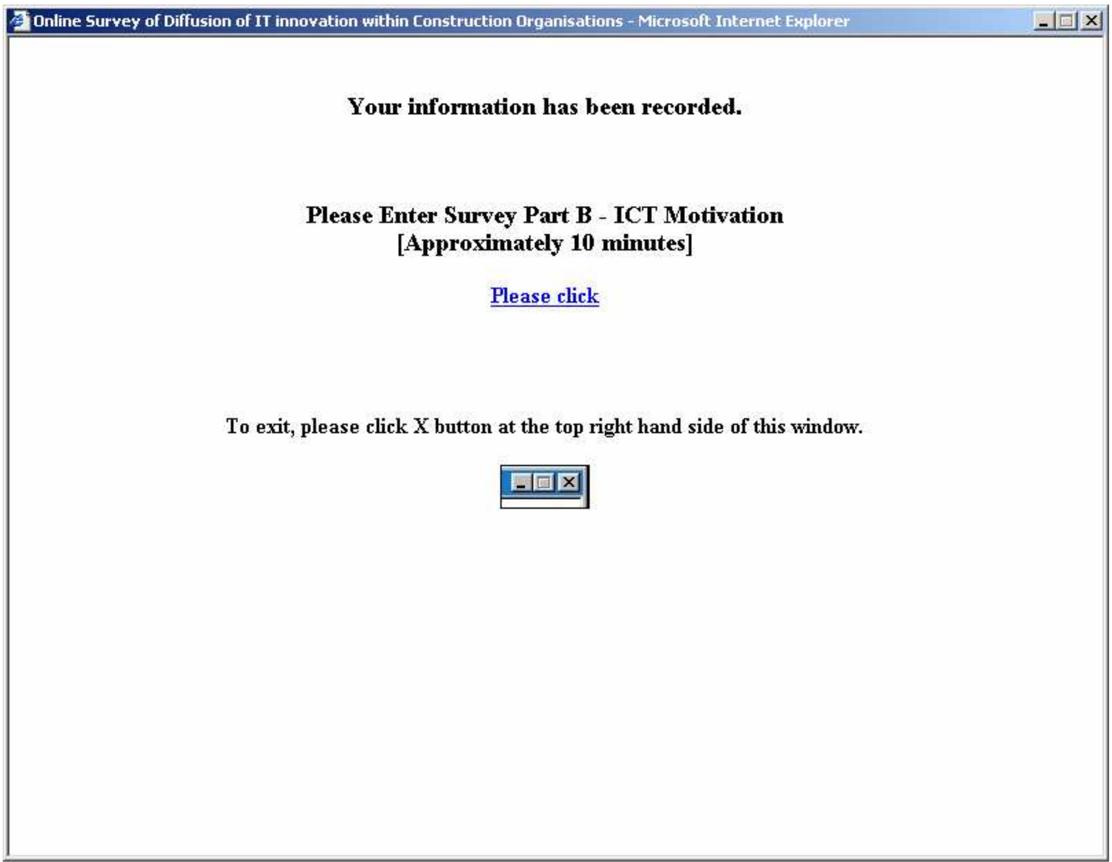


Figure A.15: The confirmation by the web-page of completion of Part B

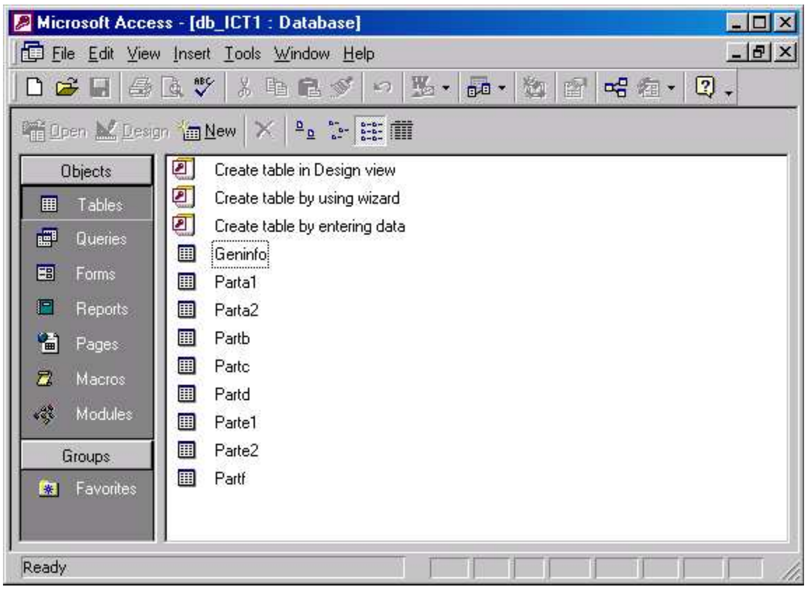


Figure A.16: The details of tables in the Access Database 'db_ICT1.mdb'

All input data are stored into Microsoft Access Database named 'db_ICT1.mdb'. Figure A-16 shows the details of a database that contains nine tables. It is named as 'Geninfo', 'Parta1', 'Parta2', 'Partb', 'Partb', 'Partc', 'Partd', 'Parte1', 'Parte2', and 'Partf'. Each table is named similar to a webpage. For example, the general users' information will be stored in table 'Geninfo'. Each table establishes the fields that correspond with variables in each webpage. For example, the table 'Geninfo' contains the variables that store respondents' information such as UserID, Fname, Lname, Title …etc. (See Figure A-17)

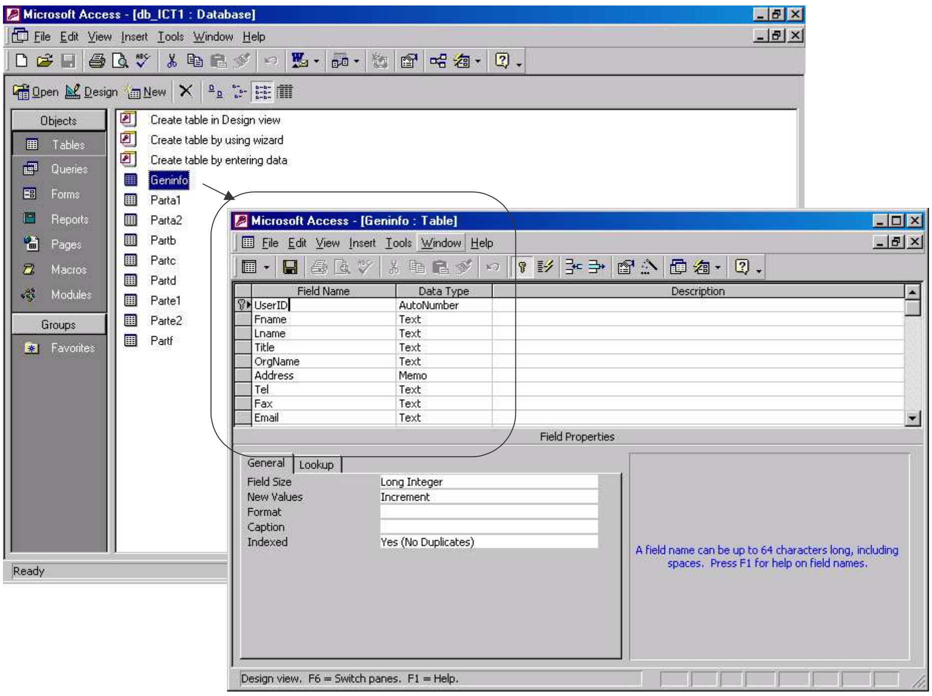


Figure A.17: The details of the variables in the Table 'Geninfo'

A3 Context of survey questionnaire

Post this survey to: Professor Derek Walker, Faculty of Business, Research and Development Unit, RMIT University, PO Box 2476V, Melbourne 3001 – Fax 03-9925-5595 or email derek.walker@rmit.edu.au

Welcome to ICT Diffusion Survey Online

Dear survey participant

Your input and assistance is vital to the CRC team undertaking research about effective information and communication technologies (ICT) use.

Part A of this survey helps us to better understand what ICT tools you use and your need to use them. It gives us some useful background information on ICT use in general by you and your organisation.

Parts B, C, and D relate to how your organisation supports your ability to use ICT to share information, respond to requests for information and to make decisions. Part E and F of this survey relates to how knowledge is shared and about how to better use ICT.

We are aiming for the survey questionnaires to be take about 1 hour at the most to complete. We anticipate that we will be able to use this data to help gain a picture of current overall drivers and barriers to use of ICT that supports information exchange and knowledge management. We have developed this as a web-based system for you to complete, however, you will notice that if you prefer to print off the survey and post is you can do so (see the address on the downloaded document)

You may exit the survey at the end of each part (e.g. Part B). Data is automatically recorded at the completion of each part. If you exit before completing any part (e.g. Part C, D etc.) you can re-enter at any further time and you will automatically see page that you exit. Thus you should exit after completing in each part.

We are aiming for your survey responses to be completed by close of business on May 8, 2002. Survey information will REMAIN CONFIDENTIAL at the individual response level and be summarised for analysis.

Thank you for generously giving up your time.

Professor Derek Walker - RMIT University and Program 2B Leader for the CRC in Construction Innovation
Mr. Vachara Peansupap - PhD Candidate Student at RMIT University and researcher

If you have any further problems and questions please email Derek.walker@rmit.edu.au or phone 03-9925-2804.

PART A – General ICT Use - Approximately 15-20 minutes
We may need to follow up with you, particularly where your responses provide some interesting issues that may need face-to-face interaction or follow up clarification. All of individual information will remain confidential and secure.

Identification

Name ____
Title/Position ____
Company ____
Contact Address ____
____
Phone # ____________________Fax # __________________
E-mail ____________________

Your workplace based on ☐ *the project site* ***or***

☐ *city main office*

1.1 Access to Electronic Communication Technologies

We are interested in your exposure to information and communication technologies (ICT). This may have come from outside of your work environment or from within it. We are also interested to see the extent to which ICT tools are relevant and used in your day-to-day work activities. We will use this data in a consolidated form to provide us with a picture of the organisational use of software packages in general.

Please indicate **Y or N** yes/no:

☐ I have my own personalised work e-mail address.

☐ I have an e-mail access address at work but through a single office e-mail address (e.g. from reception) - messages then get passed to me.

☐ I have a home or family e-mail address.

☐ I have general Internet access at work.

☐ I have general Internet access at home

☐ I have a hand-held organiser e.g Palmtop for personal/work use

☐ I have a hand-held organiser e.g Palmtop for organisational use integrated 'hot synched' with company ICT systems

Comments: Anything that you would like to add?

Please indicate in the first column after the statement, the level of your belief that the software tool is relevant to your work. In the following column please indicate your current level of need of those software tools. We understand that some/many of these may not be specifically relevant to you. Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where **the extent** to which **you believe** that the following statements are true to the RELEVANCE TO YOU in effectively performing your job (2nd column) is:

1 = Very low	4 = somewhat high
2 = somewhat low	5 = very high
3 = neither low nor high	X = not applicable/cannot answer this

YOUR LEVEL OF NEED to use the following to effectively perform your job (3rd column) is:

1 = Never/ I do not need to	4 = Quite often need
2 = Rarely need	5 = Frequently need
3 = Sometimes need	X = not applicable/cannot answer this

1.2 Software Package Tools	Relevance to the job	Your need of use
1.2.1 Word processing when writing reports, memos etc		
1.2.2 Spreadsheets when calculating financials or doing some simple data base applications		
1.2.3 Graphics presentation eg 'Powerpoint' for presentations/drawing figures and diagrams		
1.2.4 Image manipulation e.g 'Photoshop'		
1.2.5 Design e.g 'AUTOCAD' etc		
1.2.6 Time planning/scheduling e.g. 'MS Project' or Primavera etc		
1.2.7 Simulation software e.g. SIMON I-Think etc		
1.2.8 Estimating		
1.2.9 Quantity Surveying/Cost Planning		
1.2.10 General e-mail (text only) correspondence		
1.2.11 Sending and/or receiving e-mail document with attachments (e.g. drawings, pictures, sound/video)		
1.2.12 Video conferencing for meetings		
1.2.13 Web board (integrated video conferencing with decision support software and other organisational systems via the internet connection)		
1.2.14 Internet - searching for general information		
1.2.15 Organisational Internet-based networked systems for management control/monitoring, contract administration or for organisational manuals/procedures.		
1.2.16 Internet-based networked systems for accessing corporate knowledge, e.g. project history information, business intelligence/development activities		
1.2.17 Knowledge management systems e.g. information bases storing expert knowledge such as construction methods or other tips and tricks-type, lessons learned.		

Comments: Anything that you would like to add?

Part B - ICT Motivation - Approximately 10 minutes

We are interested in how you feel about using **information and communication technologies (ICT).** We are interested in drivers and inhibitors to its use. Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where **the extent** to which **you believe** that the following statements are true is:

1 = Very low	4 = somewhat high
2 = somewhat low	5 = very high
3 = neither low nor high	X = not applicable/cannot answer this

2 Statement about applying information and communication technology (ICT) tools by ME or within my work group	**(1- 5 or X)**
2.1 I am **confident** with my use of ICT tools that I am expected to use here	
2.2 I am a bit of an adventurer and **enjoy** being exposed to **new challenges** such as **exploring** new tools or discovering new ways to use existing tools	
2.3 I **enjoy** learning from others about applying ICT tools that we are expected to use here	
2.4 My **skill in using** ICT tools that we are expected to use here is **relatively high** compared to my fellow workers	
2.5 I receive **tangible** rewards (advancement, additional pay, security, or better job prospects etc) from using ICT tools that we are expected to use here	
2.6 I receive **intangible** rewards (respect, admiration, self-fulfilment, feel good about myself) from using ICT tools that we are expected to use here	
2.7 There are clear **advantages** from using ICT tools that we are expected to use here for **decision-making** in my job	
2.8 There are clear **advantages** from using ICT tools that we are expected to use here for **communications within** my team	
2.9 There are clear **advantages** from using ICT tools that we are expected to use here for **communications between** teams	
2.10 There are clear **advantages** from using ICT tools that we are expected to use here for **coordinating** teams	
2.11 ICT tools that we are expected to use here are crucial to support me an my organisation in developing and building **professional credibility**	
2.12 ICT tools that we are expected to use here have **relevance to me** and allow me to effectively perform MY job	
2.13 I am confident that ICT tools that we are expected to use here have the necessary levels of **system response rate** to motivate me to use them.	
2.14 I am confident that ICT tools that we are expected to use here have the necessary levels of **functionality** to motivate me to use them.	
2.15 I am confident that ICT tools that we are expected to use here have the necessary levels of hardware/software **accessibility** to motivate me to use them.	

Comments: Anything that you would like to add?

Part C - ICT Training & Technical Software/Hardware Support - Approximately 10 minutes

We are interested in how you feel about the organisational influences on your use of **information and communication technologies (ICT).** We are interested in training and other forms of learning support. Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where **the extent** to which **you believe** that the following statements are true is:

1 = Very low	4 = somewhat high
2 = somewhat low	5 = very high
3 = neither low nor high	X = not applicable/cannot answer this

3 Statement about applying information and communication technology (ICT) tools for ME or within my work group	**(1- 5 or X)**
3.1 My immediate supervisor **encourages** me to learn about and/or apply ICT tools that I am expected to use here	
3.2 I have **confidence** that I am **capable** of learning about and applying ICT tools that I am expected to use here	
3.3 I am given **enough quality of training** for learning about and applying the ICT tools that I am expected to use here	
3.4 I am given **enough time for training** for learning about and applying the ICT tools that I am expected to use here	
3.5 I am given **enough flexibility in my job demands** (in terms of rescheduling daily demands and activities etc) to learn how to apply ICT tools that I am expected to use here	
3.6 **Our work procedures support** our capacity to use ICT tools that I am expected to use here	
3.7 I have been given sufficient **time to think** about how I can best use ICT tools that I am expected to use here	
3.8 Organisational **technical support** is sufficient (eg. help desk, and getting software operational) to allow me to learn about and apply ICT tools that I am expected to use here	
3.9 **Functionality / ease of use** of ICT tools I need to use **at my workplace** is adequate for me to do my job	
3.10 Access **speed** and **reliability** of networked **hardware at my workplace** is adequate for me to do my job	
3.11 **Mentoring support** is sufficient to allow me to learn about and understand how to effectively apply the ICT tools that I am expected to use here	
3.12 ICT tools that I am expected to use here are **compatible** with my experience of existing systems and work procedures.	
3.13 I was given the opportunity to **trial and experiment** ICT tools that I am expected to use here.	
3.14 The **result/benefit of using** ICT tools that I am expected to use here were **easy to observe**.	
3.15 I believe that ICT tools that I am expected to use here **are better than** ones that I have previously/traditionally used.	

Comments: Anything that you would like to add?

