Business Process Implications of E-commerce in Construction Organisations

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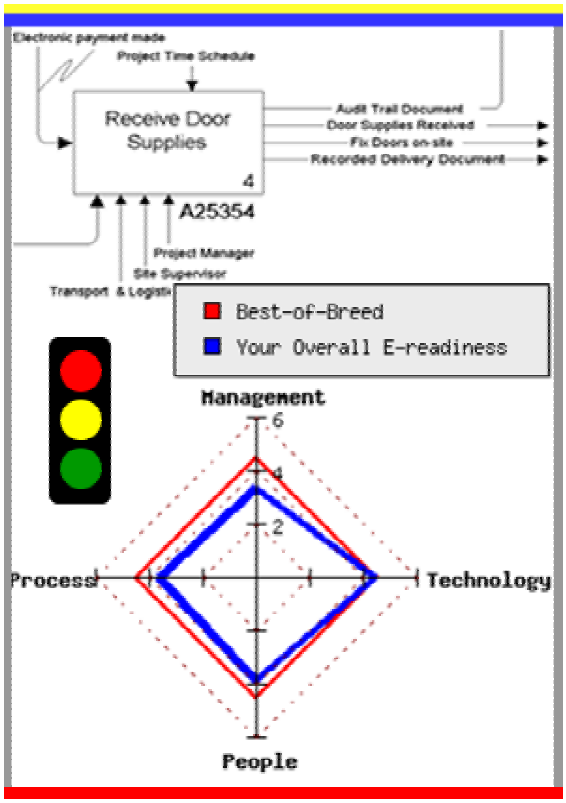

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BUSINESS PROCESS IMPLICATIONS OF E-COMMERCE IN CONSTRUCTION ORGANISATIONS

By
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A dissertation thesis submitted in partial fulfilment of the requirements for the award of the Engineering Doctorate (EngD) degree, at Loughborough University.

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Kirti Ruikar

ABSTRACT

The need for construction to change its traditional working practices has been repeatedly expressed in government, industry, and academic publications. The Internet has been a major catalyst for change in most industry sectors, including the construction sector. The implementation of Internet-based technologies, such as e-commerce for achieving business targets, bring about changes in an organisation, its current practices, systems, processes and workflows. It is therefore important to evaluate the business process implications of adopting e-commerce in construction organisations. This was the focus of this study.

The early stages of the research established the possible benefits, barriers, and drivers for the adoption of e-commerce technologies within construction. This was done by conducting an industry-wide survey that explored attitudes, current usage, barriers and enablers of IT and e-commerce within the UK construction sector. Survey results indicated that the exact benefits of using e-commerce within the construction industry were not known and more needed to be done to establish the effects of incorporating e-commerce applications into construction business processes and to demonstrate the opportunities of e-commerce for construction.

To address this need a typical business process model that used the principles of business process re-engineering and demonstrated opportunities for e-commerce, was developed. Using this model it was possible to illustrate how, with the use of e-commerce applications, different members of the construction supply chain could derive business benefits and overcome traditional process inefficiencies. In order to effectively adopt e-commerce technologies in construction, companies may have to re-engineer their current working methods, which could lead to a step change in current work practices. To facilitate such a step change it was essential to study and document the impact of specific e-commerce applications on their current end-user business processes. Case studies were conducted for this purpose. The case study findings showed that the end-user companies had accrued several business benefits from using e-commerce tools. Issues related to management buy-in and organisational culture were the main barriers to the wider use of e-commerce within the construction industry. The case studies and earlier findings indicated that e-commerce is ‘here to stay’ and it will not be long before it becomes an industry norm.

Taking this into account, construction companies who are currently using, and those who have yet to use, e-commerce tools need to take measures to successfully adopt and benefit from these tools. It is important for companies that seek to adopt e-commerce to assess their ‘e-readiness’ for adopting e-commerce tools to ensure a productive and beneficial implementation of these tools. To address this need an e-readiness model for construction organisations and a prototype application, VERDICT, that assess e-readiness were developed and implemented. The model is based on the premise that for any company to be e-ready, its management, people, process and technology have to be e-ready in order to derive maximum business benefits.

The research findings indicate that the use of e-commerce is still in its infancy within the construction industry. The current use of e-commerce has resulted in process automation, however, there is no evidence of process re-engineering. Such practices, although beneficial in the short-term, can have long-term implications in that the end-users are not necessarily making full use of the technology and hence not deriving full benefits from it. The model and e-readiness assessment prototype developed as part of this study will enable construction organisations to successfully adopt e-commerce and exploit its potential.

KEY WORDS

E-commerce, construction, business process, re-engineering, e-readiness assessment, ICTs and Internet.

PREFACE

The research presented within this thesis was conducted to fulfil the requirements of an Engineering Doctorate (EngD) at the Centre of Innovative Construction Engineering (CICE), Loughborough University. The Engineering Doctorate programme is described as a, 'radical alternative to the traditional PhD, being better suited to the needs of the industry[1]' the main essence being 'development of innovative thinking, while addressing real industrial problems'.

The EngD is examined on the basis of a Thesis containing at least three (but not more than five) research publications and/or technical reports. Presented within this thesis are journal papers and conference papers authored by the candidate. Each paper is referenced by a Paper Number (1 to 5) and the Appendix Number (A - F) where it can be located.

[1] Extract from CICE Web Site (www.cice.org.uk)

LIST OF PAPERS

JOURNAL PAPERS

1. Anumba, C. J., and **Ruikar**, K., 2002.

'Electronic Commerce in Construction – Trends and Prospects',

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2. **Ruikar**, K., Anumba, C.J., and Carrillo, P.M., 2003.

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3. **Ruikar**, K., Anumba, C.J., Carrillo, P.M., and Stevenson, G., 2001.

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Proceedings of the 3rd International Conference on Concurrent Engineering in Construction at University of California, Berkeley, July 2002, pp 26 – 40.

5. **Ruikar**, K., Anumba, C.J., and Carrillo, P.M., 2004.

'Impact of E-commerce Applications on End-user Business Processes',

Proceedings of the 1st International Conference on World of Construction Project Management (WCPM), 27-28 May, 2004, Toronto, Canada

JOURNAL PAPERS UNDER REVIEW

6. **Ruikar**, K., Anumba, C. J., and Carrillo, P. M., (under review).,

'End-user Perspectives on the use of Project Extranets in Construction Organisations',

Submitted to Engineering, Construction and Architectural Management (ECAM).

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'VERDICT – an E-readiness Assessment Application for Construction Companies'

Submitted to Automation in Construction.

ACRONYMS / ABBREVIATIONS

AEC	Architecture Engineering and Construction
ASP	Application Service Provider
BIW	Building Information Warehouse, also BIW Technologies
BPR	Business Process Re-engineering
CBPP	Construction Best Practice Programme
CICE	Centre for Innovative Construction Engineering
CPA	Construction Products Association
E-commerce	Electronic commerce
EDI	Electronic Data Interchange
EngD	Engineering Doctorate
HTML	Hyper Text Mark-up Language
IAI	International Alliance for Interoperability
ICT	Information and Communication Technologies
IDEF0	Integration DEFinition language 0
IFC	Industry Foundation Classes
IT	Information Technology
M4i	Movement for Innovation
MySQL	My Structured Query Language
PHP	Hypertext Preprocessor
PIC	Project Information Channel
RAD	Rapid Application Development
ROI	Return on Investment
SADT	Structured Analysis Design Technique
SC	Supply Chain
SCM	Supply Chain Management
SME	Small and Medium Enterprises
UK	United Kingdom
VERDICT	Verify End-user e-Readiness using a DIagnostiC Tool
Wi-Fi	Wireless Fidelity

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CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

The growth of the Internet in recent years has transformed the way in which people and businesses communicate and interact. It has revolutionised the way in which information is stored, exchanged and viewed. This has opened new opportunities for businesses, which were almost inconceivable before. With the help of the Internet, traditional technologies such as Electronic Data Interchange (EDI) and new, emerging technologies such as e-commerce, it is now possible to conduct business transactions internationally, within a relatively short span of time, and at a fraction of the amount it would have cost previously (using traditional methods).

Businesses have recognised the possibilities the Internet has to offer and hence the need to adopt new measures. This has had some immediate consequences. There arises a need for businesses to assess and rethink their existing processes and working methods in order to avail themselves of the opportunities that technologies such as the Internet have to offer. This may involve shifting from traditional, tried and tested methods or in some cases, radically altering these methods to benefit from new technologies. Such changes can prompt businesses to improve their traditional business processes, innovate their products and services, and develop strategies that are flexible enough to incorporate new technologies as they emerge. The increase in electronic ways of conducting business by using e-commerce technologies, has had knock-on effects on virtually every business sector. The construction industry is no exception.

In recent years, the use of e-commerce tools in construction has been on the increase (Berning and Diveley-Coyne, 2000). The benefits of using these tools on construction projects have been documented in several publications (ITCF, 2004; Berning and Flanagan, 2003; and Sturley, 2003). However, the use of these tools is still not ubiquitous within the industry. This research is based on the premise that, for those construction companies that seek to adopt e-commerce tools there is a need to undertake an analysis of their business processes and working methods to ensure a productive and beneficial implementation of these tools.

This chapter introduces the project and explores the impetus for change within the construction industry. It further defines the research problem addressed in this project and discusses the scope of the research in the context of its industrial relevance. The chapter also includes the overall structure of this thesis. The next section defines e-commerce in the context of this research.

1.1.1 E-COMMERCE DEFINITION

Electronic commerce or e-commerce has been defined in several ways. The Organisation for Economic Cooperation and Development (OECD) defines e-commerce as ‘the electronic exchange of information that support and govern commercial activities including organisational management, commercial management, commercial negotiations and contracts, legal and regulatory frameworks, financial settlement arrangements and taxation’ (OECD, 1999). A different perspective on the definition of e-commerce is presented by Kalakota and Whinston (1997). They view e-commerce as a production process that converts digital inputs into value-added outputs through a set of intermediaries. Some others define e-commerce as the process of

buying and selling goods and services online (Unisys, 2004; and Laudon and Laudon, 2002). However, this definition of e-commerce can be limited as, e-commerce is not just about buying and selling online, but also includes all forms of business activities that are conducted over the Internet (e.g. the business-to-business flow of information between companies or within a company, communication between businesses, online advertising, etc) (Learnthat, 2004). E-commerce at its grass root level can be described as an electronic method of doing business, typically over the Internet. Broadly defined, however, 'E-commerce is a modern business methodology that addresses the needs of organisations, merchants and consumers to cut costs while improving the quality of goods and services and increasing the speed of service delivery.' (Kalakota and Whinston, 1997).

The definition of e-commerce is not static (Kosiur, 1997) and depends on the adopted perspective. According to Kalakota and Whinston (1997), from a *communications* perspective, e-commerce is the delivery of information, products/services, or payments via telephone lines, computer networks, or any other electronic means. From a *business process* perspective, e-commerce is the application of technology toward the automation of business transactions and workflows. From a *service* perspective, e-commerce is a tool that addresses the desire of firms, consumers and management to cut service costs while improving the quality of goods and increasing the speed of service delivery. From an *online* perspective, e-commerce provides the capability of buying and selling products and information on the Internet and other online services. This thesis adopts this wider definition of e-commerce.

1.2 IMPETUS FOR CHANGE IN CONSTRUCTION

It has been well documented that the construction industry is characterised as being both fragmented (Anumba and Evbuomwan, 1999; Egan, 1998; Lottaz et al., 2000) and information-intensive (Gajendran, et al., 2004; Thomas et al., 2001; Tam, 1999). A considerable degree of information flows between the various participants including client, architect, structural designer, quantity surveyor, services engineer, fabricator, subcontractors, contractor and material suppliers. A construction project is a team effort, which involves several inter-organisational activities, dialogues and data flows, making it a highly complex process (Egan, 1998; Ciftcioglu, 2003). The network of communication between construction project members is complex and multifaceted in nature. Figure 1.1 illustrates the complex communication network between construction project stakeholders.

At the time when this project commenced (in year 2000), the information flow in the construction industry was still mostly paper-based and hence slow. The network of communication between the various project partners in a typical construction project was mainly one-to-one, where different stakeholders in a construction project would communicate with one another individually using faxes, telephone networks and electronic mail (Hibberd, 2000). According to Thomas, et al. (2001) as a project grows larger in size, its complexity increases and the possibility of communication blockages also grows. Research by Anumba and Evbuomwan (1999) has shown that the conventional one-to-one and paper-based methods of communicating information were grossly inadequate particularly in collaborative and concurrent engineering settings where the project team members were geographically distributed. It was therefore very important for construction project teams to explore alternative and more effective ways of communicating throughout the project lifecycle to increase efficiency and productivity of construction projects. This need was further emphasised by the Egan report (1998) which stated that the construction industry needed to overcome its fragmented nature to formulate efficient and effective business processes. It stated that the construction

industry is an important pillar of the domestic economy in UK, contributing about 10% of the total revenue and is simply too important to be allowed to stagnate.

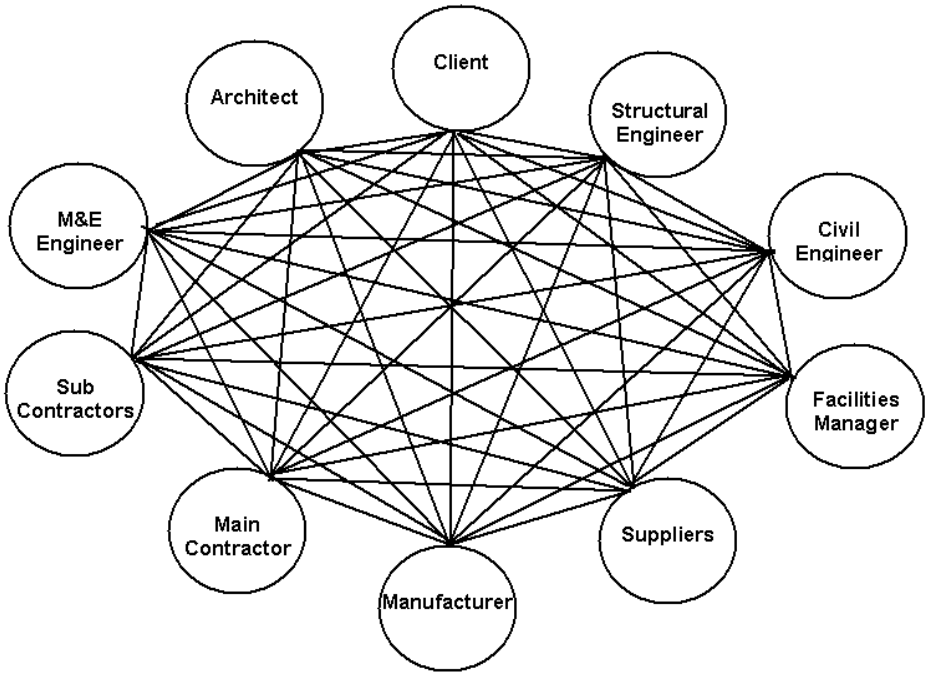


Figure 1.1 Complex Communication Network between Construction Project Members (Ruikar, et al., 2003)

In order to prevent stagnation and move forward with the times the industry should investigate ways to amalgamate new and revolutionary technologies such as e-commerce into its day-to-day working methods. The construction industry can reduce the effects of fragmentation through the use of technological tools to increase efficiency and quality of construction projects (Egan, 1998). The Egan report (1998) further states that construction processes can be effectively managed with the help of IT (Information Technology) and Internet-based innovative planning and management techniques. Construction projects can also incur considerable savings in terms of time and money, by adopting dynamic methods of information exchange and communication that are facilitated by IT and Internet-based e-commerce tools. Collaborative information technology tools can be used to improve co-ordination between project partners. The Internet can be used as a tool to store, exchange and view information. Use of such technologies can prompt construction businesses to improve traditional business processes, innovate their products and services, and develop strategies that are flexible enough to incorporate new technologies (such as e-commerce) as and when they emerge.

1.3 PROBLEM DEFINITION

Companies across several industries (including construction) are increasingly leveraging the Internet to achieve competitive advantage (Cheng et al., 2003). Internet-based tools such as project extranets are being used to manage construction projects. Such tools can be used to monitor, control, manipulate and store project information and to make it available to all participants of the construction supply chain (Alshawi and Ingirige, 2002). Examples of Internet-based tools include a computer-mediated tendering system for services or contracts, purchasing of materials via the Internet by a

contractor, project extranets for project management, and specifying products online by a manufacturer (ITCBP Intelligence, 2002). All these tools can be encompassed under a single banner of e-commerce tools for construction as they facilitate trading, exchange of data and information, and automation of the business processes and workflows (Kalakota and Whinston, 1996).

Research studies (Ruikar et al., 2001; Paper 1, Appendix A) and recent publications (Stephenson and Turner, 2003; Laudon and Laudon, 2002) have documented the possible benefits and business opportunities for companies using e-commerce tools such as project extranets. In spite of these documented benefits the UK construction industry has been relatively slow in the uptake of these tools in their day-to-day workings (ITCBP Intelligence, 2003). A survey of the UK construction industry, undertaken by the Construction Products Association (CPA, 2000), predicted that by 2005, 50% of the industry's business activity would be undertaken using e-commerce. However, another survey carried out a year later by the same organisation indicated a considerable reduction in these projected figures to 22%, which is less than half of what was initially predicted, indicative of a much slower uptake than anticipated. The construction industry stepping back from the initial 'dot-com fever' was seen as the main reason of this change (CPA, 2001). Additionally, some other factors that have also contributed to this slow uptake are:

- E-commerce technology is relatively new and there is limited availability of information or feedback on its performance on previous construction projects;
- As with most technologies, it can be difficult to gauge the quantitative return on investment (ROI) from using new technologies such as e-commerce; and
- The teething problems and changes in working culture and practices which are required, initially, with the adoption of any new technology, very often deters new users.

Although the uptake of e-commerce technology in the UK construction industry has been relatively slow (Construction Industry Times, 2002; Stewart and Mohamed, 2003), it is seen that the industry has recognised the enormous potential for the use of e-commerce in the construction sector. The UK construction sector is trying to maximise the use of this new and innovative technology through several industry and government-backed initiatives [e.g. M4I (Movement for Innovation), CBPP (Construction Best Practice Programme), CPA (Construction Products Association), Construct-IT, etc.] that promote research into the use of new technologies such as e-commerce in construction. It is now the industry view that, e-commerce is here to stay and it will not be long before it becomes an industry norm (Ruikar, et al., 2004).

Implementation of any new technology such as e-commerce for achieving business targets requires major changes in an organisation, its current practices, systems, processes and workflows (ITCBP Intelligence, 2003). The right strategies and implementation plans have to be developed, communicated and implemented. This is not easy, thus issues such as getting 'buy in', defining a strategy, selecting a system, developing a training programme, defining operating procedures, modifying organisational structures, reviewing use, extending use, etc. need to be thoroughly researched (ITCBP Intelligence, 2003). Taking this into account, construction companies that are currently using, and those who have yet to use, e-commerce tools need to take measures to successfully adopt and use this technology. It is important for companies that seek to adopt e-commerce tools to analyse their businesses to ensure a productive and beneficial implementation of these tools. This means that:

- They need to evaluate the impact of using e-commerce tools on their day-to-day business processes; and
- Measure their 'e-readiness' for adopting e-commerce tools.

These two aspects form the main focus of this research project, details of which are discussed in subsequent chapters.

1.4 INDUSTRIAL CONTEXT

This research project was initiated by the industry sponsor, BIW Technologies Ltd (formerly, the Building Information Warehouse), in collaboration with CICE at Loughborough University. At the time the project began the concept of using e-commerce tools within the UK construction sector was relatively immature. Many application service providers had developed e-commerce tools such as Web-based collaborative tools that were used on construction projects. After an initial hectic period in 2001 some high profile ventures failed (Hampton, 2003). Things that were proven over time to be sound business practices were simply ignored by these start-ups (Jackson, 2001). One possible reason for this could have been that they developed tools built around a generic information sharing model that did not address the specific needs of construction business processes. These companies saw a lucrative opportunity and a market niche, but underestimated the complexity of AEC (Architecture Engineering and Construction) requirements and the entrenched processes of the construction industry (Gross, 2001).

The Information Channel was developed specifically for the UK construction industry by a team of industry practitioners with years of experience in the UK construction sector. The Information Channel is a Web-based e-commerce tool which the entire construction supply chain can use to communicate, exchange and archive information (records of what was done, when, by whom, etc.) throughout the lifecycle of the construction project.

In its bid to implement new collaborative business processes using advanced technologies such as the Information Channel, BIW hoped to address some of the underlying issues related to fragmentation of the construction processes. With this vision in mind BIW hoped to continue its practice of continuous improvement and customer focus by initiating this project to evaluate the business process implications of their core business product, the Information Channel, on their end-user business processes. Through this study, it would be possible to understand, whether the Information Channel was really meeting the needs of its end-user business processes and to take adequate measures to address any shortcomings.

It should be noted, however, that although the original problem was formulated by the industry sponsor, as highlighted in Section 1.2 and Section 1.3, this is a wider industry problem.

1.5 RESEARCH SCOPE

Broadly, this research study focussed on investigating the impact of e-commerce tools on the day-to-day workings of construction organisations. Two secondary themes emerged as the project progressed, these include:

- The development of process models that use the concept of business process reengineering (BPR) and incorporate e-commerce applications to

facilitate and enhance the current construction business process; and

- The development of an e-readiness model that assesses the readiness of construction organisations for the adoption of e-commerce tools into their current business processes. This led to the development of a prototype e-readiness application.

Figure 1.2 gives an overview of the overall EngD project. It illustrates the steps that were taken as a part of this research that have led to:

- Identification of the main drivers, benefits and barriers to the adoption of e-commerce tools within the construction sector;
- The development of a reengineered business process that highlights opportunities for the use of innovative e-commerce tools within the construction process;
- The conduct of case studies that assess the impact of e-commerce tools on the end-user processes; and
- The development of an e-readiness model and prototype called VERDICT (**V**erify **E**nd-user e-**R**eadiness using a **Di**agnostic Tool) that assess the readiness of construction organisations for adopting e-commerce.

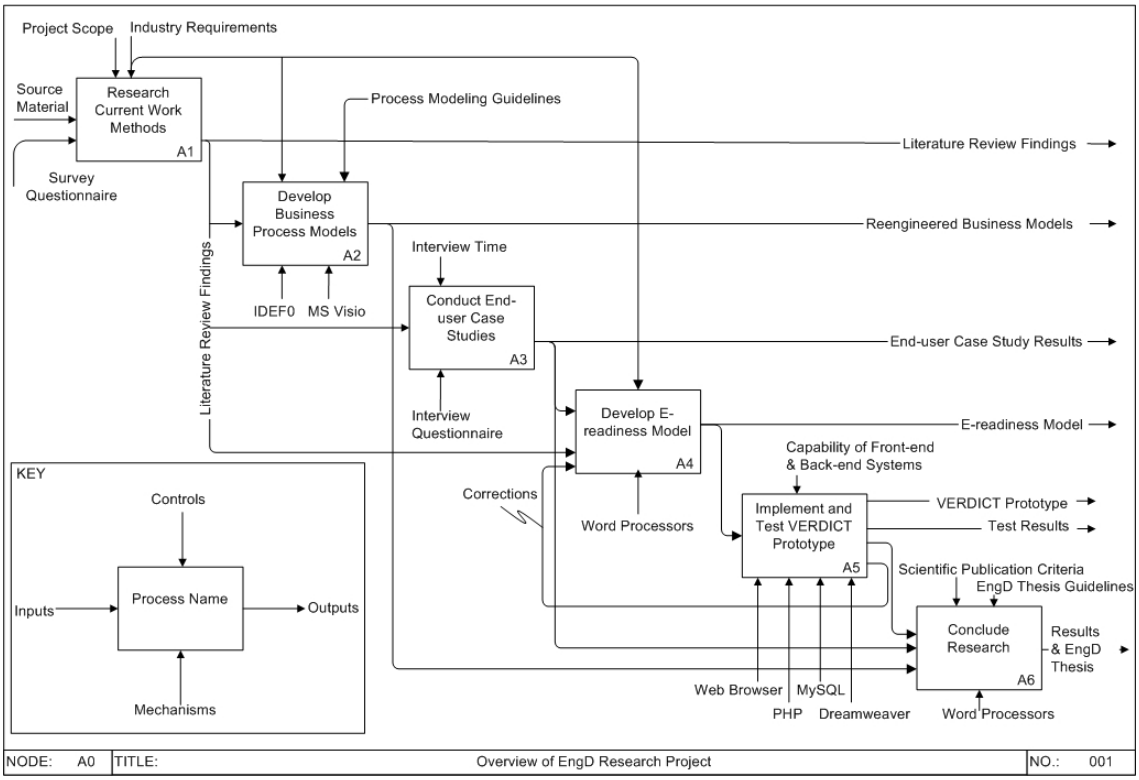


Figure 1.2 Overview of the EngD Research Project

As shown in the process model, industry requirements have played a major role in contributing towards the development of the reengineered business model and the development of the e-readiness model. The project commenced with a literature review phase that explored the current working methods within the construction industry and the evolution of e-commerce. The next stage investigated the concept of BPR and developed process models using principles of BPR to optimise the current construction

business processes. This reengineered process highlighted the opportunities for using an Internet-based collaborative tool developed by the industrial sponsor (Paper 3, Appendix C). Case studies were then undertaken to investigate the impact of specific e-commerce applications on end-user processes. Findings of each of these stages led to the development of an e-readiness model and a prototype e-readiness application to demonstrate innovation in the application of knowledge to the engineering business environment. The results from the different stages of the project are published as scientific papers in refereed journals and conferences (see Appendices A to E). Details of the research project with respect to its aim, objectives, work undertaken, findings and conclusions are included in the subsequent chapters of this thesis. The next section outlines the structure of this thesis.

1.6 STRUCTURE OF THESIS

This thesis documents the work undertaken in the research project. It is structured as follows:

Chapter 1 introduces the EngD research project and states the research problem. It also discusses the scope of the research project and introduces the steps undertaken for this research.

Chapter 2 states the aim and objectives of this EngD project. It also describes the activities undertaken to meet the goals of each objective and lists the publications resulting from the research project.

Chapter 3 This chapter reviews a range of research methodologies and highlights those adopted for the EngD research project.

Chapter 4 presents the work undertaken to meet the objectives of this project. This includes the development of process models annotated with opportunities for using e-commerce applications and the development of an e-readiness model for construction organisations.

Chapter 5 presents the key findings of the research project, including the evaluation results of the prototype application. It also discusses the impact of the research on the industrial sponsor organisation and its implications for the wider industry. Finally, the chapter presents the conclusions of this research and explores areas for future work.

Appendices A to E include the five scientific papers that were published in support of this research study. A summary listing of the publications, along with full bibliographical references is included in Table 2.1 of Chapter 2. These papers are an integral part of the thesis and should be read in conjunction with the thesis, as they contain further details of the work done.

Appendix F includes support material such as the survey and interview questionnaires, the VERDICT e-readiness assessment model questions, and the VERDICT prototype evaluation questionnaire.

CHAPTER 2 PROJECT AIM AND OBJECTIVES

2.1 INTRODUCTION

This chapter states the overall aim of the EngD research project and lists the objectives that were defined to meet this aim and the activities undertaken to achieve each objective. The chapter also includes a list of all the publications that resulted from this research project.

2.2 PROJECT AIM

The main aim of this research study is, 'To evaluate the business process implications of adopting e-commerce in construction organisations'. In order to satisfy this aim, five objectives were defined. A detailed timeline was outlined for each of the objectives and the deliverables (i.e. project milestones) identified. These were in the form of reports and publications. The five identified project objectives are stated in the next section.

2.3 OBJECTIVES

The specific project objectives are as follows:

1. To review related work on e-commerce in the construction industry, including the current use of IT and electronic transactions;
2. To study the current working methods of the construction sector and investigate the potential impact of e-commerce on construction business processes;
3. To investigate in depth the impact of specific e-commerce applications on the business processes and supply chains of end-user construction companies;
4. To develop an e-readiness model and associated prototype application to facilitate adoption of e-commerce by construction organisations; and
5. To summarise the research and identify areas with potential for future work.

2.3.1 OBJECTIVE 1

To review related work on e-commerce in the construction industry, including the current use of IT and electronic transactions.

This was the exploratory phase of the project which mainly focused on researching the concept of e-commerce, both within and outside construction. This work was carried out between July 2000 and September 2001. A detailed timeline for Objective 1 is included in Figure 2.1.

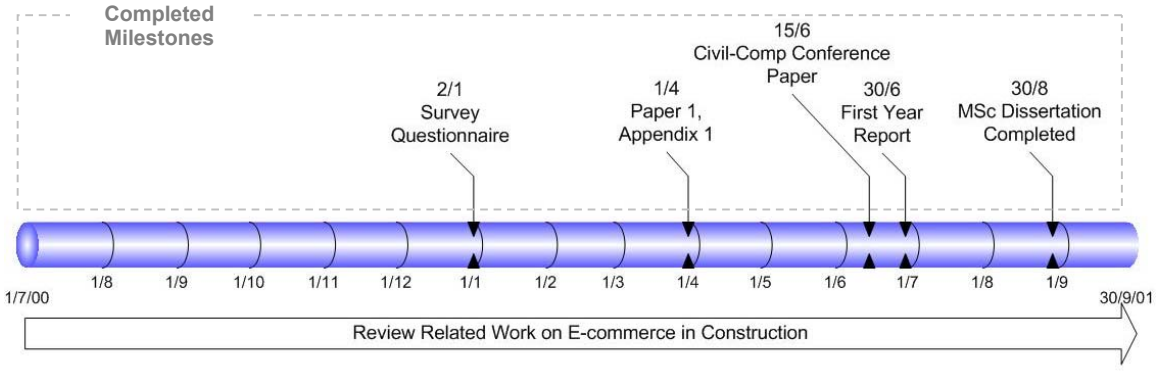


Figure 2.1 Detailed Timeline for Objective 1

The following tasks were undertaken to meet Objective 1:

- Identifying the business drivers that have contributed to the evolution of e-commerce;
- Identifying and establishing the enablers and barriers to the adoption of e-commerce in general and with particular focus on the construction industry. The findings of this are published in Paper 1 (Appendix A);
- Examining case study examples within the construction industry to identify the benefits of, and barriers to the implementation of e-commerce in the construction sector; and
- Preparing a detailed survey questionnaire to establish the current use of IT and e-commerce within the construction industry. The findings of this are published in Paper 2 (Appendix B).