Part D - ICT Workplace Support - Approximately 10 minutes

We are interested in how you feel about using **information and communication technologies (ICT).** We are interested in ICT use relating specifically to how the workforce environment is structured and how it operates in practice to support effective ICT use. Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where **the extent** to which **you believe** that the following statements are true is:

1 = Very low	4 = somewhat high
2 = somewhat low	5 = very high
3 = neither low nor high	X = not applicable/cannot answer this

4 Statement about applying information and communication technology (ICT) tools for ME or within my work group	**(1- 5 or X)**
4.1 MY **organisation** is generally **committed** to providing necessary resources and systems to make ICT tools that I am expected to use here work for me	
4.2 **I** am **committed** to effectively use ICT tools that I am expected to use here	
4.3 I can **trust my immediate supervisor** that if I make some mistakes when first getting to grips with ICT tools that I am expected to use here I will not be blamed and pressured when learning and practicing these tools	
4.4 ICT tools that I am expected to use here are making my job too **difficult, complex** or **frustrating** to handle	
4.5 **I am anxious** about making mistakes when learning and practicing using ICT tools that I am expected to use here	
4.6 I *feel safe in* **openly discussing** any difficulties about using ICT tools that I am expected to use here	
4.7 Most of my *colleagues/fellow workers feel safe in* **openly discussing problems** about difficulties in using ICT tools that I am expected to use here	
4.8 I feel **unduly pressured to be effective** in using ICT tools that I am expected to use here	
4.9 My **immediate supervisor** in my organisation **is open to suggestions** on improving the way that ICT tools that I am expected to use here are used	
4.10 My **organisation in general is open to suggestions** on improving the way that ICT tools that I am expected to use here are used	

Comments: Anything that you would like to add?

Part E - ICT Information Sharing - Approximately 10 minutes

We are interested in how you feel about the effectiveness of formal and informal methods of the way in which experiences about using **information and communication technologies (ICT)** is shared. Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where **the extent** to which **you believe** that the following statements are true is:

1 = Very low	4 = somewhat high
2 = somewhat low	5 = very high
3 = neither low nor high	X = not applicable/cannot answer this

5.1 Statement about supporting information and communication technology (ICT) tools use for ME or within my work group	**(1- 5 or X)**
5.1.1 Our organisation supports our ability to **share experience** of ICT tools that I am expected to use here	
5.1.2 Our organisation provides **tangible rewards** (bonus, promotion, etc) to those who **share ideas** and experience about ICT tools that I am expected to use here	
5.1.3 Our organisation provides **intangibly rewards** (recognition, thanks or public praise) to those who **share ideas** and experience about ICT tools that I am expected to use here	
5.1.4 I feel comfortable and keen to **help and explain** (mentoring) **one-on-one** to others on how to effectively use ICT tools that we are expected to use here	
5.1.5 My **colleagues** in my immediate work group are willing and keen to **help me formally** through discussing and demonstrating ICT tools that I am expected to use here	
5.1.6 My **colleagues** in my immediate work group are willing and keen to **help me informally** through discussing and demonstrating ICT tools that I am expected to use here	

Comments: Anything that you would like to add?

We are interested about formal and informal methods of how you develop and share experiences about using **information and communication technologies (ICT).** Please enter a number 1 to 5 or "**X**" to reflect how you feel about the following.

Where the frequency of access is:

1 = Never	4 = Quite often
2 = Rarely /perhaps once or twice	5 = Very often
3 = Occasionally	X = not applicable/cannot answer this

Where the helpfulness of each media to help you learning of ICT tools is:

1 = No help	4 = Very helpful
2 = Rarely helpful	5 = Highly helpful
3 = Occasionally help	X = not applicable/cannot answer this

5.2 Source/Medium that you use to learn about ICT tools that you are expected to use in your job	**WITHIN Working Hours**		**OUTSIDE Working Hours**	
	Freq. Access	Helpful-ness	Freq. Access	Helpful-ness
5.2.1 General **text** media - Newspaper or magazine articles				
5.2.2.**Audio-visual** media - Radio/TV/Video/CDs				
5.2.3 **Exhibitions/**Fairs/shows				
5.2.4 **Internally** organised conferences				
5.2.5 **Externally** organised conferences				
5.2.6 **Formal** external programs of study eg short courses or university study				
5.2.7 **Formal** internal programs of study eg short courses organised through my working group organisation				
5.2.8 **Informal** discussion groups with colleagues/workmates				
5.2.9 **Informal** through friends, spouse or children				
5.2.10 **Informal** through surfing the internet and/or newsgroups				

Comments: Anything specific that you would like to add or clarify?

Finally, would you be prepared to participate in a continuing study that we would like to undertake to better understand how the use of ICT tools and innovations are spread throughout organisations? We do not wish you to feel pressured to answer yes.

If your answer was YES then again many thanks.

We would like to hold some brief focus group meetings (about 1 hour) and we would expect that these might occur once or twice.

We are also considering looking for a few people to help us by maintaining a brief log (which we will supply) that tracks who you help and why and what advice you have sought and why in using ICT the tools that you are required to use in your work. We expect that the log (which we will supply and could be either kept as hardcopy or electronically) would briefly require responses to the following questions:

- Who did you contact?
- Was the request critically urgent (must know today), very important (must know within the next few days), important (must know within a week), peripheral (would like to know ASAP)?
- What was the response like (meeting response time, meeting the response content requirement)?
- Were you referred to somebody else and if so who was that?
- What was the qualification of the person whose advice you sought (in terms of expert in that aspect, having the authority to fix a problem, having the influence to get the problem fixed)?
- To what extent was the problem fix communicated to others?
- How was the communication undertaken when seeking advice?

These are the sort of things that we would ask. We expect that it will help us to better design ways in which knowledge about using ICT tools can be established in organisations. We also expect to better map out the patterns of communication and influence relating to ICT tool use.

Yes or No (Y/N) ☐

If your answer was NO then

Many thanks for taking the time to help us with this survey.

A4 Plain language statement of survey questionnaire

Date: ____________________

Name of Participant_________________
Position __________________________
Name and address of organisation or company

Re: Questionnaire for studying diffusion of IT innovation within best-practice construction organisation

Dear ___________,

An important objective of this project is to understand how information and communications technology (ICT) innovation is diffused or 'rolled-out' throughout and within organisation and to map the way in which ICT and this innovation in particular takes place in a series of case study organisations.

We aim to facilitate a better understanding of drivers and inhibitors to ICT innovation diffusion so that innovative technologies and processes can be more effectively identified and applied in organisations. This research will draw also upon theory from social networking and strategy. It will explain how innovative change occurs and highlight how innovation, knowledge management and change management can be better supported for strategic and operational improvement. We expect to be able to generate best practice guides on innovation diffusion and templates for specific innovation initially concentrating on IT innovations such as e-mail, networked sites for managing projects, and several other emerging IT applications used both within the construction industry and from other industries which may be applied in the construction industry.

At a more generalised level, this research module will study best practice case histories of how knowledge management may be applied in the construction industry and how innovation (focussing on significant recent ICT applications that involved a significant change management process) is diffused in construction organisations.

We are therefore collaborating with several organisations to help them, and through that exercise. These will be better understanding on how ICT was diffused. We are asking you to respond to a survey that we have prepared to get an idea of how you are using ICT. There are no 'right/wrong' or 'good/bad' answers and the data that we will gather will remain confidential with only summary finding being fed back to your organisation and used in the study's publications. We will be undertaking interviews later in which we hope to gain a picture of how networks of people have influenced each other with their current use of ICT. These influential people may well be located outside the organisation, such as your children, partners, friends as well as work mates. Thank you for generously giving up your time.

Sincerely Yours,

Mr. Vachara Peansupap,
Ph.D. student

Professor Derek Walker,
Supervisor

Research and Development Unit, RMIT University PO Box 2476V Melbourne 3001
Fax 03-9925-5595

Table A-1 The raw data from survey questionnaire Part A – 1.1 General ICT use

Userid	title	title_no	orgc	q1	q2	q3	q4	q5	q6	q7
1	Manager Contracts	1.00	1	0	1	1	0	1	1	1
2	Manager - Knowledge Management	1.00	2	0	1	0	0	0	0	0
3	ESTIMATOR	2.00	2	0	1	0	0	0	0	1
4	Commercial Manager - Building	1.00	2	0	1	0	0	0	1	1
5	Business Development Manager	1.00	2	0	1	0	0	0	1	1
6	Corporate Travel Manager	1.00	2	0	1	0	0	0	1	1
7	Group IT Manager	1.00	2	0	1	0	0	0	0	0
8	Operations Manager, Building	1.00	2	0	1	0	0	0	1	1
9	Principal	2.00	3	0	1	0	0	0	1	1
10	HR Manager Southern Region	1.00	2	0	1	0	0	0	1	1
11	Systems Manager	1.00	2	0	1	0	0	0	1	1
12	Senior Associate	1.00	3	0	1	0	0	0	1	1
13	CAD Technician	2.00	3	0	1	0	0	0	1	1
14	Structural Engineer	2.00	3	0	1	0	0	0	0	1
15	Senior Associate	1.00	3	0	1	0	0	0	1	1
16	Graduate Engineer	2.00	3	0	1	0	0	0	1	1
17	Senior Construction Engineer	2.00	2	0	1	0	0	0	1	1
18	Regional Manager	1.00	3	0	1	0	0	0	1	1
19	Project Manager	1.00	3	0	1	0	0	0	1	1
20	Acoustic Engineer	2.00	3	0	1	1	0	1	1	1
21	Principal Project Officer	2.00	1	0	1	0	0	0	0	1
22	Integrated Systems Engineer	2.00	2	0	1	0	0	0	1	1
23	Engineer	2.00	3	0	1	0	0	1	1	1
24	Graduate Engineer	2.00	3	0	1	0	0	1	1	1
25	Corporate Communications Manager	1.00	2	0	1	0	0	0	1	1
26	Senior Associate	1.00	3	0	1	0	0	0	1	1
27	Adrian Claridge	2.00	2	0	1	0	0	0	1	1
28	Group Planning Manager	1.00	2	0	1	0	0	0	1	1
29	Group Secretary	2.00	3	0	1	0	0	1	1	1
30	Lotus Notes Support	2.00	2	0	1	0	0	0	1	1
31	Senior Technician	2.00	3	0	1	0	0	0	1	1
32	Associate	2.00	3	0	1	0	0	0	1	1
33	Engineer	2.00	3	0	1	0	0	0	1	1
34	Principal Project Officer	2.00	1	0	1	0	0	0	1	1
35	Group Integrated Systems Manager	1.00	2	0	0	0	0	0	0	0
36	A/Senior Accommodation Planner	1.00	1	0	1	0	0	0	1	1
37	Group Knowledge Director	1.00	3	0	1	0	0	0	0	0
38	Maintenance Planner	1.00	1	0	1	0	0	0	1	1
39	Senior Associate, Acoustics Group Leader	1.00	3	0	1	0	0	0	1	1
40	Senior Engineer	2.00	3	0	1	0	0	0	1	1
41	Senior Engineer	2.00	3	0	1	1	0	1	1	1
42	Business Development Advisor	1.00	1	0	1	0	0	0	1	1
43	Principal Consultant - Maintenance Services	1.00	1	0	1	0	0	0	1	1
44	PA to General Manager Qld/ Regional Travel Co-Ordi	1.00	2	0	1	0	0	0	1	1
45	PA TO GENERAL MANAGER - SOUTHERN REGION	1.00	2	0	1	1	0	1	1	1
46	HR Manager	1.00	3	0	1	0	0	0	1	1
47	Design Engineer	2.00	3	0	1	0	0	0	1	1
48	Manager, Logistics	1.00	1	0	1	0	0	0	1	1
49	National Quality Manager	1.00	3	0	1	0	0	0	1	1

50	Manager - Project Management	1.00	3	0	1	1	0	1	1	1
51	Associate	2.00	3	0	1	0	0	1	1	1
52	Associate	2.00	3	0	1	0	0	0	1	1
53	Compliance Officer	2.00	1	0	1	0	0	0	1	1
54	Information Technology Project Officer	2.00	1	0	1	0	0	0	1	1
55	GENERAL MANAGER - SOUTHERN REGION	1.00	2	0	1	0	0	0	0	0
56	Chief Engineering Estimator	2.00	2	0	1	0	0	0	1	1
57	Construction Manager - Engineering	1.00	2	0	1	1	0	0	1	1
58	Engineering Manager	1.00	2	0	1	0	0	0	1	1
59	Design Manager	1.00	2	0	1	0	0	0	1	1
60	Business Development Manager	1.00	2	0	1	0	0	0	0	0
61	Project Manager	1.00	2	0	1	0	0	0	0	1
62	Mechanical Site Engineer	2.00	2	0	1	0	0	0	1	1
63	Project Officer	2.00	1	0	1	0	0	0	1	1
64	Manager MIMSOE Development and reporting	1.00	1	0	1	0	0	0	1	1
65	Project Officer	2.00	1	0	1	0	0	0	1	1
66	Senior Engineer	2.00	3	0	1	0	0	0	1	1
67	Senior Engineer	2.00	3	0	1	0	0	0	1	1
68	National Manager Industrial	1.00	2	0	1	0	0	0	1	1
69	Structural Engineer	2.00	3	0	1	0	0	0	1	1
70	Finance Manager	1.00	3	0	1	0	0	0	1	1
71	Graphics	2.00	3	0	1	0	0	1	1	1
72	Senior Associate	1.00	3	0	1	1	0	1	1	1
73	Engineer	2.00	3	0	1	0	0	0	1	1
74	associate structural engineer	2.00	3	0	1	0	0	0	1	1
75	Graphics Manager	1.00	3	0	1	0	0	0	1	1
76	Engineer	2.00	3	0	1	1	0	0	1	1
77	Associate	2.00	3	0	1	0	0	0	1	1
78	associate	2.00	3	0	1	1	0	1	1	1
79	Chief Estimator - Building	2.00	2	0	1	0	0	0	1	1
80	Principal	2.00	3	0	1	0	0	0	1	1
81	Senior Secretary	2.00	2	0	1	0	0	0	1	1
82	Senior Associate	2.00	3	0	1	0	0	0	1	1
83	Associate	2.00	3	0	1	0	0	0	0	1
84	Engineer	2.00	3	0	1	0	0	0	0	1
85	Project Manager	1.00	3	0	1	1	0	1	0	0
86	SITE MANAGER	1.00	2	0	1	0	1	0	0	0
87	Engineering Planning Manager	1.00	2	0	1	0	0	0	0	1
88	Sinior Manager	1.00	2	0	1	0	1	0	1	1
89	Bus. Development Manager	1.00	2	0	0	0	0	0	1	1
90	PA to GM, Rail/HRC	2.00	2	0	1	0	0	0	1	1
91	National Manager Defence	1.00	2	0	1	0	0	0	1	1
92	Construction Manager - Building	1.00	2	0	1	0	0	0	1	1
93	Manager Rail Investments	1.00	2	0	1	0	0	0	1	1
94	Plans and Service Officer	2.00	1	0	1	0	0	0	1	1
95	Director Procurement Services	1.00	1	0	1	1	0	0	1	1
96	Business Development	1.00	2	0	1	0	0	0	1	1
97	Quality / Environmental Manager - Southern Region	1.00	2	0	1	0	0	0	1	1
98	Electronic Project Delivery	2.00	1	0	1	0	0	0	1	1
99	Sen Consultant (Maintenance Assessment)	1.00	1	0	1	0	0	0	1	1
100	Principal Mechanical Engineer	2.00	1	0	1	0	0	0	1	1
101	Principal Consultant - Business Systems	2.00	1	0	1	0	0	0	1	1

102	Office Administration	2.00	1	0	1	0	0	0	1	1
103	Administration Officer	2.00	1	0	1	1	0	1	1	1
104	Manager Information services Branch	1.00	1	0	1	0	0	0	0	0
105	Senior Architect	2.00	1	0	1	0	0	0	1	1
106	Principal Scientific Officer	2.00	1	0	1	1	0	1	1	1
107	Project Officer	2.00	1	0	1	0	0	0	1	1
108	Administration Officer	2.00	1	0	1	0	0	0	1	1
109	Senior Policy Officer	2.00	1	0	1	0	0	0	1	1
110	Specification Coordinator and Architect	2.00	1	0	1	1	0	1	1	1
111	Maintenance Manager	1.00	1	0	1	0	1	0	1	1
112	ADMINISTRATION OFFICER	2.00	1	0	1	0	0	0	1	1
113	Administrative Officer	2.00	1	0	1	0	0	0	1	1
114	A/Maintenance Manager	1.00	1	0	1	1	0	1	1	1
115	Plans and Records Manager	1.00	1	0	1	1	0	1	1	1
116	MANAGER SUSTAINABLE DEVELOPMENTS	1.00	1	0	1	0	0	0	1	1
117	Policy Project Officer	2.00	1	0	1	1	0	1	1	1

Table A-2 The raw data from survey questionnaire Part A – 1.2 Software Package tools (Q1.2.1-Q1.2.17) (Relevance to the job)