2.3.2 OBJECTIVE 2

To study the current working methods of the construction sector and investigate the potential impact of e-commerce on construction business processes.

Objective two covered both the exploratory and investigative phases of the research project. It mainly focussed on investigating the impact of e-commerce on the current construction business processes. This work was carried out between October 2001 and July 2002 (see Figure 2.2).

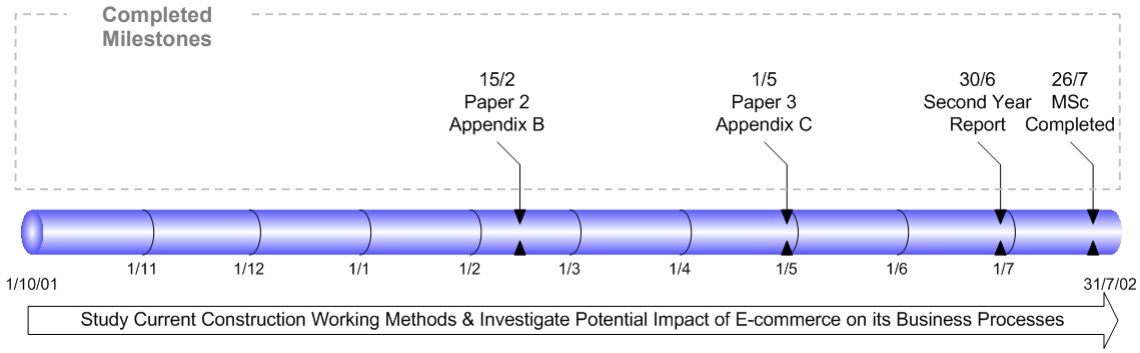


Figure 2.2 Detailed Timeline for Objective 2

The following tasks were undertaken to meet this objective:

- Carrying out a comprehensive literature review to study the current working methods within the construction sector;
- Conducting case studies to establish the current network of communication and data exchange between construction project partners and the current work culture; and
- Assessing the current workings of the construction sector (identified in activities one and two) in order to identify opportunities for the adoption of e-commerce at various stages of the construction process.

2.3.3 OBJECTIVE 3

To investigate in depth the impact of specific e-commerce applications on the business processes and supply chains of end-user construction companies.

This stage of the research involved a thorough investigation of the impact of specific e-commerce applications on the business processes of end-user companies. This work was undertaken between August 2002 and February 2004 (see Figure 2.3)

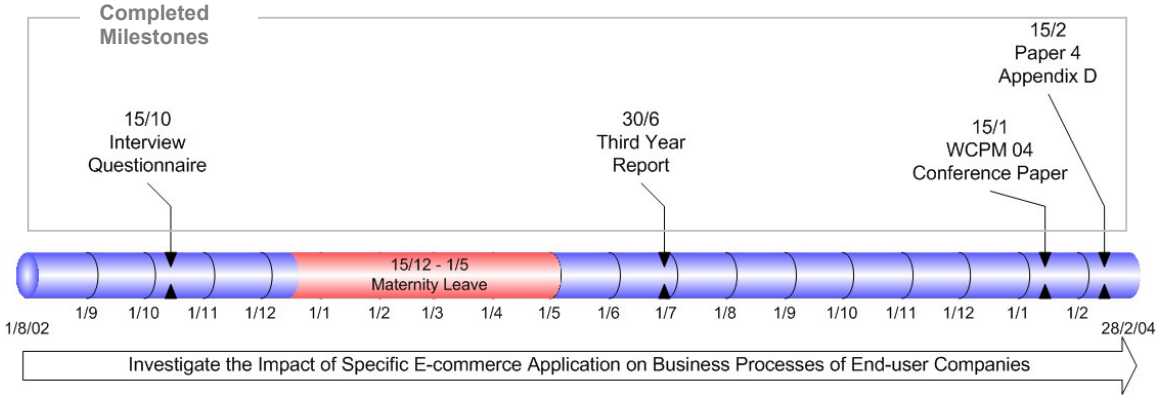


Figure 2.3 Detailed Timeline for Objective 3

The following tasks were undertaken to meet this objective:

- Studying in detail specific applications developed by case study organisations;
- Developing an interview questionnaire (for end-user companies) to gauge the impact of specific e-commerce applications on business processes of the end user companies;
- Studying the uptake of case study applications by end-user companies (customer, supplier and others); and
- Examining the impact of these applications on the existing business processes of end-user construction companies and their supply chains.

2.3.4 OBJECTIVE 4

To develop an e-readiness model and associated prototype application to facilitate adoption of e-commerce by construction organisations.

This objective covered the development and implementation phase of the project. This stage involved the development of an e-readiness assessment model and associated prototype application to facilitate the uptake of e-commerce applications in construction companies. The following tasks were undertaken to fulfil this objective:

- Developing an e-readiness model that assesses the readiness of construction organisations for using e-commerce applications;
- Developing and implementing a prototype e-readiness assessment application; and
- Evaluating and validating the prototype e-readiness application.

A detailed timeline, highlighting the main milestones for objective 4 is shown in Figure 2.4.

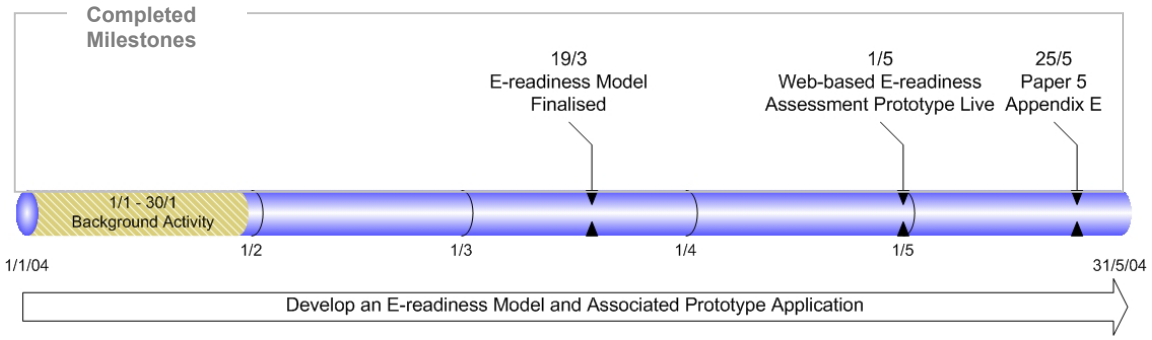


Figure 2.4 Detailed Timeline for Objective 4

2.3.5 OBJECTIVE 5

To summarise the research and identify areas with potential for future work.

This was the final stage of the research which involved summarising the research work by critically appraising information from previous objectives and identifying dissemination and implementation routes. Any areas with potential for future work were also identified at this stage. The data presented in the main body of this thesis was derived from the outputs and findings of previous objectives of this research. This data was then synthesised in the concluding months of the project (duration indicated in Figure 2.5) and presented in the final thesis.

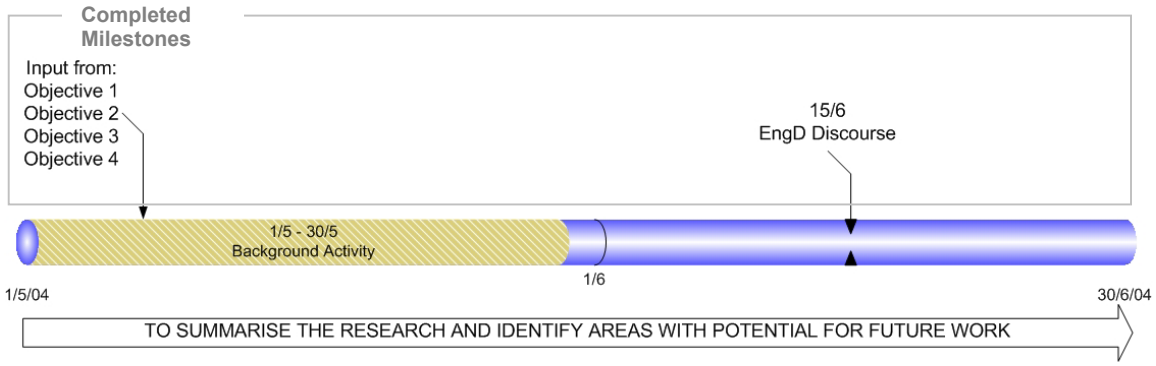


Figure 2.5 Detailed Timeline for Objective 5

2.4 LIST OF PUBLICATIONS

This section includes a list of *all* the papers that were completed as part of this research project, including their full bibliographical references (see Table 2.1). It also includes a brief description of each paper and states how each contributes towards achieving the broader research aim. Only those papers that are included in this thesis have been identified by paper numbers and the corresponding appendices where they can be located.

Table 2.1 List of Publications

PAPER NO.	PAPER TITLE	BIBLIOGRAPHICAL REFERENCE	STATUS	DESCRIPTION
	E-commerce in Construction: Barriers and Enablers	**Ruikar**, K., Anumba, C.J., Carrillo, P.M., and Stevenson, G., (2001). 'E-commerce in Construction: Barriers and Enablers' *Proceedings of the 8th International Conference on Civil and Structural Engineering Computing*, Eisenstadt, Austria, B. H. V. Topping (Editor) Civil-Comp Press, Stirling, United Kingdom, Paper 2, 2001.	Published	This paper discusses the trends of e-commerce in the construction industry and examines the barriers and enablers that influence e-commerce adoption. The potential benefits of e-commerce to the construction sector are also discussed.
Paper 1, Appendix A	*Electronic Commerce in Construction – Trends and Prospects*	Anumba, C.J and **Ruikar**, K., (2002). 'Electronic Commerce in Construction – Trends and Prospects', *Automation in Construction*, Elsevier Science B.V. Vol.11, pp 265-275.	Published	This paper reviews the developments of e-commerce in construction and presents a taxonomy for e-commerce. The paper also reviews e-commerce trends in construction including the barriers and enablers of e-commerce in construction. Finally, it predicts future trends for e-commerce.
Paper 2, Appendix B	*Industry Perspectives of IT and E-commerce in Construction*	**Ruikar**, K., Anumba, C.J., and Carrillo, P.M., (2002). 'Industry Perspectives of IT and E-commerce in Construction', *Proceedings of the third International Conference on Concurrent Engineering in Construction*, at University of California, Berkeley, July 2002, pp 26 – 40.	Published	This paper presents the results of a survey undertaken to establish the views of industry practitioners on the uptake of IT (and e-commerce in particular) within the UK construction sector. The survey explored attitudes, current usage, barriers and enablers amongst other things. The findings of the survey are discussed and outline ideas for more effective deployment of IT and e-commerce in construction organisations are presented.

Paper 3, Appendix C	*Reengineering Construction Business Process through Electronic Commerce*	**Ruikar**, K., Anumba, C.J., and Carrillo, P.M., (2003). 'Reengineering Construction Business Process through Electronic Commerce', *The TQM Magazine, Special issue: Managing Quality in E-Operations*, Emerald Press, UK, Vol. 15, No. 3, pp 197 – 212.	Published	Previous research has indicated that there is a lack of defined or clear objectives within the UK construction industry regarding e-commerce usage. Also, a majority of the industry players are unsure of the exact benefits of e-commerce applications in construction. This paper tries to address these shortcomings by presenting how the current construction business process can be improved through the use of new and innovative e-commerce applications.
	Impact of E-commerce Applications on End-user Business Processes	**Ruikar**, K., Anumba, C.J., and Carrillo, P.M., (2004). 'Impact of E-commerce Applications on End-user Business Processes', *Proceedings of the 1st International Conference on World of Construction Project Management* (WCPM), at Ryerson University, Toronto, Canada, 27-28 May, 2004.	Published	A small percentage of projects are currently being managed using e-commerce tools. To encourage industry-wide adoption of these tools, there is a need to analyse and document the effects of e-commerce tools on business processes of end-user construction companies that have already used these. This paper discusses findings of the case studies conducted to study the impact of a specific e-commerce application on end-user business processes. It also presents end-user viewpoint regarding the benefits and drawbacks of using the case study application.
Paper 4, Appendix D	*End-user Perspectives on the use of Project Extranets in Construction Organisations*	**Ruikar**, K., Anumba, C. J., and Carrillo, P. M., (under review)., 'End-user Perspectives on the use of Project Extranets in Construction Organisations', Submitted to the Engineering, *Construction and Architectural Management* Journal.	Under Review	This paper presents the findings of case studies that were conducted as a part of objective three. It discusses the drivers for successful implementation of project extranets within end-user organisations and the effects of project extranets on traditional processes of end-user organisations. It further discusses the end-user viewpoint on the benefits of, and barriers to, the use of project extranets within the industry.
Paper 5, Appendix E	*'VERDICT– an E-readiness Assessment Application for Construction Companies'*	**Ruikar**, K., Anumba, C.J., and Carrillo, P.M., (under review). 'VERDICT – an E-readiness Assessment Application for Construction Companies' Submitted to *Automation in Construction*.	Under Review	This paper discusses the concept of e-readiness and the need for an e-readiness assessment tool for construction companies. It discusses in detail the e-readiness model and prototype application adopted and a justification for it.

2.5 SUMMARY

This chapter stated the overall aim of the EngD research project and listed the project objectives. It described in brief, the work carried out to meet the goals of each objective. The chapter also included a list of all publications emanating from this research project. The next chapter discusses the research methodology adopted for this project.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter reviews a range of research methodologies and in particular those adopted for the EngD research project.

3.2 RESEARCH METHODOLOGIES

A research methodology sets out and justifies the techniques adopted for collecting, analysing and interpreting data (Carrillo, 2001). There are a number of research methods that can be adopted; these include interviews, questionnaires, one-to-one discussions, observation, experiments, etc (Robson, 1996). Research methods can be classified in various ways. However, one of the most common distinctions is between qualitative and quantitative research methods. This section reviews different research methodologies and includes a brief description of each.

3.2.1 QUALITATIVE RESEARCH

Qualitative research involves the use of qualitative data, such as interviews, conversations with participants, field notes, documents, and participant observation data, to understand and explain social phenomena (Myers, 2004). According to Hancock (1998), the main methods of collecting qualitative data are:

- individual interviews;
- focus groups;
- direct observation; and/or
- case studies.

3.2.1.1 Interviews

Interviews can be structured, semi-structured or unstructured. *Structured interviews* consist of the interviewer asking each respondent the same questions in the same way. For structured interviews a tightly structured schedule of questions is used. *Semi-structured interviews* involve a series of open-ended questions based on the topic areas the researcher wants to cover. The open-ended nature of the question defines the topic under investigation but provides opportunities for both interviewer and interviewee to discuss some topics in more detail. If the interviewee has difficulty answering a question or provides only a brief response, the interviewer can use cues or prompts to encourage the interviewee to consider the question further. *Unstructured interviews* are interviews where the interviewer wants to find out about a specific topic but has no structure or preconceived plan or expectation as to how they will deal with the topic (Hancock, 1998).

3.2.1.2 Focus Groups

Focus groups are defined as a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research (Powell and Single, 1996). A focus group may consist of 8-12 carefully selected participants with whom a professional researcher (or moderator) conducts a guided conversation. The moderator may run this conversation off a discussion guide, or a road map of questions and issues for the group that have been

carefully worked out beforehand. According to Gibbs (1997), the benefits of focus group research include gaining insight into people's shared understandings of everyday life and the ways in which individuals are influenced by others in a group situation.

3.2.1.3 Direct Observation

Observation is the careful watching and study of those participating in a study (Brainyencyclopedia, 2004). It is a technique that can be used when data collected through other means can be of limited value or is difficult to validate (Hancock, 1998). The accurate observation of participants is key to the success of this method and determines the validity of the findings. For example, in interviews participants may be asked about how they carry out work on a daily basis. Simple as it may seem, some may find it difficult to interpret their daily tasks in words. In such situations, the observation technique may be used, where it is possible to see how they actually work or respond to given situations.

3.2.1.4 Case Studies

Case studies are detailed investigations of individuals, groups, institutions or other social units. The researcher conducting a case study attempts to analyse the variables relevant to the subject under study (Key, 1997). The principal difference between case studies and other qualitative research studies is that the focus of attention is on the individual case and not the whole population of cases. They are chosen on the basis that they are representative of a sample group that can be used to demonstrate particular facets of the topic of research (Beatham, 2003). Most studies search for what is common and pervasive. However, in the case study, the focus may not be on generalisation but on understanding the particulars of that case in its complexity (Key, 1997).

These qualitative approaches to data collection usually involve direct interaction between individuals on a one-to-one basis or in a group setting. Data collection can be time-consuming and consequently data is collected from smaller numbers of people than would usually be the case in quantitative approaches such as the questionnaire survey. Generally, qualitative research focuses on the subjective experience and perception of research subjects. The benefits of using these approaches include richness of data and deeper insight into the phenomena under study (Hancock, 1998).

3.2.2 QUANTITATIVE RESEARCH

The focus of quantitative research is on objective measures rather than subjective experience. The types of quantitative methods include (SJI, 1999):

- Experiments: These are characterized by random assignment of subjects to experimental conditions and the use of experimental controls;
- Quasi-Experiments: These share almost all the features of experimental designs *except* that they involve non-randomized assignment of subjects to experimental conditions; and
- Surveys: These include cross-sectional and longitudinal studies using questionnaires or interviews for data collection with the intent of estimating the characteristics of a large population of interest based on a smaller sample from that population.

In a quantitative approach the data is usually analysed statistically. The common

tools of quantitative research include test performance scores, physiological readings, survey responses and spectrometer readings (University of Wollongong, 2001). This data may be statistically analysed using mathematical techniques (Carrillo, 2001). In a quantitative approach the data and its analysis results may be displayed in the form of tables and charts (e.g. bar charts, line graphs, pie charts, radar diagrams, etc). The most common quantitative techniques include (OWBC, 2001):

- Personal surveys;
- Telephone surveys; and
- Mail surveys.

Table 3.1 highlights the advantages and disadvantages of each of these techniques.

Table 3.1 Advantages and Disadvantages of Different Quantitative Techniques (OWBC, 2001)

Advantages	Disadvantages
Personal Surveys	
• Interviewer can observe reactions, probe and clarify answers • Technique usually nets a high percentage of completed surveys • Flexibility with location and time for gathering information • Allows for good sampling control	• Costly • Time consuming • May contain interviewer biases
Telephone Surveys	
• Fast • Lower cost than personal surveys • Small response bias • Wide geographic reach compared to personal surveys	• Survey length is limited • Difficult to reach busy people • Difficult to discuss certain topics • Can be expensive compared to mail surveys
Mail Surveys	
• Wide distribution and low cost • Interviewer bias is eliminated • Anonymity of respondents • Respondent can answer at leisure	• Accurate lists are not always available • Response is not necessarily representative of the target population • Limited to length of survey • Not timely • Clarifying and probing of answers is not possible • Question order bias • Unable to guarantee a specific total sample

3.2.3 QUALITATIVE VS. QUANTITATIVE RESEARCH

The advantage of a qualitative approach is that a wealth of detailed information about a specific event is produced. According to Myers (2004), although this increases the understanding of the cases and situations studied, it reduces the possibility of generalising findings. On the other hand, using a quantitative approach it is possible to

measure the reactions of many people to a limited set of questions, thus facilitating comparison and statistical aggregation of data. A broad, generalised set of findings result from such a quantitative approach. The main characteristics of qualitative and quantitative research methods are included in Table 3.2.

Table 3.2 Characteristics of Qualitative and Quantitative Research (Adapted from Key, 1997).

Point of Comparisons	Qualitative Research	Quantitative Research
Focus of research	Quality (nature, essence)	Quantity (how much, how many)
Associated phrases	Fieldwork, ethnographic, naturalistic, grounded, subjective	Experimental, empirical, statistical
Goal of investigation	Understanding, description, discovery, hypothesis generating	Prediction, control, description, confirmation, hypothesis testing
Design characteristics	Flexible, evolving, emergent	Predetermined, structured
Sample	Small, non-random, theoretical	Large, random, representative
Data collection	Researcher as primary instrument, interviews, observations	Inanimate instruments (tests, questionnaires, surveys, computers)
Mode of analysis	Inductive by researcher	Deductive (by statistical methods)
Findings	Comprehensive, holistic, expansive	Precise, narrow, reductionist

3.2.4 TRIANGULATION

Another research method is triangulation, which involves the use of both qualitative and quantitative approaches. Using the triangulation method, theories can be developed qualitatively and tested quantitatively (Khalfan, 2001). Triangulation increases the validity and reliability of the data, since the strengths of one approach can compensate for the weaknesses of another (Sunyit, 2004). Triangulation in research refers to the combination of two or more theories, data sources, methods, or investigators in one study of a single phenomenon to converge on a single construct.

3.3 ADOPTED RESEARCH METHODOLOGY

Given the industrial context of this project the research methodology evolved as the project progressed. The primary aim of the project as stated in Section 2.2 is evaluate the business process implications of adopting e-commerce in construction organisations. Several objectives were defined to meet this primary project aim. These objectives gave a clearer perspective on how the project would be approached and defined the project scope.

The very nature of this project meant that right from its onset a number of approaches needed to be adopted to meet the goals of individual project objectives. This was necessary because the early stages of the project reviewed e-commerce on a broader scale (across-industries); the focus was then narrowed down to the construction industry. As the project progressed, the research concentrated on specific e-commerce applications and their impact on end-user business processes. Thus, a 'whole to parts' approach, that combined different research methods was adopted (see Figure 3.1). Taking this into account, it becomes necessary to discuss the methodology adopted for each project objective.

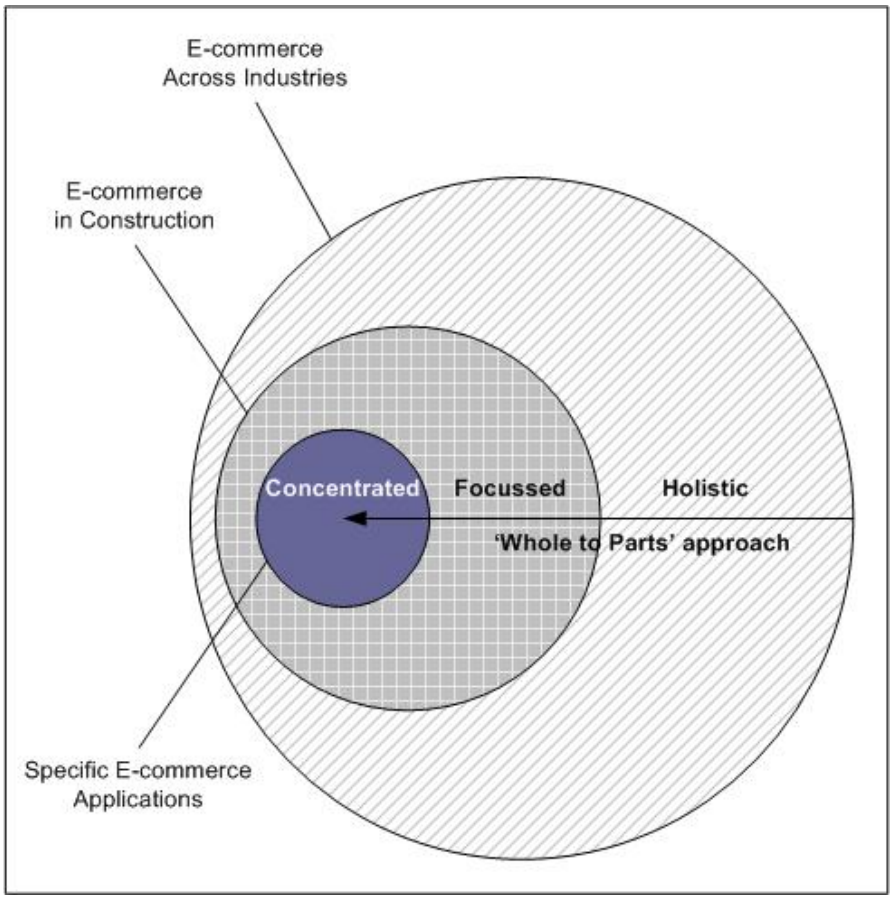


Figure 3.1 A 'Whole to Parts' Approach

The following section discusses the methodologies adopted to meet the goals of each objective. It also describes the development of the research focus through a series of Venn diagrams.

3.3.1 REVIEW OF E-COMMERCE AND CONSTRUCTION PRACTICES

The first project objective focused on exploring the concept of e-commerce in general and its particular significance in the construction industry. The areas of interest for this objective and the overlap between these areas are illustrated using a Venn diagram (see Figure 3.2). A Venn diagram identifies the major methodological and topical components that were explored and studied in the project. Each Venn square represents a specific area of interest (or study) (Schooley, 1995). Subject matter that is common to two or more areas is located at the junction of these areas, becoming a new area of interest.

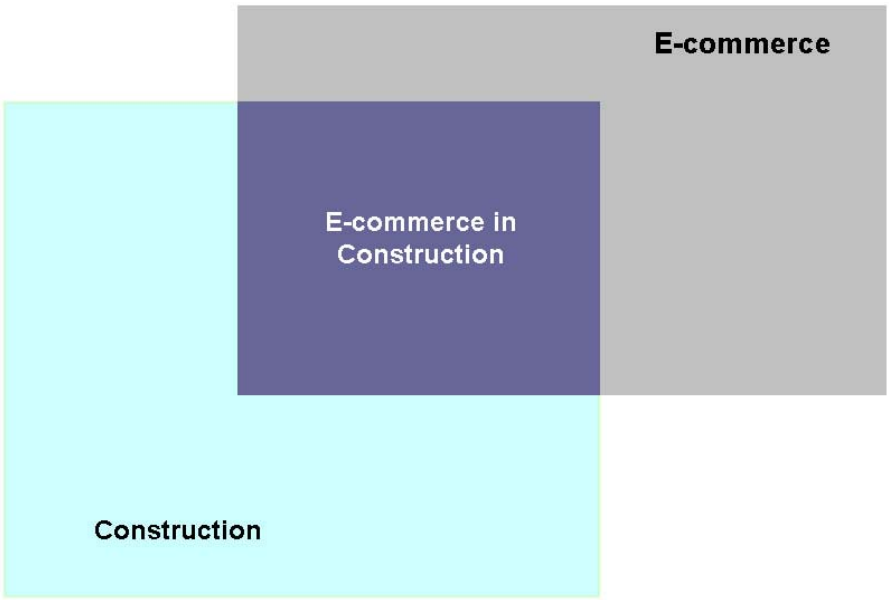


Figure 3.2 Areas of Interest for Objective One

To meet the goals of objective one, a combination of research methods were used. A qualitative approach was adopted to study the technologies and business drivers, which have contributed to the evolution of e-commerce. This was done by means of a comprehensive review of the relevant literature with information drawn from various sources including research and industry publications, the Internet, and attending e-commerce seminars and conferences. Information obtained from these sources was critically analysed. The findings were substantiated using suitable examples from within the construction sector and other industry sectors (see Paper 1, Appendix A) .

The enablers and barriers to the adoption of e-commerce were also studied and the findings were published in two research papers, a journal paper (Paper 1, Appendix A) and a refereed conference paper (Ruikar, et al., 2001). Special emphasis was given to the construction sector in order to study the current use and impact of e-commerce on the construction industry. Developments in e-commerce were reviewed, with a particular focus on its applicability and uptake within the construction sector. In addition, an assessment of the use of e-commerce within construction and its impact on the wider industry was also done, using qualitative and quantitative approaches. This involved interviewing a wide and random sample of industry practitioners and carrying out a detailed survey on use of IT and e-commerce within UK construction organisations.

The survey explored attitudes, current usage, barriers and enablers of IT and e-commerce within the UK construction sector. A detailed questionnaire was prepared using a qualitative approach based on information derived from the literature review and interviews. This questionnaire was distributed by post to a random sample of 145 construction organisations encompassing various construction disciplines including architects, engineers, contractors, manufacturers and suppliers within the UK. Analysis of the results was done using a quantitative approach where the findings were presented in bar charts and pie charts as appropriate. The findings of the survey were published in Paper 2 (Appendix B) and helped to outline ideas for more effective deployment of IT and e-commerce in construction organisations.

3.3.2 E-COMMERCE AND CONSTRUCTION BUSINESS PROCESSES

Objective two focused on investigating the existing working methods of construction companies, including their business processes. It also investigated the impact of e-commerce tools on these construction business processes. The areas of interest for this objective and the overlaps between these areas are illustrated using a Venn diagram (see Figure 3.3).

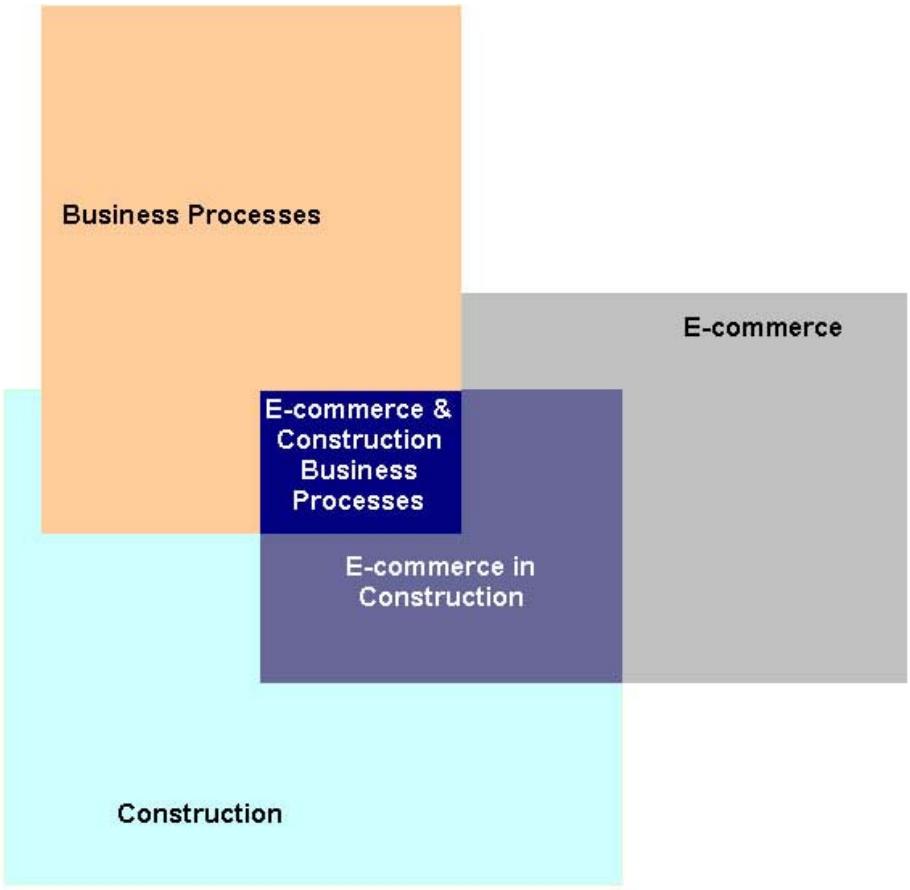


Figure 3.3 Areas of Interest for Objective Two

The goals of objective two were met using a three stage approach. The work carried out for each of these stages was done concurrently and iteratively as deemed necessary. The first stage involved a detailed case study of the e-commerce tool developed by the sponsoring organisation. The functionality and the workings of this tool were studied using a 'hands on approach'. Further, a series of discussions and interviews were conducted within the case study organisation to capture and document the perceived benefits and future usage of such tools within the construction industry.