Userid	qa 1	qa 2	qa 3	qa 4	qa 5	qa 6	qa 7	qa 8	qa 9	qa 10	qa 11	qa 12	qa 13	qa 14	qa 15	qa 16	qa 17
1	4	4	4	2	x	4	x	x	x	5	4	1	x	4	4	x	3
2	5	5	3	2	2	5	x	3	3	4	4	2	1	3	4	x	4
3	4	5	1	2	x	x	x	5	5	4	4	1	x	2	x	x	3
4	5	5	3	3	1	3	1	1	1	5	5	3	1	4	5	3	3
5	5	x	5	x	x	x	x	x	x	5	5	x	x	4	x	5	4
6	4	4	3	2	x	x	x	x	x	5	5	3	1	5	5	5	5
7	5	5	5	3	x	3	x	x	x	5	5	3	1	4	4	3	3
8	5	5	4	2	2	4	x	4	4	4	4	3	1	3	2	2	4
9	5	5	5	3	5	4	2	3	4	5	5	5	3	5	4	5	4
10	5	5	4	4	x	x	x	x	x	5	5	4	x	4	4	4	4
11	3	3	3	1	1	2	1	1	1	5	5	4	2	5	2	2	4
12	5	5	5	5	5	3	5	1	1	5	5	5	4	5	5	5	5
13	3	3	3	4	5	1	1	2	2	5	5	1	1	4	3	2	4
14	4	5	4	2	5	4	3	3	2	5	5	3	2	4	5	5	5
15	5	5	5	5	3	3	2	2	2	5	5	5	4	5	5	5	5
16	4	5	3	1	x	x	x	x	1	4	5	3	1	5	4	4	4
17	4	5	4	4	2	5	1	5	3	5	5	3	1	5	4	3	4
18	5	5	5	4	5	5	2	3	2	5	5	5	3	5	5	5	5
19	4	4	3	2	1	4	1	3	3	5	5	3	4	4	5	5	4
20	5	5	5	3	3	3	2	1	1	5	5	4	2	4	5	5	5
21	5	5	5	2	1	5	1	x	x	5	5	1	x	5	5	5	4
22	4	5	3	3	1	2	x	x	x	4	5	1	1	5	3	5	5
23	4	4	3	3	4	4	2	3	1	5	5	3	1	5	4	4	5
24	3	2	2	3	4	x	x	1	2	3	3	2	x	4	3	x	3
25	5	5	5	5	1	1	1	1	1	5	5	3	1	5	5	5	2
26	3	3	2	1	x	2	x	x	x	3	4	2	x	2	x	1	2
27	3	5	4	3	3	5	1	1	1	5	5	2	1	3	3	3	5
28	3	5	5	2	2	5	x	2	2	5	4	3	2	5	4	4	4
29	5	4	4	4	x	3	x	x	x	5	5	2	x	3	3	3	3
30	4	2	4	1	1	1	1	1	1	5	5	2	1	5	1	1	5
31	3	3	5	5	5	1	x	x	2	4	4	2	x	2	3	3	3
32	5	5	5	5	5	5	x	3	4	5	5	5	5	5	5	5	5
33	5	5	5	3	4	4	5	3	4	5	5	5	4	5	5	5	5

34	5	5	3	1	1	4	1	1	1	5	5	1	1	3	1	3	3
35	5	5	5	2	1	5	x	x	x	5	5	4	2	5	5	5	5
36	5	5	3	4	5	4	2	4	4	5	5	2	2	4	5	5	5
37	5	5	5	5	5	5	x	5	5	5	5	5	5	5	4	5	5
38	5	5	3	5	2	5	x	3	2	5	5	1	1	4	5	4	3
39	5	5	5	3	1	3	1	1	1	5	5	4	3	4	5	5	3
40	5	4	2	3	4	4	5	x	5	4	5	3	3	5	3	4	5
41	5	5	5	5	5	5	x	x	x	5	5	5	x	5	5	5	5
42	5	3	4	4	1	1	1	1	1	5	5	1	1	5	4	3	3
43	5	5	5	2	1	5	x	1	2	5	5	5	3	5	5	3	4
44	5	4	5	3	1	1	1	1	1	5	5	4	1	5	1	5	5
45	5	4	5	2	x	x	x	x	x	5	5	3	x	5	x	x	x
46	5	4	3	1	1	1	1	1	1	5	5	4	1	3	1	3	3
47	5	5	3	2	4	3	2	2	2	4	4	2	2	4	4	3	4
48	5	3	5	2	1	2	1	1	1	5	5	3	1	3	4	4	4
49	5	5	4	4	1	4	1	1	1	5	5	4	2	5	5	4	4
50	4	4	4	2	1	4	1	1	1	5	5	2	1	3	4	2	3
51	5	3	2	2	4	4	4	2	1	4	4	2	1	3	5	4	4
52	5	5	5	5	5	3	x	x	x	5	5	4	x	5	x	x	x
53	5	3	1	1	1	1	1	1	1	5	5	1	1	5	3	5	3
54	5	5	5	4	5	3	1	1	1	5	5	2	1	5	1	3	4
55	4	4	4	x	x	x	x	x	3	5	4	4	x	3	x	x	2
56	3	5	3	1	5	3	1	5	5	5	4	1	1	3	1	1	4
57	5	4	4	2	1	5	1	4	4	5	5	4	4	4	3	3	4
58	4	4	4	2	3	4	1	4	2	5	5	3	2	3	2	3	4
59	5	4	1	1	1	1	1	1	3	5	5	2	2	4	3	2	1
60	5	5	5	3	2	3	3	2	2	5	5	3	3	4	5	5	5
61	5	5	3	2	5	5	x	5	5	5	5	4	2	3	2	2	4
62	5	5	3	3	5	3	1	4	3	5	5	1	1	3	5	5	5
63	5	4	3	3	2	3	x	x	x	5	5	1	1	5	3	4	2
64	4	3	3	x	x	3	x	x	x	4	x	x	x	2	x	x	x
65	4	2	3	1	x	2	x	x	x	5	5	x	x	4	4	4	3
66	5	5	4	4	4	4	5	4	1	5	5	4	3	5	5	4	5
67	5	4	2	2	5	3	4	4	3	5	5	3	x	5	5	5	5
68	5	5	2	1	2	4	1	4	4	5	5	1	1	5	4	5	5
69	5	5	3	3	4	4	x	x	x	5	5	1	1	4	3	4	4
70	5	5	4	1	1	3	1	1	1	5	5	3	2	4	3	4	4
71	5	3	5	5	5	1	1	1	1	4	5	3	2	4	1	2	2
72	5	5	5	4	1	5	5	1	1	5	5	5	5	5	5	5	5
73	5	5	5	4	5	4	x	3	3	5	5	4	4	5	4	4	4
74	5	4	2	1	1	1	1	2	2	4	5	1	1	5	4	4	4
75	5	2	5	5	3	2	2	3	x	5	5	3	1	5	1	2	3
76	4	5	4	3	4	2	x	1	2	4	4	2	1	3	x	2	3
77	5	5	5	4	5	4	1	5	5	5	5	5	4	5	5	5	5
78	5	5	5	4	5	3	5	2	1	5	5	4	2	4	4	5	4
79	3	5	3	2	1	3	x	5	5	5	4	2	1	2	2	1	3
80	5	5	5	4	2	2	1	1	2	5	5	3	2	3	3	x	3
81	5	2	2	2	x	x	x	x	1	5	5	x	x	3	1	1	1
82	5	3	4	3	1	4	1	1	1	5	5	3	1	4	4	5	4
83	5	5	3	2	5	3	1	3	2	5	5	3	1	5	5	5	5
84	5	5	4	4	4	3	x	x	x	5	4	2	1	4	5	5	4
85	4	4	3	1	3	4	x	2	2	5	5	2	1	4	2	1	2
86	5	5	1	3	3	5	x	1	1	4	4	1	x	4	5	3	5
87	5	5	3	1	1	5	1	2	4	5	5	1	1	3	3	1	5
88	5	5	1	3	x	3	1	5	5	5	4	2	1	3	3	3	3
89	4	4	3	3	1	1	1	1	1	4	5	2	1	4	5	4	4

90	5	5	5	1	1	4	1	1	1	5	5	5	1	4	3	3	3
91	4	5	3	x	4	5	x	5	4	5	4	x	x	5	x	5	3
92	4	5	3	1	2	5	1	5	5	5	3	2	1	3	5	5	4
93	5	5	5	3	2	4	1	2	3	5	5	3	3	5	5	5	4
94	4	3	1	1	1	1	1	2	1	4	4	1	1	3	2	1	1
95	4	4	2	1	1	3	1	2	1	1	5	1	1	3	4	4	4
96	5	4	4	4	2	3	1	4	2	5	5	4	x	5	5	5	5
97	5	4	3	2	2	2	1	1	1	5	5	2	1	4	5	5	4
98	5	3	3	5	4	3	1	3	3	5	5	5	3	5	3	5	3
99	5	5	4	3	1	4	x	2	2	5	4	2	2	5	x	2	2
100	5	5	2	2	1	4	1	3	1	5	5	3	x	5	4	3	5
101	5	5	5	5	x	1	x	x	x	5	5	3	x	5	5	5	5
102	4	5	2	1	2	1	x	x	x	5	5	x	3	3	4	4	2
103	4	3	1	1	1	1	1	1	1	5	5	1	1	3	4	3	3
104	5	5	5	2	2	5	2	2	2	5	5	2	2	5	4	5	5
105	5	4	4	4	5	4	x	x	x	5	5	2	2	4	5	5	4
106	5	5	5	5	4	4	x	3	5	5	5	4	3	5	5	5	5
107	4	3	3	1	1	4	1	1	x	5	5	x	x	5	4	4	3
108	3	3	1	1	1	1	1	1	1	4	5	2	1	2	1	2	1
109	5	3	3	1	1	1	1	1	1	5	5	2	1	5	2	5	4
110	5	3	3	3	4	3	2	2	2	5	5	2	1	4	4	4	2
111	4	2	4	2	x	4	x	3	x	5	5	x	x	4	5	3	3
112	3	5	x	x	x	x	x	4	x	5	5	x	x	4	5	4	x
113	5	5	3	4	1	x	x	2	x	5	5	x	x	3	5	5	3
114	5	5	1	x	x	2	x	x	x	5	5	x	x	3	5	x	x
115	4	3	2	2	2	2	1	1	1	5	5	1	1	3	5	2	5
116	5	5	5	3	4	2	1	x	x	3	5	2	2	5	3	4	5
117	5	2	3	1	1	1	1	1	1	5	5	2	1	4	3	2	3

Table A-3 The raw data from survey questionnaire Part A – 1.2 Software Package tools (Q1.2.1-Q1.2.17) (Your need of use)

Userid	qa 18	qa 19	qa 20	qa 21	qa 22	qa 23	qa 24	qa 25	qa 26	qa 27	qa 28	qa 29	qa 30	qa 31	qa 32	qa 33	qa 34
1	5	4	3	2	x	3	x	x	x	5	5	1	x	4	3	x	3
2	5	5	4	3	1	3	x	1	1	5	5	2	1	4	4	x	4
3	4	5	1	2	x	x	x	5	5	4	4	1	x	2	x	x	3
4	5	5	3	3	1	3	1	1	1	5	5	3	1	4	5	3	3
5	5	x	3	x	x	x	x	x	x	5	5	x	x	2	x	3	3
6	4	4	3	2	x	x	x	x	x	5	5	3	1	5	5	5	5
7	5	5	5	3	x	3	x	x	x	5	5	3	1	4	4	3	3
8	5	5	3	2	2	3	x	4	2	4	4	3	4	3	2	2	x
9	5	5	5	3	5	3	1	1	1	5	5	5	1	4	4	5	5
10	5	5	4	3	x	x	x	x	x	5	5	4	x	4	4	4	4
11	3	2	3	2	1	2	1	1	1	5	5	4	2	5	3	3	3
12	5	5	5	4	3	2	4	1	1	5	5	5	3	5	5	5	5
13	3	4	3	5	5	1	1	2	2	5	5	1	1	4	3	2	4
14	4	5	4	2	5	4	3	3	2	5	5	3	2	4	5	5	5
15	5	4	4	3	2	3	2	3	1	5	5	5	3	5	5	5	4
16	4	5	3	1	x	x	x	x	1	4	5	3	1	5	4	4	4
17	4	5	4	4	2	5	1	5	3	5	5	3	1	5	4	3	4
18	5	5	5	4	3	3	1	1	1	5	5	5	3	5	5	5	3
19	5	5	2	2	1	3	1	2	2	5	4	2	1	3	4	4	2
20	5	5	5	3	3	3	2	1	1	5	5	4	3	4	4	5	5
21	5	5	5	3	1	5	1	x	x	5	5	1	x	5	5	5	4
22	4	5	3	3	1	3	x	x	x	4	5	1	2	4	3	5	5

23	4	4	3	3	4	3	2	2	1	5	5	3	1	5	4	4	5
24	3	2	2	3	3	x	x	1	1	3	2	1	x	4	1	x	1
25	5	5	5	1	1	1	1	1	1	5	5	3	1	5	5	5	2
26	4	3	2	x	x	2	x	x	x	4	4	2	x	2	x	2	2
27	4	5	4	3	3	5	1	1	1	5	5	2	1	3	3	3	5
28	3	5	5	2	2	5	x	2	2	4	4	3	1	5	4	4	4
29	5	4	4	4	x	3	x	x	x	5	5	2	x	3	3	3	3
30	4	2	3	2	1	1	1	1	1	5	5	2	1	5	1	1	5
31	3	3	5	5	5	1	x	x	2	4	4	2	x	2	2	3	4
32	5	5	5	5	4	4	x	3	4	5	5	5	4	5	5	5	5
33	4	4	3	3	2	2	5	1	2	5	5	3	2	5	5	3	4
34	5	4	4	x	1	4	1	1	1	5	5	1	1	3	1	2	3
35	5	5	5	2	1	5	x	x	x	5	5	3	2	4	5	5	5
36	5	5	3	4	5	4	2	2	2	5	5	1	1	4	5	5	5
37	5	5	5	2	1	2	x	1	1	5	4	5	1	5	2	3	3
38	5	5	3	5	2	5	x	3	1	5	5	1	1	4	5	4	3
39	5	5	4	4	1	3	1	1	1	5	5	4	1	5	3	3	1
40	5	4	3	3	3	3	5	x	4	4	5	3	2	4	1	3	5
41	5	5	5	5	5	5	x	x	x	5	5	5	x	5	5	5	5
42	5	3	4	4	1	1	1	1	1	5	5	1	1	5	4	3	3
43	5	5	3	2	1	4	x	1	2	5	5	3	2	5	5	3	3
44	5	4	5	3	1	1	1	1	1	5	5	4	1	5	1	5	5
45	5	4	5	2	x	x	x	x	x	5	5	3	x	5	x	x	x
46	5	3	2	1	1	1	1	1	1	5	5	3	1	5	1	2	4
47	4	5	2	2	3	2	2	1	1	4	3	1	1	4	3	2	4
48	5	3	5	2	1	2	1	1	1	5	5	3	1	3	3	3	3
49	x	5	4	4	1	4	1	1	1	5	5	4	2	5	5	4	4
50	4	4	4	2	1	4	1	1	1	5	5	2	1	3	4	2	3
51	4	3	2	2	2	5	4	2	1	4	3	2	1	3	4	3	3
52	5	5	4	4	4	3	x	x	x	5	5	4	x	5	x	x	x
53	5	3	1	1	1	1	x	1	x	5	5	1	1	5	3	5	3
54	5	5	5	4	5	3	1	1	1	5	5	2	1	5	1	3	4
55	2	2	2	x	x	x	x	x	1	5	4	3	x	2	x	x	2
56	4	5	3	1	5	3	1	5	5	5	5	2	1	3	1	1	3
57	5	4	4	2	1	2	1	2	3	5	5	4	3	3	2	2	4
58	4	4	4	2	2	3	1	2	2	5	5	3	1	3	2	3	2
59	5	5	2	1	1	2	1	1	3	5	5	2	2	4	3	2	4
60	5	5	4	3	2	3	3	2	2	5	5	3	2	4	5	5	5
61	3	5	3	2	1	5	x	5	5	5	5	4	1	2	1	1	4
62	5	5	2	4	4	1	1	2	1	5	5	1	1	4	4	4	4
63	5	4	3	3	1	3	x	x	x	5	5	1	1	5	3	4	2
64	5	4	3	x	x	2	x	x	x	3	x	x	x	2	x	x	x
65	5	2	3	1	x	2	x	x	x	5	5	x	x	4	4	4	3
66	5	4	4	3	4	1	4	4	1	5	5	4	2	5	2	5	5
67	4	3	1	3	1	x	4	3	x	5	5	3	x	5	5	4	4
68	4	5	1	2	2	3	1	3	2	5	5	2	1	5	3	5	3
69	5	5	3	4	2	2	1	x	1	5	5	1	1	4	3	2	1
70	5	5	3	1	1	3	1	1	1	5	5	3	2	4	3	4	4
71	4	3	4	5	5	1	1	1	1	5	4	3	1	4	1	2	2
72	5	5	5	4	1	5	5	1	1	5	5	4	5	5	5	5	5
73	5	5	5	4	4	4	x	x	x	5	5	3	1	5	2	3	3
74	5	5	2	1	1	1	1	1	2	5	5	1	1	5	4	4	2
75	5	2	5	5	3	2	2	4	x	5	5	3	1	5	1	1	2
76	4	4	3	3	1	2	x	2	2	4	4	2	1	3	x	3	3
77	5	5	3	2	1	3	1	4	4	5	5	4	2	5	5	4	4
78	5	5	5	4	4	3	3	2	1	5	5	4	2	4	4	5	5