The second stage involved studying the workings of the construction supply chain including the current methods of document exchange and communication. This was accomplished with the help of a comprehensive literature review and by attending lectures and conferences that focused on these aspects. Analysis of the data collected from these sources helped identify the shortcomings in the current construction business processes and the complexity of the existing communication and document exchange models within construction.

At the third stage an in-depth study of the concept of business process reengineering and techniques for process modelling was carried out using a qualitative approach. Relevant literature in the topic area was reviewed and lectures in the subject area were attended. The study highlighted modelling as one of the most effective techniques for understanding and communicating business processes. It was seen that in a process model, superfluous detail can be eliminated, thus reducing the apparent complexities of the systems or processes under study (TWCC, 2000). The outcome of the study conducted resulted in the development of a typical business process model annotated with opportunities for e-commerce. The processes were mapped out using the IDEF0 methodology (details of this can be found in Paper 3, Appendix C).

3.3.3 E-COMMERCE APPLICATIONS AND END-USER CONSTRUCTION COMPANIES

At this stage the focus of the study was narrowed down to specific e-commerce applications and their impact on the business processes of end-user construction companies (see Figure 3.4).

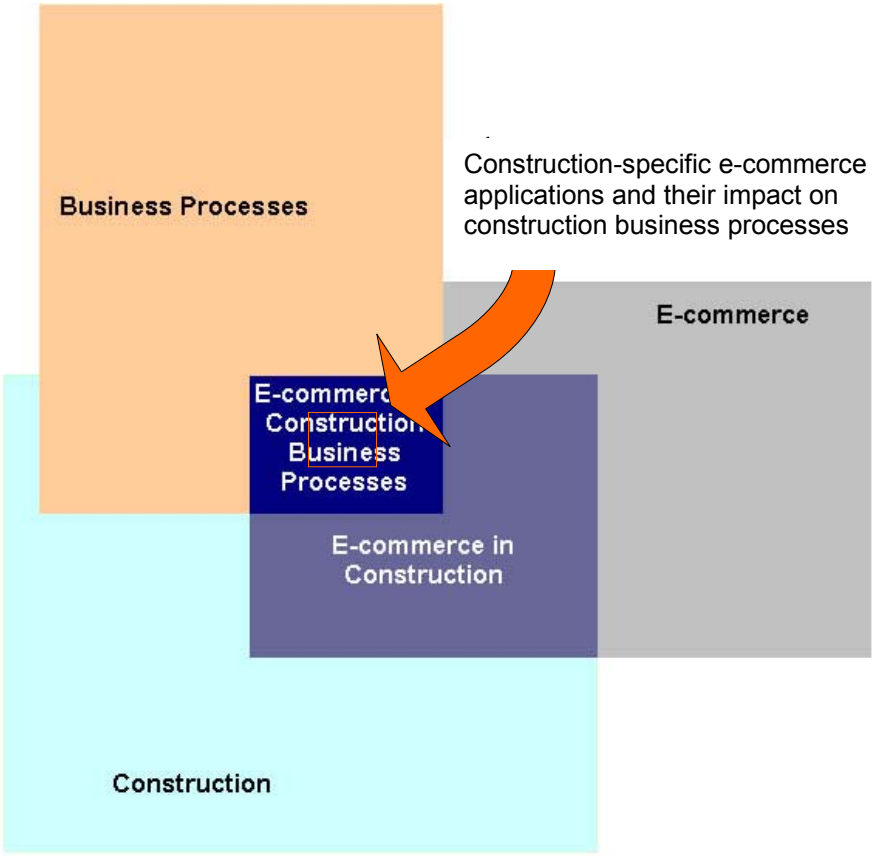


Figure 3.4 Areas of Interest for Objective Three

Two of the UK's leading, construction-specific e-commerce applications were selected for this purpose and detailed case studies were undertaken to investigate the integration of these applications into the business processes of their end-user companies. These applications were selected based on results of an UK project collaboration survey conducted by Construction Plus (Alshawi and Ingirige, 2002). The survey results indicated that one of the case study applications had the highest number of users and the other the highest capital value of projects.

With the help of the case studies, it was possible to establish the effectiveness and suitability of the applications from an end-user perspective. The case studies were carried out in the following two stages:

1. Initial Review Process, and
2. Impact Review Process.

The *initial review* process involved the analysis and detailed study of each software application developed by case study organisations. This was based on a thorough literature review of product and process information obtained from different sources within participating organisations (e.g. promotional brochures, demonstration CD's, training brochures/user guides, and hands-on usage of the application to study its functionality and working, etc). Semi-structured telephone interviews were also carried out with staff of the case study organisations in order to capture key company and product-specific information. Such information provided an insight into the background, scope, functionality, and other intricacies of each application.

For the *impact review* process, end-users of the case study applications were interviewed. This was done to assess the impact of the case study applications on their end-user business processes. A list of end-user companies was obtained from each case-study organisation. Between 3-5 end-user companies for each application were randomly selected for interviews. Telephone interviews were conducted for this purpose and each interview lasted between an hour to an hour and a half. All the interviews were semi-structured, where the main subject matter of the interview questionnaire included questions aimed at capturing information on:

- the impact of the case study applications on the traditional business processes of their end-user companies; and
- the benefits of, and barriers to the effective implementation of the case study e-commerce application.

The participants were encouraged to elaborate on topics, if deemed necessary. The interviews were recorded with full consent from the participants and the data was then transcribed and documented. Analysis of the data was done qualitatively and the findings were published in two research papers, Paper 4 (Appendix D) and another conference paper (Ruikar et al., 2004).

3.3.4 E-READINESS ASSESSMENT: MODEL AND PROTOTYPE APPLICATION

At this stage of the research project the e-readiness assessment model and the VERDICT prototype application were developed. This objective was achieved using a two-stage approach. The first stage involved development of an e-readiness assessment model for gauging the readiness of construction organisations for using e-commerce applications. Information drawn together from objectives one, two and three, was critically analysed using qualitative methods to develop a theoretical framework for this model (see Figure 3.5).

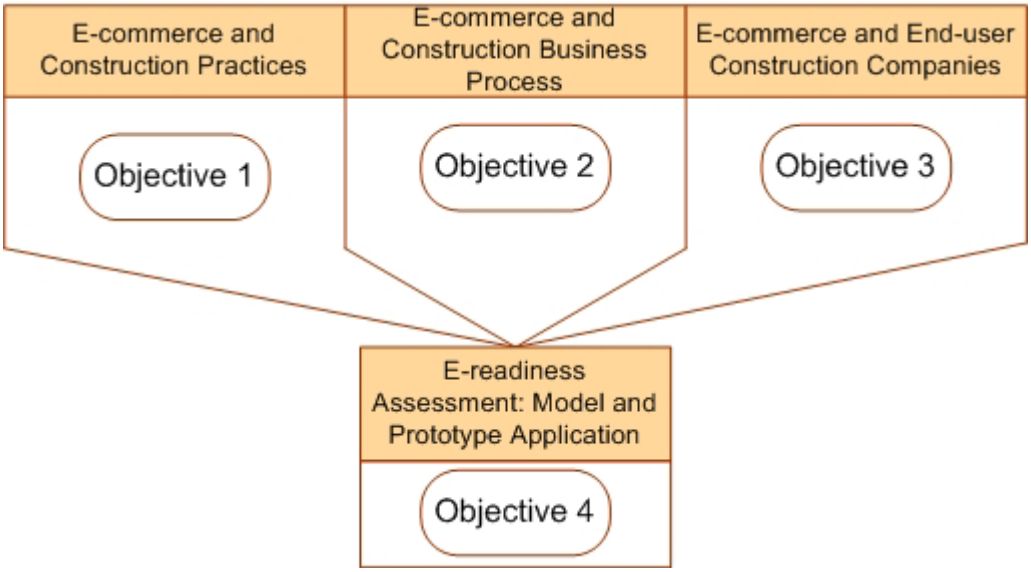


Figure 3.5 Data Input for E-readiness Assessment Model and Prototype Application Development

A triangulation methodology was adopted to measure e-readiness. Using a qualitative approach, a review of existing literature on the subject matter (i.e. readiness assessment models and tools) was carried out. The most appropriate models in the context of this research study were then adapted to develop a model that assesses the e-readiness of construction organisations. The existing processes, working methods, procedures and practices in construction organisations were also analysed using qualitative methods such as one-to-one discussions, case studies and interviews. The outcome of this led to the development of a set of questions that assess the overall e-readiness of construction organisations for adopting and implementing e-commerce technologies. Further, a quantitative approach was adopted to analyse end-user responses (by calculating cumulative and average scores) and presenting the findings graphically.

The second stage involved the development and evaluation of a prototype Internet-based application for e-readiness assessment. The development of the application was an iterative process based on the Rapid Application Development (RAD) methodology of software development. RAD is a concept that facilitates the faster development of application software (Webopedia, 2004). It is performed iteratively through several stages as illustrated in Figure 3.6.

Applications that are developed using RAD methodology are developed faster through (Whatis, 2000):

- Gathering end-user requirements from qualitative methods such as case studies and focus groups;
- Prototyping and early iterative user-testing of designs;
- A rigidly paced schedule that defers design improvements to the next product version; and
- Less formality in reviews and other team communication that run in parallel to the software development process.

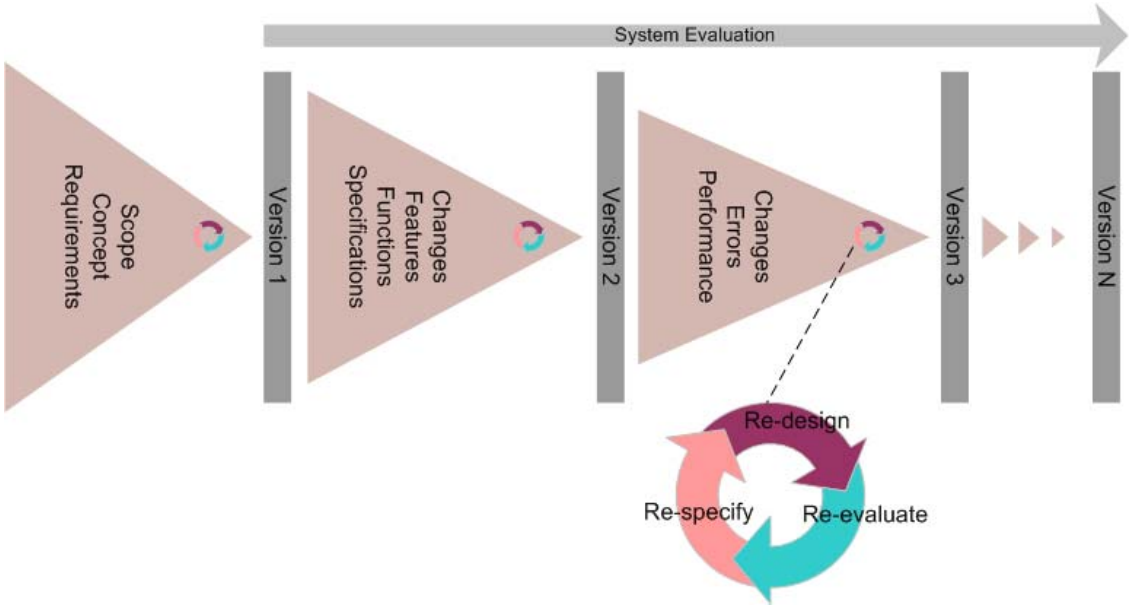


Figure 3.6 Rapid Application Development using Iterative Prototyping (Adapted from Maner, 1997)

The e-readiness prototype was evaluated using a number of methods including self-evaluation and peer reviews during the development phase and then through industry validation of the final prototype application, as follows:

- Self evaluation: The tool was continually tested for any errors which were then corrected immediately;
- Peer reviews: A carefully selected panel of researchers conducted the peer review process to test the prototype and report errors.
- Industry reviews: A random sample of relevant industry practitioners evaluated the prototype application.

Evaluation was based on the functionality of the prototype application, its user-friendliness, errors, and its relevance to its target audience i.e. construction companies. Details of the work undertaken for evaluation are included in Section 4.5.2.4 and details of the evaluation findings are included in Section 5.2.2.

3.3.5 RESEARCH SYNTHESIS

This stage involved the writing-up of the EngD thesis. This involved synthesis, analysis and interpretation of the data accrued from the four year research project (see Figure 3.7).

At this stage appropriate dissemination routes were identified for the publication of the research outputs. This involved reviewing relevant construction and IT journals and international conferences. In addition, the research was also publicised using the following routes:

- Poster presentations;
- Design and distribution of project ‘flyers’ to industry practitioners; and
- A brief industry-oriented article for the research newsletter ‘Innovation and

Research Focus'.