79	3	5	2	1	2	2	x	5	5	5	3	3	1	2	2	1	3
80	5	5	5	2	2	2	1	1	1	5	5	3	1	3	3	x	3
81	5	3	2	2	x	x	x	x	1	5	5	x	x	3	1	1	1
82	5	3	4	2	1	3	1	1	1	5	5	2	1	4	4	5	3
83	5	5	2	2	5	2	1	2	2	5	5	2	1	5	4	4	4
84	5	5	3	3	3	3	x	x	x	5	3	2	1	4	5	5	4
85	4	4	3	1	2	4	x	2	2	5	5	2	1	4	2	1	2
86	5	5	1	4	1	5	x	1	1	4	4	1	x	3	5	4	4
87	5	5	1	1	1	5	1	1	4	5	5	1	1	3	3	1	3
88	5	5	2	3	x	3	2	5	5	5	4	2	1	3	3	3	3
89	4	4	3	3	1	1	1	1	1	4	4	2	1	5	4	4	3
90	5	5	5	1	1	4	1	1	1	5	5	5	1	4	3	3	3
91	5	5	4	x	4	4	x	5	4	5	4	x	x	4	x	3	3
92	3	4	2	1	1	4	1	2	3	5	3	2	1	3	5	5	4
93	5	5	5	3	2	4	1	2	3	5	5	3	1	5	5	5	4
94	4	3	1	1	1	1	1	2	1	4	4	1	1	3	2	1	1
95	4	4	3	1	1	3	1	2	1	1	5	1	1	3	3	3	3
96	5	5	4	4	2	3	x	3	2	5	5	4	x	5	5	5	5
97	5	4	3	2	3	3	2	3	2	5	5	1	1	4	5	5	4
98	5	3	3	5	4	3	1	3	3	5	5	5	3	5	3	5	3
99	5	5	3	3	1	4	x	3	2	5	3	2	3	4	x	2	2
100	5	5	2	2	1	3	1	3	1	5	5	3	x	5	4	3	4
101	5	5	5	4	x	5	x	x	x	5	5	3	x	5	5	5	5
102	4	4	2	1	1	1	x	x	x	5	5	x	3	3	4	3	1
103	4	3	1	1	1	1	1	1	1	5	5	1	1	3	4	3	3
104	3	3	3	1	1	5	2	2	1	3	3	2	2	4	4	3	4
105	5	4	4	4	5	4	x	x	x	5	5	2	2	4	5	5	4
106	5	5	5	5	3	4	x	3	4	5	5	4	3	5	5	5	5
107	4	2	4	1	1	4	1	1	x	5	5	x	x	5	3	4	4
108	3	3	1	1	1	1	1	1	1	4	5	2	1	2	1	2	1
109	5	3	3	1	1	1	1	1	1	5	5	2	1	x	2	5	4
110	5	4	3	3	3	3	2	2	2	5	5	2	1	4	4	4	2
111	4	3	4	2	x	3	x	3	x	5	5	2	x	3	4	3	3
112	3	5	x	x	x	x	x	4	x	5	5	x	x	4	5	4	x
113	5	5	2	4	2	x	x	2	x	5	5	x	x	3	5	5	3
114	5	5	2	x	x	2	x	x	x	5	5	x	x	3	4	x	x
115	4	3	2	2	2	2	1	1	1	5	5	1	1	3	5	2	5
116	5	5	5	3	4	2	1	x	x	3	5	2	2	5	3	4	5
117	5	2	2	1	1	1	1	1	1	5	5	2	1	4	2	2	3

Table A-4 The raw data from survey questionnaire Part B - ICT Motivation (Q2.1-Q2.15)

Userid	qb1	qb2	qb3	qb4	qb5	qb6	qb7	qb8	qb9	qb10	qb11	qb12	qb13	qb14	qb15
1	4	4	4	4	1	4	4	4	4	3	4	4	4	4	4
2	5	5	5	4	1	3	4	5	5	5	4	5	3	3	4
3	4	5	4	4	1	4	x	x	x	x	4	3	2	2	2
4	5	4	4	3	1	1	4	5	5	5	5	5	5	5	5
5	3	4	5	3	1	5	5	4	2	5	4	4	3	4	4
6	4	5	5	4	1	3	5	5	5	5	5	5	3	3	5
7	5	3	4	4	1	3	4	4	4	4	4	4	4	4	4
8	5	5	3	3	1	2	3	5	4	4	4	5	4	4	4
9	5	5	5	5	3	4	5	5	4	4	4	4	4	3	3
10	5	5	4	5	3	4	4	5	5	5	5	5	5	4	4
11	4	4	4	3	3	3	4	4	4	4	4	4	4	4	4
12	5	3	3	3	1	1	5	5	5	5	5	4	3	4	4
13	4	5	4	4	2	3	4	3	4	4	3	4	3	3	4

14	5	5	5	5	2	4	4	4	4	4	5	5	4	4	4
15	3	4	5	3	x	5	3	5	5	5	4	5	4	3	2
16	3	4	5	3	1	4	4	4	4	4	4	4	2	2	3
17	5	3	4	3	4	4	4	4	4	4	5	4	5	4	5
18	5	5	5	5	3	4	5	5	5	5	5	5	4	4	5
19	4	5	4	5	1	4	4	4	5	5	4	5	4	4	4
20	5	4	4	5	2	4	4	4	2	4	4	4	2	2	4
21	5	5	5	4	1	4	4	4	4	4	4	4	4	4	4
22	4	5	4	4	1	1	5	5	5	5	4	4	3	3	3
23	5	5	5	5	1	3	3	5	4	4	3	5	5	5	5
24	4	3	4	3	1	4	4	1	1	1	3	4	3	4	3
25	5	5	5	3	1	2	3	4	4	3	4	5	3	3	3
26	2	1	1	1	x	x	2	2	2	2	1	2	1	1	1
27	5	5	3	4	1	3	3	4	4	3	3	5	3	4	5
28	4	3	4	5	1	4	4	4	2	2	5	5	4	4	4
29	5	4	5	5	1	5	4	4	5	4	5	5	5	5	5
30	3	5	5	2	1	2	4	5	5	5	4	4	4	3	5
31	4	4	3	3	1	3	3	3	4	4	4	4	x	3	3
32	3	4	4	3	2	2	4	5	5	5	5	4	3	3	3
33	4	4	4	3	3	4	4	5	5	5	5	5	3	5	5
34	4	2	4	4	1	4	4	5	3	3	4	5	2	4	3
35	3	x	3	4	x	x	4	4	4	4	4	3	3	3	3
36	5	5	5	5	2	4	4	3	5	4	5	5	x	3	3
37	4	4	5	3	3	4	5	5	5	5	4	5	5	5	5
38	5	5	5	5	1	3	5	5	5	5	5	5	3	3	4
39	4	4	4	4	1	3	4	4	2	1	1	3	4	4	5
40	4	4	4	4	3	4	3	4	4	4	4	4	3	4	3
41	5	5	5	5	x	x	x	5	5	5	5	5	5	5	5
42	4	4	4	3	3	3	4	4	4	4	4	4	3	3	3
43	4	4	4	5	1	3	5	4	4	3	5	5	3	2	2
44	5	5	5	4	1	5	4	5	5	5	5	5	4	4	5
45	4	4	4	3	4	3	3	4	3	3	3	3	3	4	4
46	2	4	5	2	1	1	3	5	5	3	2	3	4	3	3
47	5	5	5	4	3	4	4	5	4	4	4	5	4	4	4
48	3	2	3	2	1	4	2	5	5	5	5	5	4	4	4
49	4	4	5	3	2	4	5	5	5	4	4	5	4	4	4
50	4	3	3	4	3	3	4	3	3	3	3	3	3	3	3
51	3	3	4	3	2	2	3	3	4	4	3	3	3	3	3
52	5	5	5	5	x	4	4	5	5	5	5	5	5	5	5
53	5	3	4	x	3	5	5	5	5	5	5	5	5	5	5
54	4	5	5	4	1	2	4	4	4	4	5	4	4	4	4
55	3	2	3	2	2	2	3	4	4	4	4	3	3	3	3
56	3	2	3	4	1	3	4	4	5	5	5	5	3	4	4
57	4	3	4	3	3	4	4	4	4	4	4	5	4	4	2
58	3	3	4	4	3	4	2	5	5	5	5	5	4	3	3
59	4	3	3	x	x	2	x	4	4	4	5	5	x	3	3
60	5	5	4	5	2	4	5	5	5	5	5	5	4	4	5
61	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4
62	4	5	5	5	1	3	4	4	4	3	3	5	5	4	4
63	4	4	4	3	1	1	1	3	4	3	3	3	4	4	2
64	4	4	4	4	x	3	3	4	4	3	3	4	3	3	3
65	5	4	4	3	1	3	2	3	3	3	3	3	2	2	2
66	5	4	4	4	1	3	4	4	5	5	4	4	3	4	3
67	3	3	4	3	2	2	4	5	5	4	4	5	3	3	3

68	5	5	3	4	3	4	4	3	3	3	4	4	4	4	4
69	4	5	4	5	1	2	4	5	5	5	4	5	3	3	x
70	4	4	4	4	3	4	4	3	4	4	3	4	2	2	2
71	5	4	4	4	3	4	2	x	5	4	4	4	3	4	3
72	4	5	5	4	1	3	5	5	5	5	5	5	5	5	5
73	4	4	4	3	4	4	3	5	5	3	3	5	4	5	5
74	4	4	4	3	2	4	3	5	5	5	5	4	3	3	2
75	5	5	5	4	2	4	4	4	4	4	4	5	5	5	5
76	3	3	4	2	1	2	x	2	3	4	4	4	2	2	3
77	5	5	5	4	4	4	4	4	5	5	5	5	3	3	3
78	4	5	4	3	1	3	4	5	5	5	5	5	4	5	5
79	4	4	3	4	5	5	5	5	5	5	4	5	5	4	5
80	4	2	3	2	2	4	3	5	5	5	3	4	2	3	3
81	4	3	4	4	x	4	x	4	4	4	4	5	3	4	5
82	5	3	2	3	3	3	3	3	3	3	3	3	3	3	3
83	4	4	4	3	3	4	4	4	4	4	4	3	3	3	3
84	4	5	3	5	3	4	5	5	5	4	3	5	3	3	4
85	4	4	4	4	1	3	3	3	3	4	3	3	3	3	3
86	4	3	5	3	1	4	5	5	5	5	5	4	3	4	4
87	4	4	4	3	3	3	4	4	4	4	4	4	4	4	4
88	3	4	4	2	x	3	5	5	5	5	5	5	5	5	4
89	4	3	3	2	1	1	1	1	1	4	4	2	2	2	2
90	5	4	4	3	3	4	1	3	3	1	1	4	3	4	4
91	5	3	3	4	1	1	3	3	3	3	3	4	5	5	5
92	4	4	3	3	x	3	5	5	5	5	4	5	4	4	4
93	5	5	3	5	3	4	5	5	5	5	4	5	5	5	5
94	5	4	5	4	3	4	5	5	3	3	3	4	4	4	4
95	4	4	4	3	1	2	2	2	2	2	2	3	4	4	3
96	5	4	5	3	3	3	5	4	5	5	5	5	5	4	4
97	4	4	5	5	5	4	4	5	5	5	5	5	4	4	4
98	5	5	3	5	3	5	5	5	5	5	5	5	5	5	5
99	5	5	4	5	2	4	3	3	3	3	4	4	3	3	3
100	5	5	5	5	1	5	4	4	4	3	5	5	4	5	5
101	4	4	5	4	3	4	5	5	5	5	5	5	4	4	4
102	5	5	5	3	x	3	3	4	4	3	3	3	4	4	4
103	4	5	5	4	1	4	4	5	5	4	5	5	4	4	4
104	5	3	4	5	1	3	3	3	4	4	3	4	3	3	2
105	5	5	5	4	3	4	4	4	5	5	5	5	5	4	5
106	5	4	4	5	3	4	5	4	5	4	5	5	5	4	5
107	4	4	3	4	1	1	4	4	4	4	3	4	3	4	4
108	4	4	3	4	3	4	3	4	3	3	3	3	3	3	3
109	4	5	3	4	2	3	5	5	5	3	5	5	4	4	4
110	4	4	3	5	2	4	4	4	4	4	4	4	4	4	4
111	3	3	4	3	1	3	3	5	5	4	5	4	3	4	3
112	4	4	4	3	x	x	4	4	x	x	2	3	3	4	3
113	5	5	5	4	1	4	5	5	5	5	5	5	4	5	5
114	5	5	5	5	x	5	5	5	5	2	5	5	5	5	5
115	5	4	4	4	4	5	4	5	5	5	5	5	4	4	4
116	5	5	5	5	3	4	4	4	5	4	5	5	4	4	4
117	3	2	4	3	x	4	2	3	4	4	4	3	3	3	x

Table A-5 The raw data from survey questionnaire Part C - ICT Training & Technical Software/Hardware Support (Q3.1-Q3.15)

Userid	qc1	qc2	qc3	qc4	qc5	qc6	qc7	qc8	qc9	qc10	qc11	qc12	qc13	qc14	qc15
1	3	4	4	4	4	4	4	2	4	3	3	4	4	4	4
2	4	5	4	4	4	5	4	5	3	3	x	3	x	x	4
3	3	5	1	1	1	2	2	4	2	4	2	2	1	2	2
4	4	4	4	4	4	5	3	5	5	5	4	5	3	5	3
5	1	3	5	5	3	4	5	5	3	2	3	3	4	4	1
6	3	5	3	3	3	4	3	3	5	4	5	3	2	4	5
7	5	5	3	4	5	5	5	5	5	5	5	5	5	5	5
8	3	5	4	3	4	4	3	4	4	4	3	4	2	4	4
9	3	5	3	2	1	2	2	2	3	4	3	4	1	3	4
10	5	5	3	3	4	5	5	4	5	4	4	5	5	5	5
11	4	4	3	3	3	4	3	3	4	3	2	3	3	3	2
12	4	4	3	3	3	4	3	2	4	1	3	4	3	4	4
13	5	5	4	3	3	2	3	3	3	5	3	4	3	4	3
14	5	5	3	3	3	4	4	3	4	5	5	4	3	4	5
15	1	4	2	3	4	4	4	3	2	3	3	3	1	2	3
16	5	4	2	1	1	1	1	1	2	1	3	3	3	4	4
17	4	4	4	4	4	4	4	4	4	5	4	4	3	4	3
18	5	5	5	4	4	4	5	5	4	4	4	5	5	5	3
19	3	5	1	2	4	3	2	2	4	4	2	2	4	4	2
20	4	5	3	3	2	3	2	3	3	4	2	3	4	3	4
21	5	5	4	5	5	5	2	4	4	3	4	4	4	4	x
22	4	4	3	3	2	3	2	3	3	2	2	2	2	3	3
23	3	5	3	3	3	4	3	4	5	5	4	4	4	4	3
24	3	4	3	2	2	3	2	2	3	1	3	2	1	4	4
25	3	4	1	1	1	3	1	3	4	3	1	1	2	2	4
26	4	3	2	1	1	2	1	3	3	3	1	2	1	1	x
27	3	4	4	4	4	4	4	4	4	4	1	4	4	4	4
28	3	4	2	3	2	4	3	4	4	4	1	4	3	4	3
29	5	5	3	3	3	4	3	3	5	4	4	5	3	3	4
30	5	5	3	3	3	4	3	4	4	3	5	4	2	3	x
31	3	4	2	1	1	1	1	2	3	2	2	3	1	2	3
32	3	5	3	2	2	2	2	3	3	2	2	3	3	4	4
33	4	4	3	3	4	4	4	4	4	4	3	x	3	4	x
34	3	4	2	4	1	4	3	2	4	5	3	3	1	4	3
35	x	3	3	3	3	3	3	3	3	5	4	4	4	4	4
36	4	5	4	3	4	4	3	3	4	4	x	5	5	4	4
37	x	4	3	3	4	3	3	3	4	4	3	4	4	3	3
38	5	5	3	4	4	3	4	2	3	3	1	3	3	4	3
39	1	3	1	1	1	1	1	4	4	4	2	2	1	1	x
40	3	5	3	3	2	2	2	3	3	3	2	3	2	3	3
41	5	5	5	5	5	5	5	5	5	5	5	5	5	5	x
42	4	4	4	4	4	4	4	4	3	2	3	3	3	3	2
43	4	5	3	3	3	3	2	2	2	2	2	2	3	3	2
44	5	5	5	5	5	5	4	5	5	5	5	5	3	4	4
45	3	4	4	4	3	4	4	3	4	2	3	3	2	3	2
46	1	3	2	3	4	4	2	1	5	5	2	4	1	3	4
47	4	5	3	3	3	3	3	2	3	3	5	4	4	5	4
48	5	5	4	4	4	4	4	4	4	4	4	4	1	4	4
49	3	4	2	2	2	4	3	2	4	2	2	4	4	4	4
50	2	4	2	2	3	3	2	4	3	4	2	3	2	4	4
51	3	4	2	1	2	2	2	3	3	3	2	3	2	3	3

52	5	5	3	3	3	3	3	3	4	5	3	4	x	5	5
53	5	4	5	5	4	5	5	5	5	5	5	5	3	5	5
54	3	5	2	2	3	4	3	5	5	5	4	4	4	4	5
55	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
56	4	3	3	2	4	4	4	5	4	3	3	3	3	4	3
57	3	4	2	2	4	3	3	3	3	2	2	3	2	2	3
58	4	4	5	5	5	4	3	5	5	4	5	4	3	4	x
59	2	5	3	3	5	4	4	4	3	4	1	x	4	4	x
60	3	5	5	4	4	5	4	4	5	5	4	4	4	4	5
61	2	4	3	3	4	4	3	4	4	4	3	4	4	4	4
62	4	5	3	3	4	4	5	5	5	3	3	4	4	4	5
63	3	5	2	3	4	3	3	3	3	4	4	4	2	4	4
64	3	4	3	2	2	3	2	3	3	3	3	3	2	3	3
65	3	5	4	4	3	3	2	1	3	3	2	3	3	3	3
66	4	5	4	3	3	4	4	4	5	3	x	3	4	4	5
67	2	4	1	1	1	3	1	4	3	4	2	4	2	2	3
68	1	5	2	1	3	4	4	4	4	4	x	4	4	4	x
69	3	5	2	2	3	3	3	4	3	4	3	4	2	3	3
70	4	4	3	2	3	3	3	2	3	2	3	3	3	4	4
71	3	4	4	3	4	4	3	3	4	5	3	5	3	3	5
72	5	5	3	3	3	3	3	2	3	5	3	3	4	4	3
73	3	5	2	3	3	4	3	3	3	3	4	4	4	5	5
74	3	4	2	2	1	1	2	2	2	4	2	3	1	3	3
75	4	5	4	4	4	5	4	3	4	3	5	5	4	4	3
76	3	2	1	1	1	1	1	2	2	3	1	3	1	2	3
77	5	5	4	4	4	4	4	4	4	4	4	4	5	4	4
78	5	5	3	2	2	4	3	1	5	5	4	5	3	4	4
79	3	5	4	1	1	5	4	4	4	4	4	4	2	3	2
80	4	5	2	3	3	3	3	5	3	3	4	3	2	3	x
81	5	4	4	4	4	5	4	3	4	4	4	4	1	4	4
82	1	4	2	2	1	2	1	1	2	3	1	4	1	1	3
83	3	4	2	2	2	3	2	2	3	4	1	2	2	3	4
84	2	5	2	2	3	2	4	5	4	2	2	4	3	4	4
85	2	4	3	1	2	3	3	4	4	4	2	4	1	4	x
86	4	4	4	3	2	4	3	3	3	3	3	4	3	4	4
87	3	4	4	4	4	4	4	4	4	4	3	4	3	4	3
88	4	4	3	2	1	4	3	3	3	3	2	3	1	3	4
89	2	4	3	3	3	3	3	4	4	4	4	4	4	4	3
90	3	5	3	3	3	3	3	4	4	2	3	1	x	3	1
91	x	5	3	x	x	5	5	5	4	4	5	5	5	5	5
92	3	4	3	3	3	3	2	2	3	3	2	4	3	3	4
93	3	5	5	4	4	4	4	5	5	5	4	4	3	4	5
94	2	5	2	1	2	3	2	4	4	2	3	3	4	3	x
95	3	5	3	2	2	2	2	3	4	4	4	3	1	2	3
96	4	4	5	4	5	5	x	3	4	5	4	4	3	3	5
97	4	5	4	3	3	4	4	4	4	5	4	4	3	4	5
98	3	5	3	3	5	5	5	5	4	5	3	5	5	5	3
99	4	5	4	4	4	3	4	4	4	4	2	4	3	3	3
100	4	5	4	4	3	3	3	2	3	1	1	4	1	4	5
101	5	5	5	5	4	4	4	3	4	2	4	3	4	3	3
102	x	5	x	x	x	4	3	x	x	3	3	x	x	3	x
103	5	5	3	3	4	4	4	5	4	4	4	3	4	5	3
104	5	5	3	3	3	4	2	4	4	3	2	4	4	3	2
105	3	5	4	4	5	5	5	5	4	5	5	5	3	4	5

106	5	5	5	5	5	5	5	5	5	5	4	4	5	5	5
107	5	5	3	3	4	4	4	3	4	4	3	4	4	3	x
108	2	4	2	3	2	3	3	4	3	3	3	4	3	3	4
109	3	5	3	3	4	4	4	4	4	5	3	3	4	4	4
110	2	5	2	2	3	3	2	4	4	4	2	4	2	4	4
111	3	4	5	5	3	4	4	5	4	3	2	3	1	3	3
112	5	5	5	5	5	5	5	5	5	4	5	5	2	5	3
113	5	5	4	3	2	3	4	4	4	3	4	5	1	3	4
114	5	5	5	5	4	5	5	5	5	3	5	5	4	5	5
115	4	4	3	3	2	2	3	4	4	5	3	3	3	3	x
116	4	5	4	3	4	5	5	4	4	3	4	4	5	5	3
117	4	4	3	2	2	3	3	3	2	3	2	4	2	3	3

Table A-6 The raw data from survey questionnaire Part D - ICT Workplace Support (Q4.1-Q4.10)

Userid	qd1	qd2	qd3	qd4	qd5	qd6	qd7	qd8	qd9	qd10
1	3	4	4	1	2	4	4	1	3	4
2	4	5	5	1	1	5	3	1	3	3
3	5	3	5	4	3	4	4	1	5	4
4	5	5	5	1	1	5	5	1	5	5
5	5	4	x	2	3	4	x	3	x	3
6	4	5	3	1	1	2	2	3	3	3
7	5	5	5	2	2	4	4	2	5	5
8	4	4	4	1	1	5	4	1	4	4
9	5	4	5	3	1	4	4	1	4	5
10	4	5	5	1	1	5	3	1	5	4
11	4	4	4	1	3	3	3	2	4	4
12	4	5	3	1	1	4	4	1	3	3
13	3	4	5	1	2	4	4	1	3	3
14	4	5	3	1	4	5	5	3	5	5
15	4	5	3	1	1	5	5	1	1	5
16	4	4	1	1	5	3	5	3	5	5
17	5	4	3	1	1	5	4	1	4	4
18	5	5	4	1	1	5	4	1	5	5
19	4	4	4	2	1	4	4	3	2	3
20	2	5	4	2	1	4	4	2	4	3
21	4	5	5	x	x	5	5	x	5	5
22	2	4	4	3	2	4	2	3	4	3
23	5	5	5	1	1	4	5	1	4	5
24	4	4	3	3	5	4	4	3	3	4
25	2	4	1	2	2	2	2	3	2	2
26	4	2	4	2	1	4	4	1	4	4
27	4	5	3	1	1	5	4	1	5	5
28	5	5	4	1	3	3	2	3	4	4
29	5	5	5	3	1	5	5	1	5	5
30	5	5	5	1	1	5	4	1	5	5
31	3	3	3	2	1	3	3	3	3	4
32	4	4	4	1	1	5	4	3	5	5
33	4	4	4	2	2	4	4	2	4	4
34	4	5	4	1	3	5	5	3	4	5
35	5	5	x	x	x	x	5	x	5	5
36	5	5	5	1	1	5	3	1	4	4
37	4	4	x	2	1	5	x	1	x	4
38	2	5	5	1	1	5	2	1	5	2
39	3	4	1	2	1	2	2	1	1	4

40	4	4	3	2	3	2	2	3	3	4
41	5	5	5	1	1	5	5	1	5	5
42	4	4	5	2	2	5	3	2	5	4
43	3	5	4	2	1	5	3	2	5	1
44	5	5	5	1	1	5	5	1	5	5
45	4	4	4	2	2	4	4	2	4	4
46	4	3	4	2	2	5	5	2	4	4
47	4	5	4	2	3	5	4	3	5	5
48	4	4	4	1	1	4	4	1	4	4
49	2	4	4	2	2	4	4	2	4	4
50	4	4	3	3	3	4	3	3	4	4
51	4	4	3	3	4	2	3	3	3	3
52	5	5	5	3	1	4	4	x	4	3
53	5	5	5	1	4	5	5	1	5	5
54	4	4	4	2	1	4	3	3	4	4
55	3	4	4	2	2	4	4	2	4	4
56	4	4	2	2	2	4	4	2	4	4
57	4	4	4	2	1	3	3	2	4	4
58	5	4	4	2	1	5	4	1	5	5
59	5	5	5	1	3	x	x	1	x	2
60	5	5	5	1	1	4	3	1	5	5
61	4	4	2	1	1	2	4	1	3	3
62	4	5	5	2	3	5	5	3	3	5
63	4	4	4	2	1	5	x	1	4	3
64	4	4	4	1	1	4	3	1	4	4
65	3	3	4	1	5	4	3	1	3	2
66	5	5	2	1	1	4	4	2	4	5
67	3	4	1	3	3	4	4	3	3	4
68	5	4	1	1	1	5	5	1	1	4
69	2	4	3	2	1	4	4	1	3	3
70	3	4	5	1	1	5	4	1	4	3
71	5	5	3	2	1	1	2	1	3	4
72	4	5	5	2	1	5	5	1	5	5
73	3	4	4	2	2	4	3	1	3	5
74	3	4	4	3	3	4	3	2	3	2
75	4	5	4	1	1	5	4	1	4	5
76	3	2	4	1	4	3	2	1	3	3
77	5	5	5	2	1	5	4	1	5	4
78	4	5	5	1	1	5	5	1	4	4
79	5	3	3	1	3	4	2	2	5	2
80	3	4	4	2	3	4	4	1	4	3
81	4	4	4	1	2	3	3	3	4	4
82	3	4	4	1	1	4	4	1	4	4
83	4	4	4	3	3	3	3	2	3	4
84	4	4	4	3	1	5	5	1	3	2
85	4	4	x	x	x	4	4	x	4	4
86	5	4	5	1	3	5	5	1	4	4
87	4	3	5	1	1	1	4	1	3	3
88	4	5	3	1	2	3	3	2	4	4
89	4	4	4	1	1	4	4	1	3	4
90	4	5	5	3	1	5	5	1	5	5
91	5	5	x	x	x	x	x	x	x	5
92	4	4	x	1	1	4	4	1	4	2
93	4	5	5	1	1	5	5	1	3	4
94	3	5	4	4	1	4	4	1	4	3
95	3	4	3	1	1	5	4	1	3	3

96	5	5	5	3	3	3	3	2	4	4
97	4	4	3	1	1	5	4	1	5	4
98	5	5	3	2	2	5	5	2	3	5
99	3	4	4	1	1	4	4	2	3	2
100	4	4	4	1	1	4	4	1	5	4
101	3	4	4	2	2	2	3	2	5	3
102	3	3	5	1	2	4	4	x	5	4
103	4	5	5	1	1	5	4	2	4	4
104	2	4	4	3	2	4	4	3	4	4
105	5	5	5	1	1	4	4	1	3	4
106	5	5	5	x	x	5	x	x	5	5
107	4	5	5	2	3	4	2	1	4	4
108	4	5	4	2	3	4	4	3	2	3
109	3	5	4	2	4	4	4	2	4	3
110	4	4	3	3	2	3	3	4	3	4
111	4	4	4	2	4	3	4	2	3	2
112	4	5	5	3	3	5	5	3	5	5
113	5	5	5	1	1	5	4	1	5	4
114	5	5	5	x	x	5	4	x	5	4
115	1	5	4	1	1	5	2	4	4	4
116	4	4	5	2	2	4	4	2	5	5
117	3	3	3	3	4	1	1	x	4	3

Table A-7 The raw data from survey questionnaire Part E - ICT Information Sharing (Q5.1.1-Q5.1.6)

Userid	qe1	qe2	qe3	qe4	qe5	qe6
1	4	1	3	4	4	4
2	4	1	2	4	3	4
3	4	x	x	2	2	2
4	4	1	2	4	4	4
5	2	1	1	2	1	4
6	5	1	1	5	4	4
7	5	1	2	4	5	5
8	4	2	3	4	4	4
9	3	1	3	4	4	4
10	3	1	2	4	4	4
11	3	3	3	3	4	4
12	3	1	2	5	5	5
13	4	2	4	5	2	4
14	5	2	3	5	5	5
15	5	1	2	5	5	5
16	3	1	3	4	4	4
17	4	3	3	4	4	4
18	3	2	4	5	4	4
19	1	1	2	5	4	4
20	2	1	4	4	3	4
21	5	x	4	5	5	5
22	3	1	1	4	3	3
23	3	1	2	5	5	5
24	4	1	4	3	3	4
25	2	1	1	3	5	5
26	4	3	3	1	2	3
27	5	1	1	5	3	3
28	4	1	4	5	5	5
29	5	1	1	5	5	5

30	3	2	4	4	4	4
31	3	2	2	4	3	4
32	4	3	3	3	3	3
33	3	3	4	4	5	5
34	2	1	3	4	4	3
35	1	x	x	5	5	x
36	5	x	3	5	4	4
37	4	3	4	5	4	5
38	1	1	2	4	4	4
39	2	1	3	3	1	4
40	3	3	4	4	2	4
41	5	x	x	5	5	5
42	4	1	2	4	4	4
43	2	1	2	5	2	5
44	5	1	4	4	5	5
45	3	2	3	4	3	3
46	3	1	1	3	4	4
47	4	3	4	4	3	4
48	2	1	1	3	3	4
49	3	2	2	4	4	4
50	4	3	3	4	3	4
51	3	2	2	4	4	4
52	5	3	3	5	5	5
53	5	x	x	5	5	5
54	3	1	1	4	4	3
55	3	2	2	3	4	4
56	4	1	2	4	4	3
57	3	2	3	3	2	3
58	4	1	4	4	5	5
59	3	x	x	3	x	4
60	5	2	4	4	3	4
61	2	3	3	4	2	2
62	3	2	3	4	2	3
63	3	1	x	4	3	5
64	3	x	3	4	4	4
65	3	1	3	1	3	3
66	3	1	4	5	5	5
67	4	4	4	5	5	5
68	4	1	1	5	x	3
69	x	1	1	5	4	4
70	4	2	3	4	3	4
71	4	3	4	5	x	x
72	5	1	1	5	5	5
73	5	3	4	3	2	3
74	3	1	3	3	3	4
75	5	2	3	5	4	4
76	3	2	1	1	2	4
77	4	4	3	5	5	5
78	4	1	3	4	5	5
79	3	3	3	4	4	4
80	3	2	4	3	2	4
81	4	3	4	5	5	5
82	2	2	2	1	4	4
83	3	2	3	3	3	3
84	1	1	1	4	4	4
85	3	1	1	4	4	4

86	3	1	2	4	3	4
87	2	2	2	3	3	5
88	4	x	1	4	4	4
89	4	1	1	3	4	4
90	5	1	1	5	5	5
91	5	x	x	4	x	x
92	3	1	1	3	3	3
93	3	3	3	5	5	5
94	3	1	1	4	3	4
95	3	1	1	3	3	3
96	5	3	4	4	4	5
97	4	3	3	5	4	5
98	5	3	3	5	3	3
99	3	1	1	4	3	4
100	3	1	1	4	4	4
101	4	2	2	2	4	4
102	4	x	x	4	4	4
103	4	1	3	4	4	5
104	4	2	3	5	4	4
105	4	2	2	4	5	5
106	5	x	4	5	5	5
107	5	2	3	4	3	3
108	3	3	3	4	4	5
109	3	1	3	4	4	4
110	2	2	2	5	2	2
111	3	1	4	3	3	3
112	x	x	x	5	5	5
113	5	2	5	5	5	5
114	5	x	x	5	4	4
115	4	1	3	4	3	3
116	4	2	4	4	4	3
117	3	1	4	2	3	3

Table A-8 The raw data from survey questionnaire Part E – PART 2 Source/Medium that you use to learn about ICT tools that you are expected to use in your job WITHIN working hours (Q5.2.1-Q5.2.10).