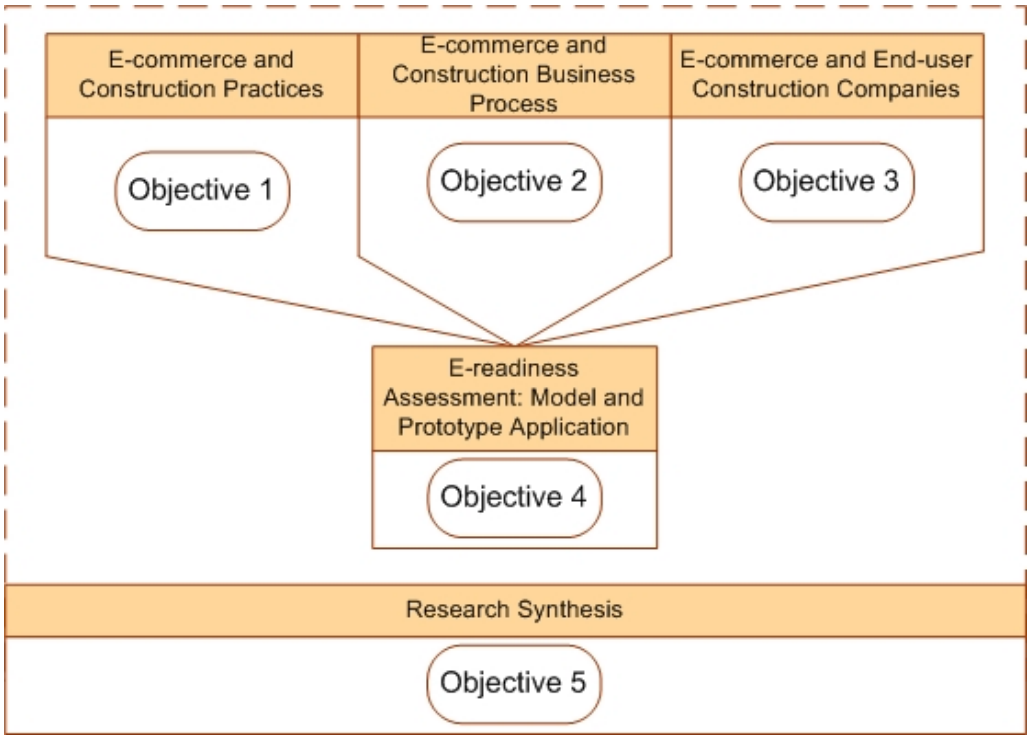


Figure 3.7 Data Input for Research Synthesis

3.4 SUMMARY

This chapter has discussed the methodology adopted for the EngD research project. It reviewed different research methodologies, and then described in detail the research methodologies adopted for this research study. The next chapter discusses the research work undertaken using these methodologies.

CHAPTER 4 RESEARCH UNDERTAKEN & RESULTS

4.1 INTRODUCTION

This chapter presents the research undertaken to meet the aim and objectives of the EngD project that were stated in Chapter 2. The research was undertaken using the methodology described in Chapter 3. This chapter also highlights the main results of the research undertaken. Where references are made to appended papers the reader is requested to read each paper in its entirety and then return to the thesis.

4.2 E-COMMERCE AND CONSTRUCTION PRACTICES

In the early stages of this project a literature review was undertaken to explore the concept of e-commerce both in construction and other industry sectors. At this stage the opportunities for using e-commerce in construction were also explored. This included identifying areas where e-commerce is being or can be used, and identifying the enablers and barriers for adoption of the technology (Paper 1, Appendix A). Paper 1 reviews the development of e-commerce in construction and discusses the benefits and barriers of this technology in the construction supply chain.

A review of the current use of e-commerce within the construction sector revealed that there were several areas within the construction industry that could benefit from the uptake of e-commerce solutions. The study highlighted some of the trends of e-commerce in construction (in year 2000):

- **Company Promotion**: The Internet was being used to promote companies by the dissemination of company information (e.g. information of products and services).
- **Product Promotion**: The Internet was used for the purpose of increasing product sales through online promotion.
- **E-procurement through Web Directories and Search Engines**: Several Websites provided a search tool for the user to access wide-ranging information about the construction industry. The Internet was being used as a tool to obtain information about construction related suppliers and their products.
- **Online Project Management**: The Internet was being used to manage construction projects online. Project documents and information were exchanged between project teams using online collaboration tools.
- **Online Tendering**: These services were used for submitting tenders online and providing tendering information online, along with project specifications.

At the time this study was carried out, there were several online project collaboration tools available for construction project teams. This study documented the possible benefits of, and barriers to, the use of such tools in construction and then focused on a Web-based e-commerce tool developed by the industrial sponsor, called the Project Information Channel (PIC). The PIC has since been renamed the Information Channel (IC) and will be referred to as the IC throughout this thesis.

4.2.1 BENEFITS AND BARRIERS OF E-COMMERCE TOOLS

Paper 1 (Appendix A) includes a comprehensive list of the benefits and barriers to

the adoption of e-commerce in construction. This section summarises some of the benefits and barriers.

4.2.1.1 Benefits of E-commerce

Some of the benefits of e-commerce are as follows:

- *Improved project efficiency* and *better access* to project data facilitated by an Internet-based centralised database;
- *Reduced project cost* due to savings in cost as a result of electronic document processing and delivery;
- *Reduced time wastages* as project information is delivered electronically;
- *Reduced errors* due to reduced need to re-key information;
- *Preservation of corporate memory* due to creation of a knowledge base of all project information; and
- Increased accountability and *reduced disputes* due to creation of an audit trail.

4.2.1.2 Barriers to E-commerce

Some of the barriers to e-commerce implementation are as follows:

- *Infrastructure issues* such as the technological capabilities of collaborating companies, telecommunication networks of globally dispersed construction companies, etc;
- *Trust and reliability issues* such as confidentiality, authentication, data integrity and non-repudiation; and
- *Regulatory issues* including tax and legal issues.

The findings of the literature review indicated that the use of e-commerce in construction could yield business benefits to its end-users and overcome some of the problems associated with the traditional methods. But, at the time this research was undertaken it was found that the trends in the market were mixed. On the one hand there were construction companies that offered purely electronic online services for tasks such as finding jobs and doing e-business while, on the other hand, there were those who had yet to accept and consider the Internet as an alternative to the traditional, tried and tested methods of carrying out business. Clearly, more needed to be done to encourage the construction industry to adopt and benefit from e-commerce. According to Russell (2000) the critical element was getting people to understand and buy into the system.

4.2.2 INDUSTRY SURVEY

An industry-wide survey was conducted to identify the current use of IT and e-commerce within the UK construction sector. It was thought vital that the barriers, enablers and the potential of using technologies such as e-commerce were identified, examined and analysed from an industry-perspective. This would help to make recommendations for the effective uptake of these technologies within the construction industry. This survey was carried out in the first half of 2001 and the primary objectives of this survey were:

- To establish the readiness of UK construction industry to adopt IT and e-commerce technologies; and
- To identify the barriers and enablers to the implementation of these technologies in the day-to-day construction processes.

The survey questionnaire occupied four sides of A4 paper (Appendix F). Paper copies of the survey questionnaire were distributed by post to a random sample of 145 construction organisations encompassing various construction disciplines including architects, engineers, contractors, manufacturers and suppliers within the UK. The overall response rate for the survey was 22%. The results of the survey were analysed and the findings were presented in a technical paper (Paper 2, Appendix B).

The survey results indicated that:

- There was a considerable usage of IT applications in the day-to-day working of most UK construction organisations;
- The level of IT investments largely depended on the size of the organisation (i.e. larger organisations had greater IT investments);
- E-commerce tools were still in the early stages of implementation in most construction organisations;
- There were very few performance measurement tools available to quantify the benefits of e-commerce;
- Most respondents were unsure of the exact benefits of e-commerce to their respective organisations;
- Issues related to Internet security and a lack of standards for information exchange across networks, were identified as the two main barriers for using e-commerce;
- Although security issues were considered as a top priority at cross-disciplinary level, these were not viewed as a high priority in IT implementation, which is usually within the organisation itself;
- Cultural issues, associated with the transition from traditional methods of working to the use of new tools, were seen as a major barrier; and
- Other issues associated with using the Internet, such as the invasion of privacy and unsolicited mail were not seen as major deterrents for e-commerce adoption.

The survey findings also showed that a common industry view was that the future of e-commerce in construction was still quite unclear and that the objectives for using e-commerce technologies in construction had not been clearly defined. This may have been due to the lack of a well-defined business process model that integrated e-commerce with the existing infrastructure of construction companies. In order to adopt IT and e-commerce strategies into the day-to-day working of construction projects, companies would have to radically alter their traditional processes of managing construction projects and also the ways in which project partners collaborate and communicate with one another. Based on these survey findings the following recommendations were made:

- There was potential for conducting future research in the development of business strategies for the adoption of e-commerce, including the most appropriate e-commerce business model(s) for the construction industry;

- Construction organisations needed to explore the new opportunities offered by e-commerce and re-engineer their business process to maximise the benefits;
- Changes in the construction business process due to the adoption of IT and e-commerce needed to be continually monitored and documented to develop a best practice strategy; and
- More e-commerce performance measurement tools needed to be developed as the technology usage matured.

Based on the literature review and the findings of the industry survey it was possible to examine and establish the current use of e-commerce within the UK construction sector. The work undertaken also helped in identifying the barriers and enablers to the adoption of e-commerce. The next section demonstrates how the findings of this part of the research work led to the development of a typical business process model that identified opportunities for e-commerce within construction.

4.3 E-COMMERCE AND CONSTRUCTION BUSINESS PROCESSES

It was evident from the research conducted that e-commerce business models had been successful in other industries (e.g. Amazon.com in the retail industry) and the resulting automated processes were faster and more efficient than their traditional equivalents. However, being a relatively new technology the exact benefits of e-commerce to the construction industry were not known. More needed to be done to establish the effects of incorporating e-commerce applications into construction business processes and to demonstrate the opportunities of e-commerce for construction.

This part of the research study focussed on developing a business process model using the principles of Business Process Re-engineering (BPR). Using this model it was possible to illustrate how, with the use of innovative e-commerce applications, different members of the construction supply chain could derive business benefits. Details of the model including the rationale and methodology are presented in a journal paper (Paper 3 , Appendix C).

4.3.1 RATIONALE BEHIND BPR MODEL

There are several online project collaboration tools available for construction project teams (Alshawi and Ingirige, 2002). The BPR model presented incorporated the use of the Information Channel (IC), one of the UK's leading collaboration tools (Construction Plus, 2001), into the construction business process. A detailed case study of the IC was conducted to study its functionality and working. The findings showed that the IC:

- Creates a hub-centric network of information and communication between project partners;
- Uses the principle of a single source for information sharing, thereby reducing the number of communication passages. For a given project, if any one of the stakeholders updates the project information, then relevant stakeholders are immediately informed of the revisions; and
- Enables easier and faster interdisciplinary communication in a secure environment through the central hub.

The IC facilitates real-time management of construction projects throughout the project's lifecycle. At the time this task was undertaken, it was proposed that the IC would incorporate a feature called I-components (intelligent components) that would facilitate the capture of 'intelligent' data during the project lifecycle. It was projected that the I-components would provide the same advantages as the IC, but in relation to the content of the documents (BIW, 2001). Being intelligent components, the I-components could learn about themselves as the project progresses. They could also be programmed to know what they are, where they are and how they should respond to their location in space, functional area or perhaps what they are connected to, for example, a door. It was also foreseen that the I-components could support the use of construction modelling systems by allowing users to exchange design components for the manufactured equivalents that contractors actually purchase – and therefore test for fit/clashes (BIW, 2000).

4.3.2 BUSINESS PROCESS RE-ENGINEERING FOR E-COMMERCE

Continuous demand for better performance and quality of services and products from customers and clients forces industries to continually improve their work methods (ProSci, 2001). This, in turn, leads to improved business processes. At a very basic level, business processes can be defined as a set of activities that transform a set of inputs into a set of outputs for another person or process using people and tools (ProSci, 2001). According to Greenberg (1996), the process of changing business processes is an iterative one, in which:

- Current work methods are documented;
- Customer/client expectations are recognised as a means to measure the process effectiveness;
- The process is performed and the process results measured against set standards;
- Improvement opportunities in the process are identified based on the data that has been collected; and
- Improved process is implemented and its effectiveness against the set standards is measured.

Such an iterative process can be repeated to achieve continuous process improvement and referred to as business process improvement or functional process improvement. Such methods for improving business processes can be effective in obtaining gradual, incremental improvement (ProSci, 2001). With the advent of new technologies such as the Internet there has been a need to change work methods in much shorter periods and companies require dramatic business process improvements rather than just incremental changes. Modern day technologies are rapidly bringing new capabilities to businesses, thereby raising the competitive bar and the need to improve business processes dramatically (ProSci, 2001). One such approach for rapid change and dramatic improvement that emerged was BPR.

According to Hammer and Champy (1993) BPR is, 'The fundamental rethinking and radical redesign of business processes to bring about dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed'. BPR can be facilitated through the use of business process mapping tools. One such tool that is used is the IDEF0 methodology.

4.3.2.1 Business Process Re-engineering Using IDEF0 Methodology

IDEF0 is an acronym for Integration DEFinition language 0, a function modelling language that is based on SADT (Structured Analysis and Design Technique) developed by Douglas T. Ross and SofTech, Inc. (Ward, 2001). Application of IDEF0 method of process modelling to a system such as the construction business process results in a hierarchical series of diagrams, text, and glossary cross-referenced to each other. The two primary modelling components are functions (represented on a diagram by boxes) and the data and objects that inter-relate those functions (represented by arrows). The diagrammatic representation of IDEF0 methodology can be seen in Figure 4.1.

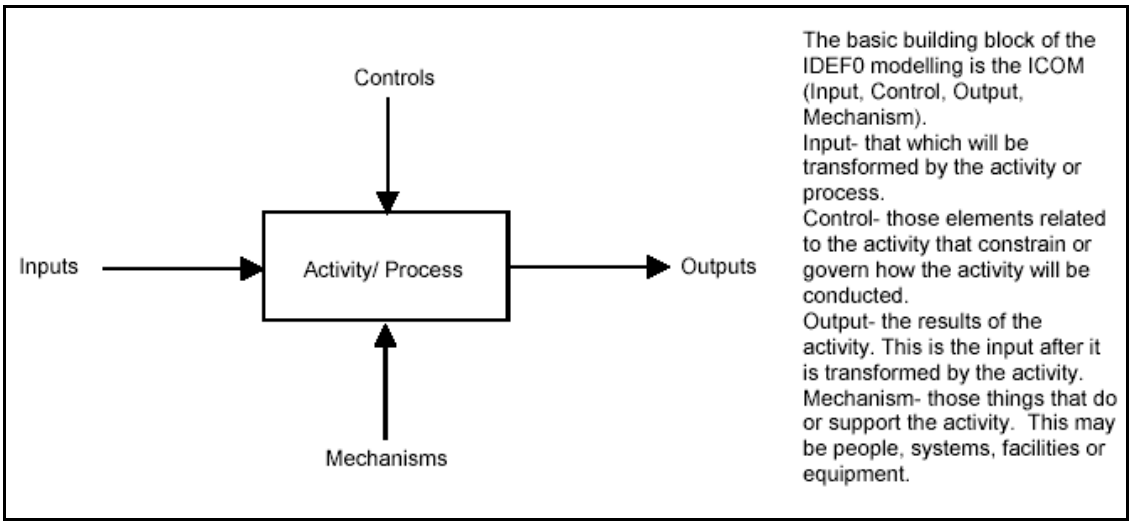


Figure 4.1 IDEF0 Notation (AIT, 1995)

4.3.2.2 A Typical Business Process Model

At this stage a typical business process model was proposed with the aim of providing an insight into how the current working of the construction supply chain could be better managed using the IC (refer to Paper 3, Appendix C). The model presented was decomposed into six levels. These six levels were:

- Node IC/A0: This was the context diagram and represented the top-level process that gave a generic view of managing the construction project;
- Node A0: This diagram represented the process for the management of project drawings;
- Node A2: This diagram represented a specific process of managing project architectural drawings;
- Node A25: This process diagram proposed the method of finalising architectural drawings;
- Node A253: This process diagram represented the selection process of the product supplier (in this case the door supplier); and
- Node A2535: This process diagram described a specific product ordering process (i.e. door ordering process) using the IC.

Each of these nodes are described in detail in Paper 3, Appendix C. The following

example illustrates the opportunities of using e-commerce tools in construction processes. The example (Node A253) described is that of an innovative procurement process. Node A253 incorporates the concept of using I-components for the door ordering process.

Node A253 Product Supplier Selection Process

The process of selection of the product supplier (in this case the door supplier) requires input from the client brief, door detail drawings and documents, including the door specifications (see Figure 4.2). The first step involves accessing the door supplier's database using the IC. This database can be an online interactive database of the door supplier's services and all door related information. The suppliers can maintain their product and service data on the Internet to ensure that only accurate and up-to-date information is available. Using the IC search engine, the user can search for relevant door information that meets the required product specifications. For example, a search for a specific door type will list the door suppliers whose products match the door specified. The user can use these search results to compare the different door suppliers using criteria such as cost, quality, availability, delivery time, etc. Following the comparison process the user can carry out a process of elimination to shortlist door suppliers. Using the IC the user could also view the online catalogues from the shortlisted door supplier's Web Pages and send tenders by invitation to these door suppliers. Once the tenders are analysed, the door supplier can then selected. This entire process, being electronic, can be documented to form a part of the project audit trail document.

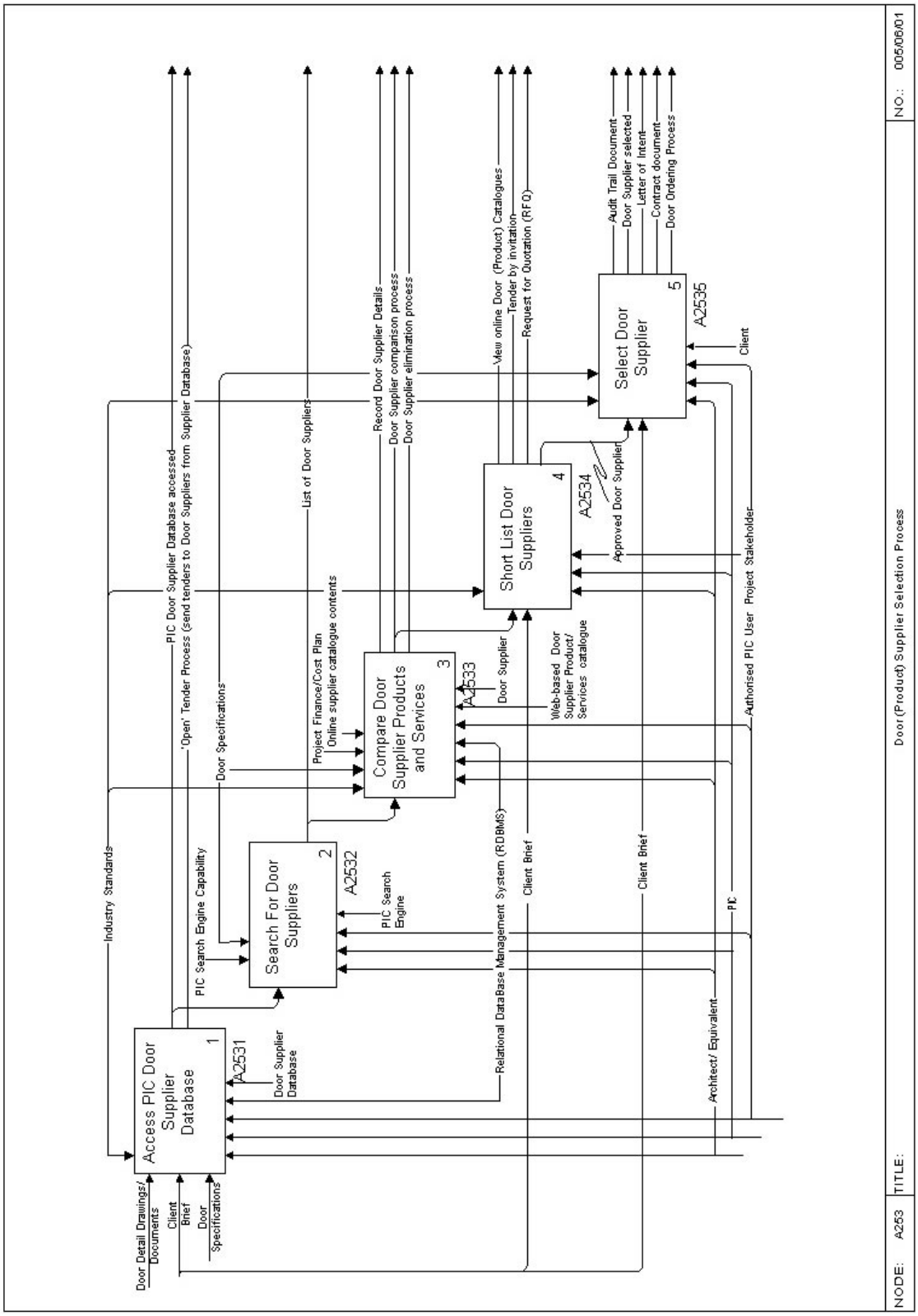


Figure 4.2 Door Supplier Selection Process

The suppliers who advertise their products on this system (the Information Channel) can easily update their product information. Such information can include product specifications that are defined by the product class and also information such as the cost of the product, its availability and quality assurance (See Figure 4.3).

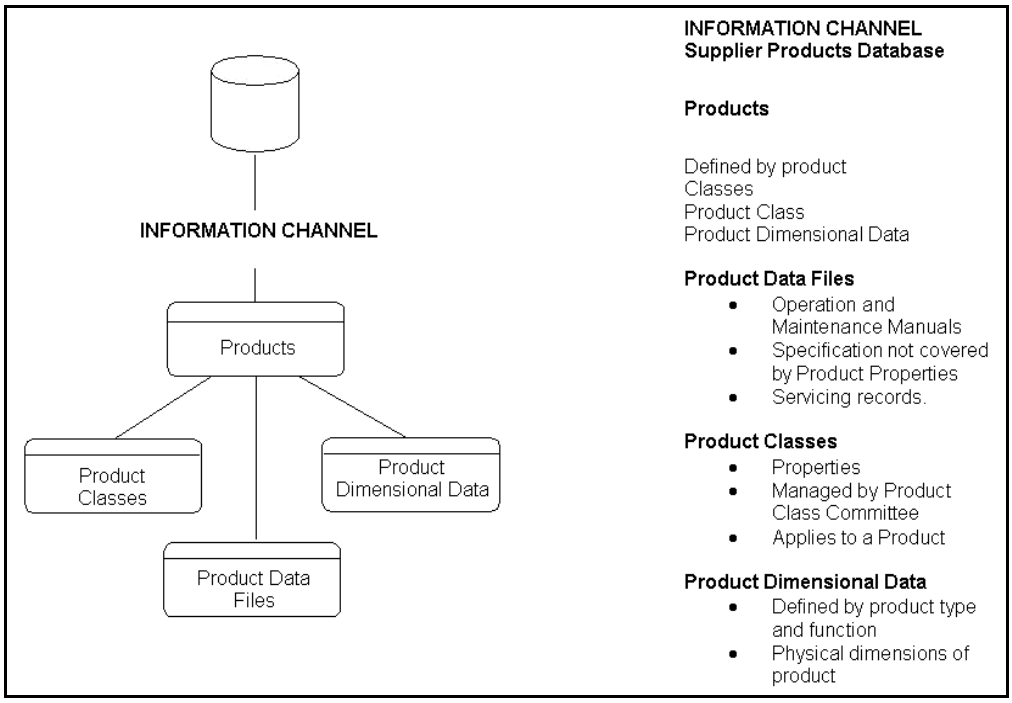


Figure 4.3 Supplier Products Database

For a given product, the typical classification can include product dimensions, finishes, physical properties, its chemical composition and its use. The information stored on such a system will not only be of use to the company that supplies the product, but also the end user who can access accurate, updated product information as and when required. For example, the quantity surveyor (QS) can have a better chance of getting an accurate schedule of elements that are required in the construction project itself and he/she can obtain input for the bill of quantities straight out of this supplier's database. The door (product) suppliers would benefit from such electronic methods of carrying out business transactions as they can keep track of door orders and better manage their inventory. The product sales can be improved by monitoring and co-ordinating the sales inventory and financial data. Such data can help the management with a complete picture of the company's operations on a day-to-day basis. Suppliers can get access to the product and order information and establish product popularity and investigate which products appeal to the users and why.

This re-engineered business process helped in highlighting the possible benefits and opportunities of e-commerce tools to the different stakeholders within the construction supply chain. These benefits are discussed in detail in Paper 3 (Appendix C). This part of the research study concluded that for construction companies to avail themselves of the benefits of e-commerce they would have to radically alter the traditional processes of managing construction projects and the ways in which project partners collaborate and communicate with one another. Doing so would lead to fundamental changes in the way construction projects are managed and executed. It was therefore necessary to study the impact of specific e-commerce applications on their end-user business processes.

4.4 E-COMMERCE APPLICATIONS AND END-USER CONSTRUCTION COMPANIES

This part of the research focussed on conducting case studies to assess the

impact of specific e-commerce applications on their end-user business processes. Research undertaken had shown that, following the examples of other industry sectors, a small but increasing number of construction organisations were beginning to adopt supply chain management (SCM) to improve their performance and address the adversarial inter-organisational purchaser-supplier relationships and fragmented processes (Saad, et al., 2002). In the past few years, the UK construction industry has witnessed the emergence of a number of Web-enabled software tools to monitor, control, manipulate and store project information and to make them available to all participants in the construction supply chain (Alshawi and Ingirige, 2002). According to one research study (ITCBP Intelligence, 2002), the UK construction industry was warming to such new developments and had realised that the key challenge was not whether e-commerce was here to stay, but how the construction organisations could exploit its power to their benefit.

The findings of the research conducted to develop the typical business process model (Section 4.3) showed that in order to effectively adopt e-commerce technologies in construction, companies would have to re-engineer their current work methods. This would lead to a step change in current work practices. To facilitate such a step change it was thought essential to study and document the impact of specific e-commerce applications on their end-user business processes. Very few end-user companies already using e-commerce tools have documented and disseminated information about the implications of using this technology in terms of the impact on their businesses, benefits incurred and possible drawbacks. Wider dissemination of this knowledge can encourage more construction companies to adopt those e-commerce technologies which have a proven record of success on projects for which they have been used.

As stated in Section 3.3.3 (Chapter 3), two construction-specific e-commerce applications (Products A and B) were selected for case studies. Detailed case studies were undertaken to:

- Investigate the integration of the identified e-commerce applications into the business processes of end-user companies;
- Examine the impact of these applications on the traditional business processes of the construction end-users and their supply chains; and
- Establish the effectiveness and suitability of these applications in terms of their benefits and barriers.

4.4.1 INITIAL REVIEWS OF CASE STUDY APPLICATIONS

In the initial review process Products A and B were reviewed for their scope and functionality using the methodology stated in Section 3.3.3. This provided an insight into the background, scope, functionality, and other intricacies of each application and helped to capture key company (ASP) and product-specific information. The next section gives a brief overview of Products A and B and illustrates with an example, the impact of these on the traditional construction processes.

4.4.1.1 Product A Overview

Product A is an online project collaboration tool with the help of which construction industry professionals can collaborate with other project partners using Web technologies during construction projects. It enables the online exchange of information and documents between construction project partners, including concept drawings, specifications, feasibility studies, detailed design drawings, fabrication drawings,

structural design drawings, Operations and Maintenance (O & M) documents, Health and Safety (H & S) records, etc.

The framework of the application is such that it facilitates the management of construction projects and provides structured access to all project and project-related documents/information. It generates a permanent database of all project information that includes drawings, revisions, comments made to prompt such revisions, documents, meeting minutes, progress on site, site photographs and all other project-related data. Using Product A, members of the construction supply chain can communicate and archive information (records of what was done, when, by whom, etc.) throughout the lifecycle of a construction project.

The following section discusses the impact of Product A on the traditional process.

Impact of Product A on the Traditional Process

This section examines the impact of Product A on the traditional construction processes. It does so through an example of the typical processes between an architect's office and the structural design office (see Figure 4.4).

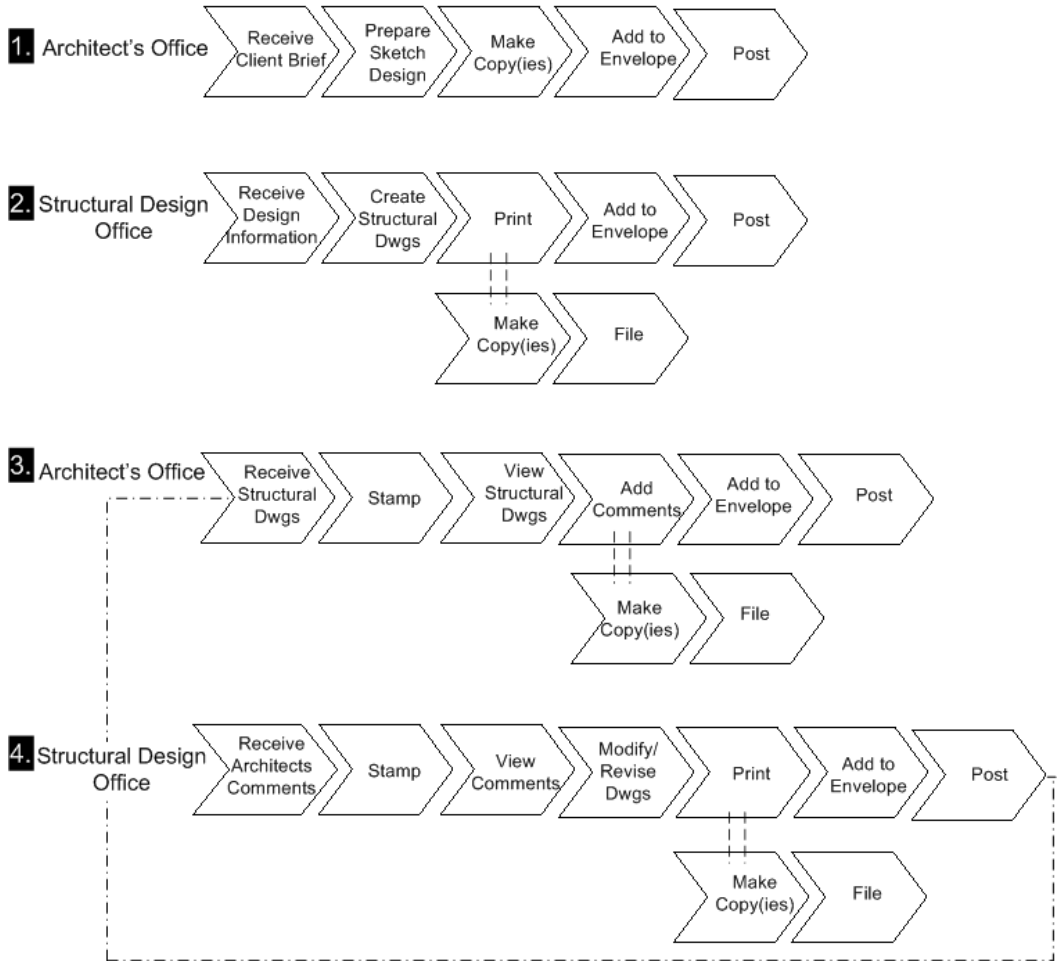


Figure 4.4 Traditional Processes

For a given construction project, typically the architect prepares sketch design drawings using client's brief, project specifications and other relevant documents. Paper copies of these documents are filed in the architect's project file and also posted

to the structural design office. On receiving this design information (that includes the design drawings and other relevant documents) from the architects office, the structural engineer prepares structural design drawings, prints copies of these, files a completed drawing set for record purposes and posts the other(s) to the architect's office for comments/approval. These structural design drawings are stamped on receipt and then viewed. If these structural drawings are found satisfactory they are accepted and the process can move to the next level (i.e. the preparation of detail drawings). However, comments may be added and changes suggested. Copies of the red-lined documents are kept for record purposes and also sent to the structural design office for corrections/modifications. This process is iterative and is repeated till the design is finalised. Similar iterations are involved in the processes between the structural design office and the steelwork fabricator. Thus, the resulting process is complex and time-consuming. Also, reliance on a third party (such as postal, courier services, etc) results in delays and affects the overall project cost, timescale and budget. This kind of one-to-one correspondence between different project stakeholders makes the project communication network very complex. Using Product A the traditional process can be considerably simplified (see Figure 4.5).