Questions QE1-QE10 represent frequency of access to source/medium

Questions QE11-QE20 represent helpfulness of source/medium

USER ID	QE 1	QE 2	QE 3	QE 4	QE 5	QE 6	QE 7	QE 8	QE 9	QE 10	QE 11	QE 12	QE 13	QE 14	QE 15	QE 16	QE 17	QE 18	QE 19	QE 20
1	4	4	4	3	4	2	2	3	2	4	4	4	4	3	4	2	2	3	2	4
2	2	2	2	2	2	3	3	3	3	2	3	3	3	3	3	3	3	4	4	3
3	4	3	1	1	1	1	1	3	1	5	4	4	1	1	1	1	1	4	1	5
4	2	1	x	4	3	x	3	4	x	2	3	x	x	4	3	x	3	4	x	2
5	3	3	3	3	4	4	4	4	4	4	3	3	3	3	4	4	4	4	4	4
6	3	2	2	2	1	1	2	4	1	1	3	3	3	4	x	x	3	4	x	x
7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	3	3	2	4	3	2	3	3	3	4	2	2	1	3	3	4	3	3	3	3
9	3	1	x	2	x	x	3	4	x	4	3	3	x	4	x	x	4	4	x	4
10	2	1	3	4	3	3	3	4	1	3	3	1	2	4	4	4	3	4	1	3
11	1	2	2	3	3	4	4	3	2	2	1	3	4	2	3	4	3	4	4	2
12	x	3	x	2	x	x	x	3	3	x	x	4	x	3	x	x	x	5	5	x
13	1	x	x	3	1	5	5	5	3	3	3	x	x	5	3	5	5	5	3	3
14	3	3	3	4	4	5	5	4	4	2	3	3	3	4	4	5	5	4	4	2

15	3	1	1	1	1	1	2	3	1	3	3	1	1	1	1	1	4	4	1	3
16	1	1	1	1	1	1	1	2	1	2	4	1	1	1	1	1	1	2	1	3
17	3	3	3	5	x	3	5	5	x	x	3	3	3	5	x	3	5	5	x	x
18	1	1	x	5	x	x	5	5	x	x	1	1	x	5	x	x	5	5	x	x
19	2	2	2	3	3	1	3	3	2	2	2	2	2	3	3	1	3	3	2	2
20	3	3	4	3	3	4	4	3	x	5	3	3	4	3	3	4	4	3	x	5
21	1	2	1	2	1	1	2	4	1	1	1	2	1	3	1	1	3	3	1	1
22	3	2	2	2	3	3	3	4	1	3	3	3	3	4	3	4	4	4	x	3
23	3	x	x	3	2	x	3	3	x	4	4	x	x	4	3	x	4	4	x	4
24	2	x	x	x	x	x	x	3	x	x	2	x	x	x	x	x	x	3	x	x
25	2	1	1	1	1	1	1	1	1	4	3	1	1	1	1	1	1	2	1	4
26	1	1	1	5	1	1	5	3	1	1	x	x	x	5	x	x	5	5	x	x
27	2	2	4	2	3	1	1	3	1	3	2	2	4	2	3	4	1	3	1	3
28	5	x	2	4	3	4	4	4	3	4	5	x	1	4	3	5	4	5	4	5
29	3	1	2	3	2	3	2	5	1	5	4	x	5	3	5	3	2	5	1	5
30	4	2	2	2	3	2	2	4	3	2	4	2	2	2	3	4	4	4	4	2
31	2	2	1	4	3	2	4	4	2	1	2	2	1	4	3	4	4	4	4	1
32	4	2	1	3	5	2	3	4	1	1	3	3	1	5	4	3	4	4	1	2
33	4	1	2	2	2	2	2	4	2	4	3	x	3	4	4	5	5	5	3	5
34	1	1	3	3	1	2	3	1	1	1	1	1	3	4	1	3	4	1	1	1
35	1	2	1	2	2	1	2	4	1	1	x	3	x	4	4	x	4	4	x	x
36	3	1	1	1	2	2	1	4	1	3	2	1	1	1	3	5	1	5	1	4
37	3	3	1	3	3	1	2	4	3	4	2	3	x	3	3	x	2	4	3	4
38	4	2	3	3	3	2	3	4	x	3	3	4	5	5	4	3	5	5	x	3
39	2	1	2	4	4	2	2	3	3	2	5	5	2	4	4	x	4	5	5	5
40	3	2	1	3	1	1	2	4	4	4	3	3	x	4	x	x	4	4	4	4
41	4	3	3	3	2	2	3	3	4	4	3	3	3	3	2	2	3	3	4	4
42	1	1	1	2	2	1	2	4	4	1	1	1	1	4	4	1	4	5	5	1
43	2	1	1	3	3	1	1	3	1	3	3	3	3	4	4	x	x	4	x	4
44	4	3	2	1	2	2	2	3	2	3	3	3	4	3	4	5	5	4	3	3
45	2	2	2	1	2	1	2	3	1	3	5	2	3	1	2	4	2	4	3	4
46	3	3	2	2	2	1	1	4	2	3	3	3	3	2	3	x	x	3	2	4
47	x	x	x	5	5	x	x	5	x	x	x	x	x	4	4	x	x	4	x	x
48	2	1	2	1	3	3	3	4	2	4	3	1	3	x	3	4	4	5	4	5
49	4	3	2	3	3	1	3	3	1	1	3	3	3	4	4	x	3	3	x	x
50	3	3	3	2	2	2	3	2	2	3	3	3	3	3	3	3	4	3	3	3
51	4	4	4	4	4	3	3	x	4	4	4	4	4	4	4	3	3	x	4	4
52	3	3	1	3	1	1	1	3	1	3	3	3	x	3	x	x	x	3	x	3
53	2	2	1	1	1	1	1	3	1	3	x	x	x	x	x	x	x	3	x	3
54	1	1	1	2	1	1	2	3	1	2	3	3	4	4	4	4	4	5	1	5
55	1	3	1	3	1	1	1	4	1	1	1	4	1	4	1	1	1	4	1	1
56	1	2	1	3	3	3	2	2	x	x	x	3	x	3	3	4	2	3	x	x
57	2	2	3	4	3	2	2	3	2	3	3	3	4	5	5	4	4	5	4	3
58	1	1	1	1	x	2	2	4	1	2	x	x	x	x	x	4	2	4	x	3
59	1	1	1	1	1	x	2	4	x	x	1	1	1	1	1	x	2	3	x	x
60	1	5	3	5	1	1	1	5	1	1	1	5	3	5	1	1	1	5	1	1
61	2	2	2	3	3	3	3	4	1	3	4	5	4	4	4	5	4	5	1	4
62	3	4	1	4	1	1	4	4	1	4	3	4	1	5	1	1	5	5	1	5
63	3	1	2	3	3	2	2	4	3	4	3	1	2	3	3	3	2	4	3	4
64	2	2	1	3	2	1	2	4	2	2	2	2	1	4	3	x	4	4	3	2
65	x	x	x	3	x	x	3	4	4	4	x	x	x	3	x	x	3	4	4	4
66	1	1	1	2	1	1	1	4	1	1	1	1	1	5	5	x	x	5	3	1
67	3	3	2	4	3	1	3	3	4	4	3	3	3	4	4	x	4	4	4	4
68	1	1	3	2	3	1	1	1	1	1	2	2	3	3	3	2	2	2	2	2
69	2	2	2	3	2	1	2	2	2	1	4	4	2	4	4	1	4	4	4	1
70	3	2	2	2	2	1	2	2	3	2	3	3	3	3	3	3	3	3	3	3
71	5	3	3	4	5	3	5	5	5	5	4	5	3	5	5	5	5	5	5	5
72	3	3	2	3	3	1	5	5	3	3	3	3	2	3	3	1	5	5	3	3

73	4	1	2	1	1	4	4	4	4	4	3	3	3	3	3	4	4	5	4	4
74	x	x	x	3	x	x	x	3	3	x	x	x	x	3	x	x	x	3	3	x
75	2	2	2	4	2	1	1	3	2	1	2	3	3	4	4	x	x	4	4	x
76	1	1	1	3	1	1	3	3	1	1	1	1	1	4	1	1	4	3	1	1
77	4	2	2	2	2	2	2	2	2	2	4	3	3	4	4	3	3	3	3	3
78	4	2	1	3	1	1	3	1	3	1	3	2	4	4	4	5	5	4	4	3
79	2	1	1	2	1	2	3	3	1	1	1	1	1	2	1	2	3	3	1	1
80	1	1	1	2	1	1	2	4	2	1	x	x	x	4	x	x	3	5	5	1
81	2	1	1	1	1	1	1	3	1	2	4	4	3	4	4	3	4	3	1	3
82	2	x	x	3	x	3	2	3	x	x	3	x	x	3	x	3	2	3	x	x
83	1	2	1	1	1	3	3	1	1	2	1	2	1	1	1	3	3	1	1	2
84	2	x	2	2	1	1	2	4	1	3	4	x	5	4	x	x	x	4	x	4
85	3	1	2	2	1	1	1	3	1	1	2	1	2	2	x	1	x	4	1	1
86	1	1	1	1	1	1	1	2	2	1	1	1	1	3	3	4	4	4	4	2
87	2	2	1	3	2	1	2	4	2	3	3	3	x	5	4	x	4	3	3	3
88	2	3	3	4	2	2	3	4	2	3	2	3	2	4	4	3	4	4	3	3
89	4	2	1	4	4	2	3	4	4	5	4	4	1	5	5	2	3	5	5	5
90	1	1	1	2	3	2	2	3	3	3	1	1	1	4	4	4	4	5	3	5
91	2	2	1	3	1	1	3	3	1	3	3	3	x	4	x	x	4	5	x	4
92	5	5	4	3	3	4	1	4	3	3	5	5	3	4	4	4	1	4	3	3
93	2	2	1	1	2	3	1	2	2	3	2	2	x	x	x	3	x	3	3	3
94	2	1	1	3	2	2	3	5	2	2	3	1	1	3	3	5	3	5	1	3
95	1	1	1	3	1	1	3	5	2	1	1	1	1	2	1	1	5	5	3	1
96	2	2	2	4	2	1	2	4	1	1	4	2	2	4	2	x	4	4	x	x
97	3	2	1	2	1	1	2	2	2	3	3	3	1	2	2	2	3	3	3	3
98	2	2	2	3	3	1	2	4	2	2	4	3	2	4	4	1	1	4	1	3
99	1	1	1	2	1	2	1	1	1	1	1	1	1	4	1	3	1	1	1	1
100	x	x	x	x	x	x	x	4	x	x	x	x	x	x	x	x	x	3	x	x
101	1	2	x	2	x	x	x	2	2	x	x	x	x	2	x	x	x	2	2	x
102	2	1	1	2	1	1	3	3	1	1	2	1	1	2	1	1	2	2	1	1
103	1	1	1	2	1	1	1	5	1	1	x	x	x	4	x	x	x	3	x	x
104	2	2	2	1	1	1	1	3	3	2	3	3	3	1	1	1	1	4	4	2
105	3	1	1	3	3	4	3	4	4	1	3	1	1	3	3	4	3	4	4	1
106	1	1	1	3	1	1	3	3	x	1	x	x	x	5	x	x	4	4	x	x
107	3	x	x	3	x	x	x	x	2	x	3	x	x	4	x	x	x	x	3	x
108	1	1	1	3	2	1	1	4	1	3	x	x	x	4	4	x	x	4	x	4
109	5	3	3	3	3	x	4	3	3	4	5	3	3	3	3	x	4	3	3	3
110	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1
111	5	2	2	4	3	2	2	4	2	1	3	2	2	2	2	2	2	3	2	1
112	3	2	3	2	3	3	2	3	1	3	2	2	4	2	3	4	3	4	2	4

Table A-9 The raw data from survey questionnaire Part E – PART 2 Source/Medium that you use to learn about ICT tools that you are expected to use in your job OUTSIDE working hours (Q5.2.1-Q5.2.10)

Questions QE21-QE30 represent <u>frequency of access</u> to source/medium

Questions QE31-QE40 represent <u>helpfulness</u> of source/medium

USER ID	QE 21	QE 22	QE 23	QE 24	QE 25	QE 26	QE 27	QE 28	QE 29	QE 30	QE 31	QE 32	QE 33	QE 34	QE 35	QE 36	QE 37	QE 38	QE 39	QE 40
1	4	4	4	2	4	2	2	3	2	4	4	4	4	2	4	2	2	3	2	4
2	2	2	2	x	x	1	1	1	3	2	3	3	3	x	x	x	x	x	4	3
3	4	3	1	1	1	1	1	1	2	5	4	4	1	1	1	1	1	1	3	5
4	4	1	x	x	3	x	x	x	3	2	4	x	x	x	3	x	x	x	3	2
5	3	3	3	3	4	4	4	4	4	4	3	3	3	3	4	4	4	4	4	4
6	5	2	1	1	1	1	1	1	4	2	4	3	x	x	x	x	x	x	3	3
7	4	1	1	1	2	5	x	2	3	5	3	1	1	1	3	5	x	3	3	5

8	3	3	2	2	3	2	3	3	3	3	2	3	2	2	3	4	3	3	3	3
9	4	4	x	x	x	x	x	x	4	4	3	4	x	x	x	x	x	x	4	4
10	2	1	3	4	3	1	1	4	2	1	3	1	2	4	4	1	1	4	2	1
11	2	1	2	3	2	3	4	3	3	3	1	3	2	3	2	3	4	3	3	3
12	x	2	x	x	x	x	x	3	3	x	x	4	x	x	x	x	x	5	5	x
13	4	5	1	x	x	5	x	x	4	x	5	5	3	x	x	5	x	x	3	x
14	3	3	3	4	4	5	5	4	4	2	3	3	3	4	4	5	5	4	4	2
15	3	3	1	1	1	1	1	1	3	4	4	3	1	1	1	1	1	1	3	3
16	3	1	2	1	1	1	1	1	2	1	4	1	2	1	1	1	1	1	2	1
17	3	3	3	x	x	3	x	x	x	x	3	3	3	x	x	3	x	x	x	x
18	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	4	4	2	x	x	x	x	1	4	4	4	4	2	x	x	x	x	1	3	4
21	1	2	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1
22	4	4	3	2	3	2	3	2	3	2	3	3	3	4	3	4	4	3	3	3
23	3	1	x	x	x	x	x	x	3	4	4	3	x	x	x	x	x	x	4	4
24	4	3	x	x	x	x	x	x	x	x	3	3	x	x	x	x	x	x	x	x
25	2	1	1	1	1	4	1	1	2	3	4	1	1	1	1	4	1	1	4	3
26	1	1	1	1	1	1	1	1	3	1	x	x	x	x	x	x	x	x	4	x
27	2	2	4	2	3	1	1	1	1	2	2	2	4	2	3	4	1	1	1	2
28	4	x	3	3	2	4	4	5	2	5	2	x	4	3	2	5	5	5	2	5
29	4	2	2	3	2	3	1	1	1	1	4	4	3	2	3	3	1	1	1	1
30	4	4	2	1	1	4	1	4	3	2	4	4	2	1	1	4	1	4	4	2
31	2	2	1	2	3	1	2	4	3	3	2	2	1	2	3	4	4	4	4	3
32	3	4	2	2	1	1	2	4	4	5	4	4	2	4	1	1	1	5	5	5
33	2	2	2	1	1	2	1	2	2	2	3	3	3	x	x	5	x	4	3	4
34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	1	2	1	1	1	1	1	1	1	1	x	3	x	x	x	x	x	x	x	x
36	2	2	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	4	3
37	2	2	1	3	3	1	2	4	3	4	2	2	x	3	3	x	2	4	3	4
38	4	4	x	x	x	x	x	2	3	3	3	4	x	x	x	x	x	3	4	3
39	5	5	1	3	3	2	x	3	3	4	5	5	1	4	4	x	x	5	5	5
40	3	3	1	1	1	1	1	2	4	4	3	4	x	x	x	x	x	3	4	4
41	3	3	3	3	2	2	3	4	5	5	3	3	3	3	2	2	3	3	5	5
42	3	1	1	1	1	1	1	1	5	1	2	1	1	1	1	1	1	1	5	1
43	4	3	2	2	3	1	1	1	2	4	3	3	3	4	4	x	x	x	3	4
44	4	3	2	x	x	2	x	2	2	3	3	3	4	x	x	5	x	3	3	3
45	3	3	2	1	1	1	1	2	3	1	5	2	3	1	2	4	2	4	4	4
46	3	3	2	1	1	2	2	2	3	5	3	3	3	x	x	3	2	3	3	4
47	x	x	x	x	5	x	x	x	3	x	x	x	x	x	4	x	x	x	4	x
48	3	4	2	1	1	2	2	3	3	5	3	4	2	x	x	4	4	4	4	5
49	4	2	2	3	3	1	3	3	2	1	3	3	3	3	3	x	3	3	2	x
50	3	3	2	1	1	1	1	1	1	3	3	3	2	1	1	1	1	1	1	3
51	4	4	4	4	4	4	3	x	4	4	4	4	4	4	4	4	3	x	4	4
52	3	3	1	3	1	1	1	3	1	3	3	3	x	3	x	x	x	3	x	3
53	2	2	1	1	1	1	1	1	1	3	x	x	x	x	x	x	x	x	x	3
54	2	1	1	2	1	1	2	3	3	3	3	3	4	4	4	4	4	5	3	5
55	1	1	1	3	1	1	3	4	4	1	1	1	1	4	1	1	4	4	4	1
56	3	5	3	x	2	2	1	1	2	3	2	x	x	x	3	x	x	x	1	2
57	3	3	3	3	3	2	2	2	4	4	3	3	4	5	5	4	4	5	4	3
58	2	3	2	1	1	1	1	3	3	3	2	3	2	x	x	x	x	4	4	4
59	2	1	1	1	1	x	x	x	3	x	1	1	1	1	1	x	x	x	2	x
60	1	5	1	5	1	1	1	5	1	1	1	5	1	5	1	1	1	5	1	1
61	3	4	3	1	2	2	1	3	3	4	5	5	4	3	3	5	2	5	3	5
62	3	4	1	1	1	1	1	1	3	4	3	4	1	1	1	1	1	1	3	5
63	2	1	1	1	1	1	2	2	3	4	2	1	1	1	2	1	3	2	3	4
64	2	3	1	1	1	1	1	2	3	2	2	2	x	x	x	x	x	4	4	2
65	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

66	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
67	3	3	1	1	2	1	2	3	4	2	3	3	x	x	4	x	4	4	4	4
68	1	1	3	2	3	1	1	1	1	1	2	2	3	3	3	2	2	2	2	2
69	4	4	2	3	2	1	1	2	2	1	4	4	2	4	4	1	1	4	4	1
70	3	1	1	1	1	3	1	1	1	1	3	3	3	3	3	3	3	3	3	3
71	4	4	3	4	5	3	5	5	5	5	4	5	3	5	5	5	5	5	5	5
72	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1	3	1
73	2	1	2	1	1	4	4	1	4	4	3	3	3	3	3	4	4	x	4	4
74	5	x	x	3	x	x	x	x	3	x	5	x	x	3	x	x	x	x	3	x
75	2	2	1	2	1	1	1	2	3	1	3	3	x	4	x	x	x	4	3	x
76	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
77	4	2	2	2	2	2	2	2	2	2	4	4	2	4	2	3	3	3	3	3
78	4	2	1	1	1	1	1	1	3	1	3	2	4	4	4	5	5	3	3	3
79	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	1	3	2	1	1	1	1	2	3	2	x	3	2	x	x	x	x	4	5	2
81	3	4	1	1	1	1	1	1	1	2	4	4	3	4	4	3	4	2	1	3
82	3	x	x	x	x	2	x	2	3	3	3	x	x	x	x	2	x	2	3	3
83	1	2	1	1	1	3	x	1	1	3	1	2	1	1	1	3	x	1	1	3
84	4	x	1	1	1	1	1	3	1	4	4	x	x	x	x	x	x	4	x	4
85	1	1	x	x	x	x	x	x	1	x	1	1	x	x	x	x	x	x	1	x
86	1	1	1	1	1	1	1	1	2	1	1	1	1	3	3	4	4	4	4	2
87	3	3	1	3	2	2	2	3	3	3	3	3	x	5	4	4	4	3	3	3
88	2	3	2	3	3	2	2	3	4	3	2	3	2	4	4	3	4	4	4	3
89	5	5	5	x	1	1	x	3	4	2	5	5	5	x	1	1	x	3	5	2
90	3	3	2	1	1	1	1	1	1	3	4	4	3	1	1	1	1	1	1	5
91	3	3	2	1	1	1	1	1	3	3	3	3	3	x	x	x	x	x	4	4
92	5	5	4	2	2	4	1	5	3	4	5	5	4	4	4	4	1	4	3	4
93	2	3	1	1	1	1	1	1	2	3	3	3	x	x	x	x	x	x	2	2
94	3	5	1	4	4	2	2	3	2	1	3	3	1	4	3	5	3	5	2	1
95	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
96	2	2	2	1	2	1	1	1	4	1	4	2	2	1	2	x	x	x	4	x
97	3	2	1	1	1	1	1	1	1	1	3	3	1	1	2	1	1	1	1	1
98	4	4	1	1	1	1	1	1	1	1	4	3	1	1	1	1	1	1	1	1
99	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	3	1	1	1	3
100	4	3	2	2	2	x	x	x	3	x	4	3	4	3	3	x	x	x	4	x
101	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
102	3	3	2	1	1	1	1	2	3	2	3	3	2	1	1	1	1	3	3	3
103	2	2	1	1	1	1	1	3	3	4	2	2	x	x	x	x	x	3	3	3
104	2	2	2	1	1	1	1	3	3	2	3	3	3	1	1	1	1	4	4	2
105	2	3	1	1	1	1	1	1	3	1	4	3	1	1	1	1	1	1	3	1
106	3	1	1	1	1	3	1	1	3	1	4	x	x	x	x	4	x	x	4	x
107	3	x	x	x	x	x	x	x	2	x	3	x	x	x	x	x	x	x	3	x
108	2	1	1	x	x	x	x	x	3	4	3	x	x	x	x	x	x	x	4	4
109	4	4	3	x	2	x	x	x	3	3	3	4	3	x	4	x	x	x	3	3
110	4	3	2	1	1	4	1	3	4	1	3	2	2	1	1	5	1	3	3	1
111	5	3	2	1	1	2	1	1	2	1	3	3	2	1	1	2	1	1	2	1
112	4	2	2	2	2	2	1	3	3	4	3	2	2	2	2	2	2	4	4	3

Appendix B – Analysis of survey Questionnaire

APPENDIX B – Analysis of survey questionnaire

The analysis of survey questionnaire consists of two main parts: Analysis of Variance (ANOVA) and Factors Analysis (FA). The ANOVA is focused on the questionnaire data in Part A, section 2. It aims to test the significance of the difference in using IT/ICT applications among three main leading construction organisations. The results of ANOVA will be illustrated in Appendix Table B1.

Table B1: The results of ANOVA analysis of users' perception of IT among three groups

		Sum of Squares	df	Mean Square	F	Sig.
Word Processing (R)	Between Groups	.568	2	.284	.648	.525
	Within Groups	49.911	114	.438		
	Total	50.479	116			
Spread Sheet (R)	Between Groups	6.629	2	3.314	3.845	.024
	Within Groups	97.406	113	.862		
	Total	104.034	115			
Graphic Presentation (R)	Between Groups	11.092	2	5.546	3.704	.028
	Within Groups	169.209	113	1.497		
	Total	180.302	115			
Image Manipulate (R)	Between Groups	18.699	2	9.350	5.749	.004
	Within Groups	175.643	108	1.626		
	Total	194.342	110			
Graphic Design (R)	Between Groups	56.182	2	28.091	13.100	.000
	Within Groups	203.706	95	2.144		
	Total	259.888	97			
Time Planning/Scheduling (R)	Between Groups	6.761	2	3.381	1.864	.160
	Within Groups	186.833	103	1.814		
	Total	193.594	105			
Simulation Software (R)	Between Groups	25.812	2	12.906	11.120	.000
	Within Groups	78.920	68	1.161		
	Total	104.732	70			
Estimating Software (R)	Between Groups	14.222	2	7.111	3.879	.024
	Within Groups	157.665	86	1.833		
	Total	171.888	88			
Quantity Surveying/Cost Planning (R)	Between Groups	15.058	2	7.529	4.154	.019
	Within Groups	155.885	86	1.813		
	Total	170.944	88			
General Email Text (R)	Between Groups	.355	2	.178	.527	.592
	Within Groups	38.414	114	.337		
	Total	38.769	116			
Sending/Receiving Email with attach document (R)	Between Groups	.885	2	.443	2.320	.103
	Within Groups	21.555	113	.191		
	Total	22.440	115			
Video Conferencing	Between Groups	27.647	2	13.824	9.689	.000

(R)						
	Within Groups	146.957	103	1.427		
	Total	174.604	105			
Web Board (R)	Between Groups	15.831	2	7.915	7.076	.001
	Within Groups	97.325	87	1.119		
	Total	113.156	89			
Internet - Search general information (R)	Between Groups	1.997	2	.998	1.162	.317
	Within Groups	97.969	114	.859		
	Total	99.966	116			
Intranet based organisation for management and control (R)	Between Groups	4.233	2	2.116	1.262	.287
	Within Groups	174.384	104	1.677		
	Total	178.617	106			
Intranet based organisation for corporate knowledge (R)	Between Groups	4.469	2	2.235	1.323	.271
	Within Groups	175.718	104	1.690		
	Total	180.187	106			
Knowledge management system (R)	Between Groups	7.240	2	3.620	3.207	.044
	Within Groups	123.037	109	1.129		
	Total	130.277	111			
Word Processing (N)	Between Groups	.969	2	.485	.980	.379
	Within Groups	55.893	113	.495		
	Total	56.862	115			
Spread Sheet (N)	Between Groups	7.129	2	3.564	4.023	.021
	Within Groups	100.113	113	.886		
	Total	107.241	115			
Graphic Presentation (N)	Between Groups	5.438	2	2.719	1.802	.170
	Within Groups	170.450	113	1.508		
	Total	175.888	115			
Image Manipulate (N)	Between Groups	11.106	2	5.553	3.831	.025
	Within Groups	153.647	106	1.449		
	Total	164.752	108			
Graphic Design (N)	Between Groups	18.249	2	9.124	4.913	.009
	Within Groups	176.445	95	1.857		
	Total	194.694	97			
Time Planning/Scheduling (N)	Between Groups	2.875	2	1.438	.891	.413
	Within Groups	164.515	102	1.613		
	Total	167.390	104			
Simulation Software (N)	Between Groups	14.678	2	7.339	7.182	.001
	Within Groups	68.464	67	1.022		
	Total	83.143	69			
Estimating Software (N)	Between Groups	9.067	2	4.534	2.990	.056
	Within Groups	128.887	85	1.516		
	Total	137.955	87			

Quantity Surveying/Cost Planning (N)	Between Groups	14.767	2	7.383	5.801	.004
	Within Groups	106.912	84	1.273		
	Total	121.678	86			
General Email Text (N)	Between Groups	.690	2	.345	.982	.378
	Within Groups	40.079	114	.352		
	Total	40.769	116			
Sending/Receiving Email with attach document (N)	Between Groups	.833	2	.416	1.111	.333
	Within Groups	42.340	113	.375		
	Total	43.172	115			
Video Conferencing (N)	Between Groups	21.759	2	10.879	8.446	.000
	Within Groups	133.961	104	1.288		
	Total	155.720	106			
Web Board (N)	Between Groups	1.528	2	.764	1.055	.352
	Within Groups	62.972	87	.724		
	Total	64.500	89			
Internet - Search general information (N)	Between Groups	4.564	2	2.282	2.518	.085
	Within Groups	102.427	113	.906		
	Total	106.991	115			
Intranet based organisation for management and control (N)	Between Groups	.839	2	.420	.227	.797
	Within Groups	191.908	104	1.845		
	Total	192.748	106			
Intranet based organisation for corporate knowledge (N)	Between Groups	1.387	2	.693	.411	.664
	Within Groups	175.361	104	1.686		
	Total	176.748	106			
Knowledge management system (N)	Between Groups	2.622	2	1.311	1.018	.365
	Within Groups	139.107	108	1.288		
	Total	141.730	110			

Next, the factor analysis (FA) is focused on the questionnaire data from Part B to PartE1. It aims to identify key factors by grouping the variables into small groups of factors. These factors could be used as representatives of variables that influence ICT diffusion during the implementation stage. The results of FA will be shown in Appendix Table B2

Table B2: The result of factor analysis (Extraction method: Principal Component Analysis and Rotation method: Varimax with Kaiser Normalization)

VARIABLES	Factor components[1]										
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Sufficient time to think	.804										
Flexibility for learning	.787										
Work procedure support	.741										
Enough time for training	.733										
Technical support	.707										
Enough quality of training	.663				.415						
Functionality / Ease of use ICT	.561			.414							
Easy to observe benefit of using ICT	.552										
Trial and experiment ICT	.496		.492								
Mentoring support	.469										
Clear advantage of using ICT for communication between teams		.817									
Clear advantage of using ICT for coordinating teams		.812									
Clear advantage of using ICT for communication within team		.783									
Receive professional credibility		.702									
Relevance to personal job		.617									
Clear advantage of using ICT for decision-making		.608									
Basic skill of using ICT			.834								
Personal confidence			.712								
Enjoy exploring new tools			.686								
Personal capability to learn ICT			.683								
Help and Explain to others (Mentoring)			.518					.493			
Personal commitment			.496								
Functionality of ICT				.781							
Accessibility of ICT				.712							
Response rate of ICT				.704							
Supervisor encourages the use of ICT					.721						
Supervisor openly suggests how to improve ICT application					.711						
Trust in supervisor when making mistakes					.640						
Organisation support for sharing ICT experience					.430						
Enjoy learning from others					.421						
Colleagues feel safe on openly discusses about ICT problems						.817					
Person feels safe in openly discusses ICT problems						.690					
Organisation openly suggests for ICT improvement						.571					
Organisation commitment (resources)						.405					
Receive tangible reward							.830				
Provide tangible rewards in sharing ICT experience							.809				
Provide intangible rewards in sharing ICT experience							.620				
Receive intangible reward							.514				
Colleagues informally help on using ICT								.852			
Colleagues formally help on using ICT								.759			
Better than previous system									.642		
Speed and Reliability of ICT									.532		
Compatibility with previous system/ work procedures	.409								.478		
Feel pressured to be effective in using ICT										.769	
Personal anxious about ICT use										.700	
Difficult, complex or frustrating to use ICT											.751
Factor Loading (Rotation Sums of Squared Loading)	5.73	4.01	4.01	3.12	2.93	2.35	2.35	2.29	2.21	1.96	1.45
% of variance	12.5	8.72	8.71	6.77	6.37	5.12	5.11	4.97	4.80	4.27	3.16
Cumulative % of variance	12.5	21.2	29.9	36.7	43.0	48.1	53.3	58.3	63.0	67.1	70.5
Reliability (Cronbach's alpha)	.916	.880	.851	.888	.733	.709	.689	.786	.650	.585	-

[1]Displays the absolute value more than .4

Results of data analysis of ANOVA and Factor analysis were calculated by SPSS. The outcome of SPSS can be described as bellows.

Appendix C – Interview Questionnaire

APPENDIX C – Interview questionnaire
C1 Plain language statement of interview case study

Plain Statement

Project Title:
The Diffusion of ICT within large construction organisations

This interview is a part of research project to investigate the effectiveness of the information and communication technology (ICT) diffusion process. ICT is defined as groupware applications.

The aim is to understand the ICT diffusion process by explaining how key factors influence the use of specific ICT applications from user's perspective.

We would like you to tell us your experience regarding the use of these specific ICT applications within your organisation. The interview will be conducted face-to-face. It should take about 30 minutes. Participation is voluntary and is an open discussion on how the factors influencing the use of ICT. The data will remain confidential, and it will not be possible to be identified from the data collected.

Your information from this interview will make a valuable contribution towards increasing our knowledge of the ICT diffusion process in construction companies. If you have any question on the detail of this research please contact me at (03) 9925-1684.

Thank you for your cooperation.
Sincerely,

Prof. Derek Walker
CRC in Construction Innovation
RMIT University

Vachara Peansupap
Researcher and Ph.D.
Candidate Student

Research and Development Unit
RMIT University
PO Box 2476V
Melbourne
3001
Fax 03-9925-5595

C2 Diffusion process interview questions

Information and Communication Technology (ICT)

The aim of this interview is to understand how key factors have impacted on the users' adoption and diffusion of the ICT application within your organisation.

In this case study, ICT is defined as a 'collaborative ICT applications/systems' such as project web, lotus/notes or electronic document exchange systems for working as a virtual team.

Questions:

1. In order to gain insight into ICT, this interview will focus on one specific application:…………….…………..

2. Could you please explain your role and your education?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

3. How long have you been using this application? ………………….

4. **Level of Use =** This is the level of personal proficiency you have in using this application.
How would you rate yourself in the '***Level of Use***'?

☐ Beginner ☐ Above Beginner ☐ Intermediate ☐ Above Intermediate ☐ Expert

5. I am **satisfied** that this technology suite my needs.

Strongly Agree 1 2 3 4 5 Strongly Disagree

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Factor 1: Professional Development and Technical Support
Training
Help Desk/Technical support
Mentors

1.1 Could you tell me about ***training*** in using this application?
Discussion (**How** – Internal/external, Group, individual, frequency, length -Improvements?)
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

I have been **satisfied** with the level of
training from the company in relation to this application

Strongly Agree 1 2 3 4 5 Strongly Disagree

Training is **important** to the use this application.

Strongly Agree 1 2 3 4 5 Strongly Disagree

1.2 Could you tell me about ***help desk/technical support*** in using this application?
Discussion (**How** – Internal/external, Group, individual, frequency, length -Improvements?)
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

I am **satisfied** with the level of assistance
from Technical support in relation to this application.

Strongly Agree 1 2 3 4 5 Strongly Disagree

This aspect is **important** to the use this application

Strongly Agree 1 2 3 4 5 Strongly Disagree

1.3 Could you tell me about ***Mentors Support*** in using this application?
Discussion (How -Face to face, phone/email frequency -Improvements?)
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

I am **satisfied** with the level of support from
my mentor in regards the use of this application.

Strongly Agree 1 2 3 4 5 Strongly Disagree

This aspect is **important** to the use this application

Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 2: Advantages and benefit of Use

(e.g. Coordinating Teams
Communication between and within teams
Receive professional credibility
It is relevant to the job
Help in decision-making)

Could you tell me about your **advantages** when using this application?

Discussion

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that these **advantages** are
important for me to use this application

Strongly						Strongly
Agree	1	2	3	4	5	Disagree

Factor 3: Personal characteristics/attributes

(e.g. confidence to use
basic IT skills
enjoyable to learn
capability to learn
personal commitment to use)

Could you tell me about your **personal characteristics/attributes** in using this application?

Discussion

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that ***personal characteristics/attributes*** are
important for me to use ICT applications……….

Strongly						Strongly
Agree	1	2	3	4	5	Disagree

Factors 4: Technical Characteristics
(e.g. Functionality
Accessibility
Response rate)

Could you tell me about ***technical characteristics*** of this application?
Discussion
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that these ***technical characteristics*** are important for me to use this application

Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 5: Positive perceptions on ICT
(e.g. Compatibility,
Speed, reliability
Better than pervious system or traditional process)

Could you tell me about your ***Positive perceptions*** of this application?
Discussion
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that **your positive perception** is important for me using this application

Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 6: Organisational/Supervisor support
(e.g. encourages,
suggests improvements
shares information/suggestion
trust in supervisor)

Could you tell me about issues of ***supervisor supports*** on using this application?
Discussion
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that ***supervisor support*** is important for me using this application

Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 7: Open discussion environment

Feel safe to openly discuss/suggest any difficulties with my colleague

Could you tell me more about open discussion in using this application?
Discussion
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

I believe that an ***open discussion*** environment is important for me using this application — Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 8: Supporting Tangible and Intangible Rewards

Tangible rewards
Advancement,
Additional pay,
Security or Better job prospects

Could you tell me about ***Tangible rewards*** when using this application?
Discussion
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

I believe that receiving **tangible** rewards is important for me using this application — Strongly Agree 1 2 3 4 5 Strongly Disagree

Intangible reward
Respect,
Admiration,
Self-fulfilment

Could you tell me about ***Intangible rewards*** when using this application?
Discussion
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

I believe that receiving **intangible** rewards is important for me using this ICT application — Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 9: Supporting Colleague Helps

Could you tell me about your ***colleague helps*** when using this application?
Discussion
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that receiving help from my **colleagues**
is important for me when using this application Strongly Agree 1 2 3 4 5 Strongly Disagree

F10: Negative workgroup environment on ICT
(e.g. feel undue pressure, feel over-anxious)

Could you tell me about ***negative workgroup environments*** when using this application?
Discussion
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I am **unduly pressured** when using this application
Strongly Agree 1 2 3 4 5 Strongly Disagree

I am **overly anxious** when using this application
Strongly Agree 1 2 3 4 5 Strongly Disagree

Factor 11: Barriers to the use of ICT
(e.g. difficult, complex or frustrating to use ICT)

Could you tell me about ***your barriers*** when using this application?
Discussion
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

I believe that these are **important barriers**
for me when using this application
Strongly Agree 1 2 3 4 5 Strongly Disagree

C3 Invitation letter for presenting the research results

November 27, 2000

Dear Participant,

We would like to invite you to give some feedback of our summary of your interview, on the topic of "*The diffusion of ICT within large construction organisations*". To minimise any confusion or misinterpretation of our results, we would appreciate any comments you may offer, to improve or modify facts and data as required, in this summary paper. This will help us to understand and validate the facts and data before we complete the case study report.

The data will remain confidential and you can be assured that you will not be identified in any reports or papers provided by us. If possible, we would like you to send the feedback to us within the next two weeks so that it confirms to us that our summaries are an accurate reflection of the interview.

Your feedback will make a valuable contribution towards increasing our knowledge of ICT diffusion in a construction organisation. If you have any questions please email vachara.peansupap@rmit.edu.au or phone 9925-1684

Thank you for your cooperation.
Sincerely,

Prof. Derek Walker
Supervisor
CRC in Construction Innovation
RMIT University
Email: derek.walker@rmit.edu.au

Vachara Peansupap
Researcher and Ph.D.
Candidate Student

You can send the information back at
Mr.Vachara Peansupap
Research and Development Unit
RMIT University
PO Box 2476V
Melbourne
3001
Fax 03-9925-5595

APPENDIX D – Evaluation tables of factors influencing ICT diffusion

Table D-1 Assessment of users' experience of factors supporting the ICT diffusion (management issues)

(1) Factors related management support issues	*Evidences for evaluating present factors supporting the ICT diffusion*			*Evaluation results based on table 7.1*		
	CA	***CB***	***CC***	***CA***	***CB***	***CC***
F1: Professional development & technical support	CA promoted the use of ICT by providing 'road shows' that display what ICT can offer. Respondents were satisfied with training and technical support and help desk groups. They agreed that training and technical support are the essential facilitators of the ICT diffusion.	Participants were satisfied with training. Training consisted of two parts: introduction and functional use. The first part explained how to access the ICT and the second part the specific functions. Users may also request advanced training as required.	Most participants were satisfied with the training that provided the initial understanding on ICT use. An implementer conducted the internal training for using ICT.	H	H	H
	Help desk provided assistance with ICT use and they were available on call everyday. The technical support was very good. Users contacted help desk by phone and email.	Although there was a help desk that supports the use of ICT by phone and email, most respondents preferred to get help from an implementer who took on the role of helping users at the construction sites and in the regional head office.	ICT technical help relied on the implementer in the construction project whereas IT staff supported the solution of any technical problems related to network infrastructure. Participants were satisfied with the implementer who dedicated time at the site.	H	H	H
			F1: Professional development & technical support	H	H	H
F5: Senior and organisation support	Participants agreed that top/senior management people were the key drivers of ICT diffusion. Senior regional business managers were committed and supported the IT investment. Senior project managers played the main role of mentors that supported and encouraged staff for their use of ICT	Senior management listened to staff. Feedback was given during the beginning of ICT introduction. Support from managers was essential but in reality they were busy and had little free time to act on ICT use issues. The discussion of ICT use mostly occurred among staff at the operational level, but rarely occurred at between workers and senior managers.	Senior IT manager developed a community of practice to bring about a commitment from senior managers on using ICT. Participants mentioned that managerial support was one of the essential factors in the initial adoption decision because the use of ICT depended upon the project manager's support. There was some managerial support for practical use of ICT, such as providing basic suggestion or discussion for improvement.	H	M	H

F5: Senior and organisation support (cont.)	All participants were satisfied with the level of organisational support. The Organisation was committed to provide computer infrastructure such as computer, Internet access. For example, a small construction project that had only foremen crews was provided a laptop to connect with the ICT system.	Organisational support for ICT use by staff throughout the organisation. Participants received enough facilities to access ICT such as computer, internet access, and personal account. However, some participants mentioned that there were limitations of peripheral hardware that might be required for full ICT usage such as drawing scanner and plotter. Participants mentioned that the level of organisational support also relies upon the scale of construction project and IT budgets in the project.	Participants agreed that their organisation supported the use of ICT. For example, organisation committed to invest on its own Intranet network and provided suitable facilities such as computers and Internet connection in construction projects.	H	M	H
			F5: Senior and organisation support	H	M	H
F7: Supporting tangible and intangible rewards	Participants did not perceive that tangible rewards could encourage ICT use. They argued that the assessment of rewards should be based upon the work performance rather than the level of ICT use.	Tangible rewards seemed to be unimportant in ICT use. Most participants disagreed on the need to provide rewards for ICT use.	Participants agreed that the use of ICT had no direct relationship with tangible reward. In addition, they disagreed with providing tangible rewards for the use of ICT because they believed ICT is a tool to assist in their job.	L	L	L
	Some felt that intangible rewards have a small impact on the extent of ICT use	Participants believed that if the ICT provided clear benefits of making job easier, it would be used and adopted naturally. This indicates the influence of intangible on ICT use.	Some people believed that use of ICT was motivated by intangible rewards such as pride. For example, a respondent said that his supervisor felt good about his ICT use.	L	L	L
			F7: Supporting Rewards	L	L	L

Table D-2 Assessment of users' experience of factors supporting the ICT diffusion (individual/personal issues)

(2) Factors related to individual or personal support issues	***Evidences for evaluating present factors supporting the ICT diffusion***			***Evaluation results based on table 7.2***		
	CA	***CB***	***CC***	***CA***	***CB***	***CC***
F3: Characteristics of an individual (potential user)	Participants presented adequate personal characteristics of basic IT skills. They argued that basic IT skill and self-confidence were considered as the essential drivers for individual usage.	Overall, the participants were committed to ICT use. Project managers and engineers generally expressed high self-confidence in using ICT as they had well developed computer skills from their courses in universities. However foremen had a low level of ICT use.	The majority of participants mentioned that they have enough basic IT skills. In addition, they experienced that the use of the ICT in CC might not be required any advanced IT knowledge skills as the ICT was quite simple.	H	H	H
	In addition, some mentioned that enjoyment of learning and personal commitment to ICT use was essential for gaining momentum in their individual ICT use.	Participants agreed that personal characteristics such as capability to learn, basic computer skills, and personal commitment are necessary for the use and diffusion of ICT.	Most participants mentioned that they enjoyed learning to use ICT, particularly if it assisted their work processes.	H	H	H
			F3: Characteristics of individual	H	H	H
F9: Positive feeling towards ICT use	Participants indicated a strong positive perception of the value of the ICT use. The use of ICT was compatible with their traditional work processes and assisted their communication and coordination.	Overall the participants were moderately satisfied about ICT. Participants were agreed on the benefits of ICT as being better than fax and phone. However, some users mentioned ICT was not fully reliable because they lost input data while they left their connection to check their work on site.	Participants showed a positive perception towards the use of ICT. They believed that ICT assisted their communication and coordination with their project teams.	H	M	H
			F9: Positive felling toward ICT use	H	M	H

F2: Clear benefit/ advantage of ICT use	Most participants clearly understood the benefits in using ICT. They agreed that the use of ICT assisted their work in terms of central information access, document archive system, and project communication and collaboration. Participants mentioned that their use of ICT could save time for them to search information and data. In addition, the use of ICT helped them to store, retrieve, and access information and data both from home and office.	Not all participants clearly understood the benefits of using ICT or were not fully clear of the advantages of using the system. Participants had mixed opinions about ICT benefits because of perceived limitation of functionalities and speed. ICT system provided the benefits to users such as supporting communication, sharing, accessing and searching information, and real time work monitoring. However, participants mentioned that the benefits of ICT use could only be realised if all project participants used it.	Most participants experienced the benefits of using ICT. It provided several benefits such as managing document and construction drawing, sending/receiving correspondence, and tracking the sequence of changes on all correspondences. However, the actual use of ICT modules depended on participants' role and their task needs. Furthermore, they also mentioned that the applications provided benefits in terms of cost and time saving in sending drawing between design firms. As the use of ICT in CC had been implemented for only a year and a half, some project managers who did not observe the capability of ICT might have limited knowledge of its benefits. However, it was believed that the use of ICT would increase over coming years.	H	M	H
			F2: Clear benefit of ICT use	H	M	H

Table D-3 Assessment of users' experience of factors supporting the ICT diffusion (technology issues)

(3) Factors related technology support issues	*Evidences for evaluating present factors supporting the ICT diffusion*			*Evaluation results based on table 7.3*		
	CA	***CB***	***CC***	***CA***	***CB***	***CC***
F4: Characteristics of technology (compatibility, functionality, connection speed, accessibility, and reliability)	Participants mentioned that the system of ICT was compatible with their internal work processes and their internal organisational system	The main functions support a majority of people working on construction projects but some participants did not agree that ICT suits the scope and nature of their work. Especially, foremen who spent most of their time on site.	Participants' experience led them to believe that ICT was compatible with their traditional work processes and assisted their communication.	H	H	H
	The ICT system consists of several functions to assist construction processes such as correspondence, site instruction, tender, and site diary.	The functions of ICT were designed to support the communication and coordination of a construction project. The main functions consisted of searching personal information, creating correspondences, managing RFIs and site instructions, registering drawings and notifying people of uncompleted task.	The ICT characteristics were quite simple. The main concepts of ICT use were designed to support project communication and coordination within internal staff and between project participants. It consisted of three main functions such as daily work list, drawing registers, and correspondence. These functions provide adequate support to document management in a construction project.	H	M	H
	In-house IT people develop ICT. It allowed configurations and modifications as users suggested. Participants were satisfied with the level of IT response.	IT department staff developed ICT in CB and it they only allowed it to be configured through this central IT department. This it might cause a slow response and delays in fixing ICT problems.	ICT was developed, located, and maintained by an external web service company. The company provided space and users account that can access a particular project that they were working on. It allowed the implementer to modify a specific user interface to suit the organisation.	H	M	H
				M-H	M	M-

F4: Characteristics of technology (Cont.)	The speed of this system was dependent on the network connection. By connecting through a local intranet network, its speed was faster than connecting via dial-up networking.	Most users received a personal account to access the ICT system. ICT only allowed users to access information on projects that they are currently working on. Speed and response rate of using ICT relies upon the speed provided by internet service providers and internet connection types such as dialup network or ADSL	Participants received personal accounts. Users were allowed to access information and data on the project that they were currently working on. Participant could access ICT system from both the local area network in a construction office/site and from a dialup-networking service.	M	M	H M
	Participants mentioned that the ICT connection was reliable and they rarely found difficulty in accessing the system. There are two options to access the systems: dialup network and internal company network. In addition, the system had the backup files and information. Participants were required to install client application software on their computer before using the ICT	Some participants claimed that ICT was not reliable and slow to upload and download the large size of drawing files. In case of accessibility, participants accessed to ICT via dialup network and Internet service provider. As the ICT is developed based on web-based internet platform, users can access the ICT from anywhere via Internet web-browser. The use of ICT did not require installing any client application software.	It was mentioned that the optimum use of ICT was realised and provided a good response rate. However, the participants found that the speed of use relied on the Internet connection speed. In CC construction projects, the Internet connection was based on and linked to the company Intranet network infrastructure.			
			F4: Characteristics of technology	H	M	H

Table D-4 Assessment of users' experience on factors supporting the ICT diffusion (workplace environment support issues)

(4) Factors related work place environment support issues	*Evidences for evaluating present factors supporting the ICT diffusion*			*Evaluation results based on table 7.4*		
	CA	***CB***	***CC***	***CA***	***CB***	***CC***
F8: Collegial help	Participants received help from their colleagues. They used telephone calls or face-to-face communication with their colleagues who were located near them. Users felt free to share their experience with others.	Participant agreed on the necessity of the supporting colleagues. They mentioned that collegial help environment was important because it can assist persons who have questions on using the ICT. In addition, the collegial interaction can bring about the experiences of users to improve ICT use	The project teams in CC provided a collegial environment of help in relation to the use of ICT. For example, a senior engineer who has used the ICT application before assisted new engineers on how to use it for their work tasks.	H	H	H
	Participants presented strong encouragement for ICT use from senior project manager and their colleagues.	As some staff members were busy with their own individual job responsibilities, the allocation of implementer could fill the gaps of collegial help. Participants mainly received support from the implementer.	Most participants felt that their colleagues helped to create a supportive workplace environment. They shared knowledge and helped in the use of ICT by discussing about how to improve its application and use.	H	H	H
			F8: Collegial helps	H	H	H
F6: Supporting an open discussion environment	There was an open environment for the discussion of ICT usage. Participants felt open to discuss about the problems and suggestions. However not all staff could dedicate their time for discussion due to their other responsibilities.	There are mixed opinion about the open discussion environment. Some participants were satisfied with the open discussion environment but some mentioned that most construction staff were busy with their own responsibilities and therefore could not have much time to discuss about ICT problems.	Generally, the work environment was open for people who would like to discuss ways of how to improve it. For example, a young engineer who first used ICT felt safe to open a discussion on the use ICT for work.	M	M	M
	Some staff did not have time to	Open discussion rarely occurred between	A project manager mentioned that he	M	M	M

	talk and discuss their experience of ICT use. Some identified their involvement as suggesting the application to use. When they found problems or had suggestions, they will discuss this with IT staff. However, some staff had insufficient level of ICT knowledge so they might not confidently discuss details issues of ICT improvement.	managers and operational workers. Organisation lacked communication regarding IT improvement issues. Participants argued that during the first few years, the organisation was committed and encouraged users to suggest change. After a while the level of commitment declined because there were too many suggestions and the upgrades become difficult.	usually supported the use of the ICT Although he had limitations about his ICT knowledge in some areas. He discussed this with his subordinate and if an issue affected everybody, he would work with the implementer to solve that problem.			
			F6: Supporting open discussion environment	M	M	M