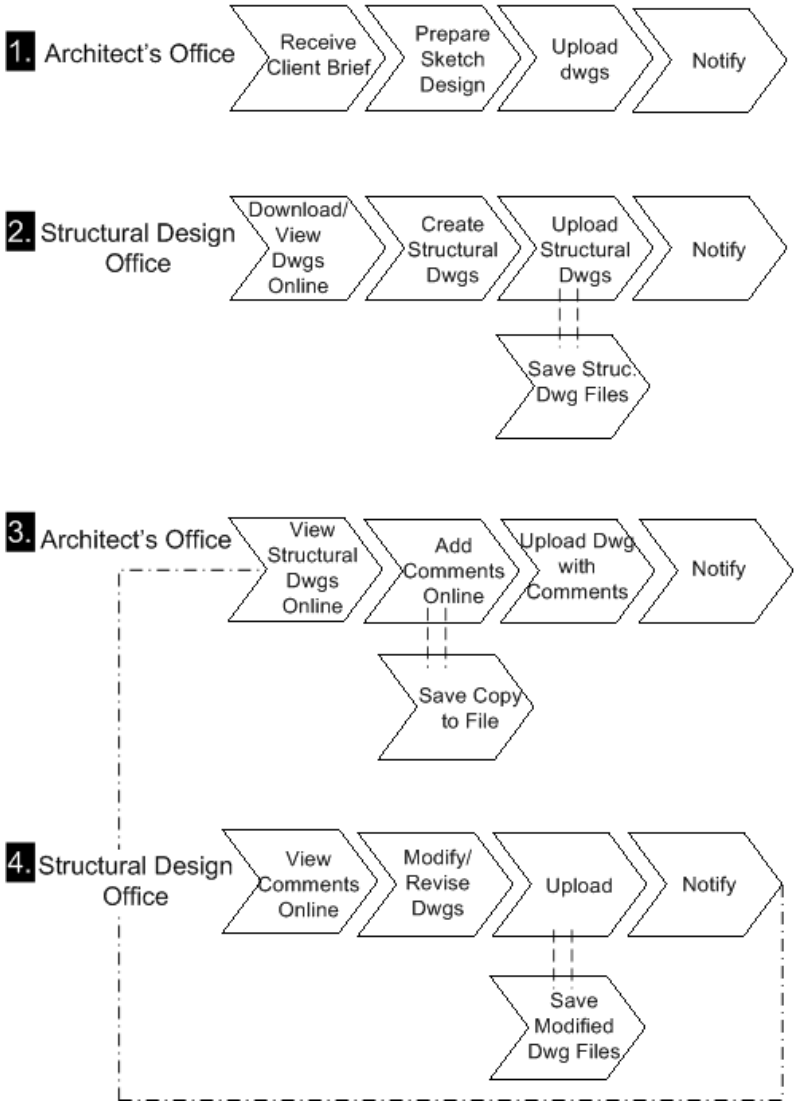


Figure 4.5 Modified Processes using Product A

Project drawings and documents can be uploaded onto the main server, where a permanent/secure database of project information is maintained. Relevant construction disciplines can then be automatically (and instantly) notified and invited to hold online discussions, comment online or respond to comments made by others. The resulting process (as demonstrated in Figure 4.5), while being much more efficient, can provide financial and time benefits to the end-users. A study carried out by an international construction management and consulting firm indicated that using Product A their firm had achieved approximately 2% savings in printing and postage costs for a £5m construction project.

4.4.1.2 Product B Overview

Product B is an Internet-based supply chain solution that facilitates online trading and material procurement by automating construction trading processes such as sourcing, procurement, administration of plants and materials, etc. Using Product B, documents such as purchase orders, invoices, despatch notes, etc, can be exchanged online between different supply chain partner applications within a secure environment. It provides back office integration with bespoke applications used by different members of the construction supply chain. Also, different applications using different document formats use the central database to send and receive trading documents to/from other end-user disciplines. The central database converts the data into the data formats of the sender or receiver, to enable seamless document exchange across end-user disciplines.

The following section examines the impact of Product B on the traditional trading processes.

Impact of Product B on the Traditional Process

A typical materials ordering cycle using traditional methods, may involve the main contractor sending out a paper-based Purchase Order to the materials supplier. On receipt of this Purchase Order, the materials supplier would acknowledge the order, create an invoice manually and send a printed copy of this paper invoice to the main contractor by post. On receipt of the invoice the main contractor would stamp it with the date the invoice was received. The invoice would be then checked against the Purchase Order details and goods received. If the contractor is satisfied with the goods received a payment is made and the invoice filed away. This traditional trading cycle involves several intermediary processes or *layers*. Figure 4.6 illustrates the various processes involved at the sender and receiver-end of the trading cycle.

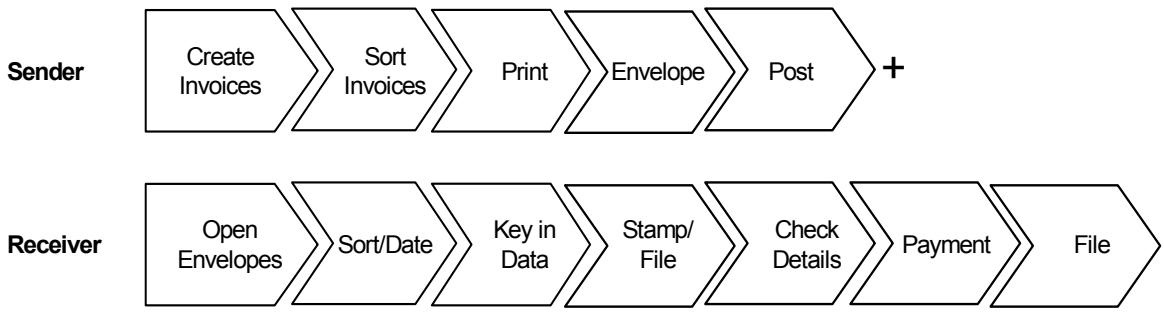


Figure 4.6 Traditional Construction Trading Process

Using Product B, the traditional trading process can be considerably simplified either by removal, modification or substitution of intermediary processes with new

processes. Using this application the sender can create an electronic invoice and transfer it via the Internet to the receiver. Given the electronic nature of the invoice, no time is wasted in re-keying data or filing the invoice. This simplified trading process also cuts out the need to print and post paper copies of the trading documents. The resulting process, as illustrated in Figure 4.7, has benefits in terms of time, money and efficiency. A survey carried out by a leading finance corporation to measure the cost benefits of using Product B showed savings of over 60% on invoice processing. This same survey also showed that while the traditional construction trading cycle takes 8 days (from creating invoices to making final payments and filing), using Product B it takes 4 days for the same trading cycle. Thus a reduction in the cycle time by half and an overall cost reduction of more than half that of the traditional cost can be achieved.

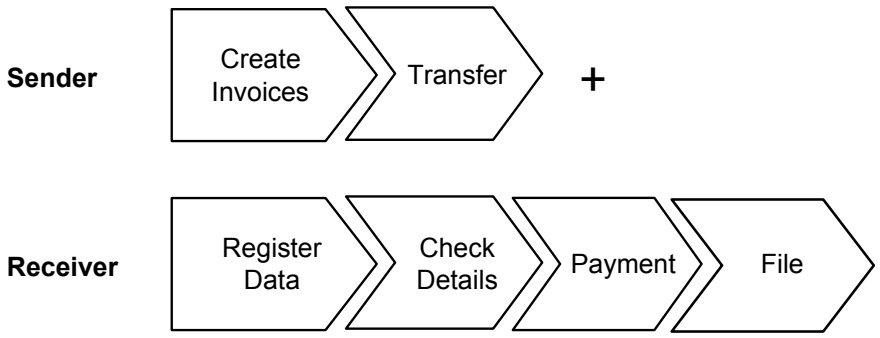


Figure 4.7 Trading Process using Product B

4.4.2 END–USER CASE STUDIES

Following the reviews of Products A and B for their functionality and working, case studies were conducted with end-user companies. Management level staff (such as senior project managers, IT managers, etc) from each of the end-user companies were interviewed using semi-structured telephone interviews. The interviews were based on a comprehensive questionnaire aimed at capturing end-user processes 'before and after' using the e-commerce applications, drivers for e-commerce adoption, their reasons for engaging in e-commerce, skills (IT and others) required by staff to operate such tools, benefits of the tools, their limitations and future improvements. The detailed questionnaire is presented in Appendix F. The companies interviewed, were from a list of end-users provided by the ASPs (Application Service Provider). An overview of the end-user companies, including the size of the company, number of employees, and the type of organisation is included in Table 4.1.

Table 4.1 Overview of Product A and B End-user Companies

	End-user Company (EuC)	**Size of Company**	**No. of Employees**	**Type of Organisation**
Product A	**EuC 1**	Large	>500	Q.S. & Project Management
	EuC 2	Large	>500	Contractor and Facilities Management
	EuC 3	Large	>500	Contractor and Property Development

	EuC 4	Large	>500	Construction Management
	EuC 5	Small	25	Architecture and Interior Design
Product B	**EuC 6**	Large	>500	Contractor
	EuC 7	Large	>500	Contractor
	EuC 8	Large	>500	Supplier

The results of these case studies are discussed in the next chapter and are also presented in detail in Paper 4 (Appendix D).

The case study findings showed that end-user companies had accrued benefits in terms of improved project performance through process automation. E-commerce technologies facilitated the construction process and increased the probability that the project would meet its target cost and time schedule. These business benefits as demonstrated by the 'early adopters' (such as the case study organisations) can act as drivers for the adoption of such technologies amongst 'late adopters' within the construction industry. Most end-user companies identified issues related to management buy-in and cultural issues as the main barriers to the ubiquitous use of this technology within the construction industry. Companies need to address these issues, amongst others, to derive maximum benefits from innovative technologies such as e-commerce. The following section addresses these issues through the development of an e-readiness assessment model and prototype application for construction organisations.

4.5 E-READINESS: MODEL AND PROTOTYPE APPLICATION

The work done for the earlier objectives showed that although the use of e-commerce tools was on the increase, this was still not ubiquitous within the construction sector**.** The early adopters had realised the potential from the use of e-commerce in the construction sector and had benefited from the implementation of this technology. It was the industry view that this technology is here to stay. As stated in Chapter 1, the implementation of any new technology such as e-commerce for achieving business targets, requires major changes in an organisation, its current practices, systems, processes and workflows (ITCBP Intelligence, 2003). The right strategies and implementation plans have to be developed, communicated and implemented. Taking this into account, construction companies who are currently using, and those who have yet to use, e-commerce tools need to take measures to successfully adopt and use this technology. It is important for companies that seek to adopt e-commerce tools to assess their 'e-readiness' for adopting e-commerce tools to ensure a productive and beneficial implementation of these tools. To address this need an e-readiness model for construction organisations and a prototype application that assess e-readiness were developed and implemented (Paper 5, Appendix E).

The triangulation methodology is adopted for the development of the e-readiness model that assess the readiness of construction organisations for e-commerce technologies, was discussed in more detail in Chapter 3.

4.5.1 READINESS ASSESSMENT MODELS

An increasing number of readiness assessment tools have been developed over the last few years. On the surface, each tool gauges how ready a society or economy is to benefit from information technology and e-commerce. However, according to

Peters (2001) different tools use widely varying approaches for readiness assessment, including different methods for measurement. Each assessment tool or model has a different underlying goal and definition of e-readiness. E-readiness can mean different things to different people, in different contexts, and for different purposes. In the context of this research e-readiness is defined as, 'the ability of an organisation, department, or workgroup to successfully adopt, use and benefit from information and communication technologies such as e-commerce'.

The different types of readiness models are discussed in Paper 5 (Appendix E). The two other readiness models that are of particular relevance to this study are the BEACON model and the IQ Net Readiness Scorecard. The following gives an overview of each:

- **BEACON model**: BEACON (**B**enchmarking and R**e**adiness **A**ssessment for Concurrent Engineering in **Con**struction) assesses the readiness of construction companies to improve their project delivery processes through the implementation of concurrent engineering (Khalfan, 2001). It consists of four elements, which are Process, People, Project and Technology. A commercial software tool has been developed to automate the process of CE readiness assessment for construction organisations. The software takes the user through a series of questions and generates a diagram called the BEACON model diagram that graphically illustrates the assessment results.
- **iQ Net Readiness Scorecard**: This was developed by CISCO and is a Web-based application that assesses an organisation's ability to migrate to an Internet Business model. It is based on the readiness theory presented in the book "Net Ready" by Hartman et al. (2000), which gauges the readiness of IT service providers. The application comprises a series of statements that fall into four categories - Leadership, Governance, Technologies and Organisational Competencies. Similar to the BEACON model, companies are required to respond to the statements and on completion, they are presented with an IQ Net Readiness Profile.

The model developed as part of this research project combines aspects of these two models and builds on them. The proposed model adopts a similar methodology where the end-users are presented with a set of statements and an assessment of their e-readiness is based on their responses. On completion, the respondents are presented with a report which includes textual and graphical data. Where the proposed model differs from the two described above is that, while the BEACON model focuses on CE and the iQ Net Readiness Scorecard addresses the readiness of technology companies (e.g. software companies, vendors and ASPs) to develop applications and profit from what is termed the "e-conomy", the proposed model assesses the e-readiness of construction organisations to adopt e-commerce technologies. The readiness assessment tool that is based on the proposed model is called, "VERDICT" (an acronym for Verify End-user e-Readiness using a Diagnostic Tool).

4.5.2 VERDICT

VERDICT is an Internet-based prototype application that assesses the overall e-readiness of end-user companies and profiles the companies in this regard, based on their responses. The name, 'VERDICT' reflects the overall aim and purpose of the application. It can be used to assess the e-readiness of construction companies, department(s) within a company, or even individual work groups within a department.

4.5.2.1 The VERDICT Model

Several research publications (Basu and Deshpande, 2004; Goolsby, 2001; IBM, 1999; and Kern, et al., 1998) and articles (Fuji Xerox, 2003; Larkin, 2003; and Emmett, 2002) indicate that people, processes and technology are the three key aspects that need to be considered for successful implementation of technologies. Emmett (2002) states that together these three elements create business value. However, he further states that *"the people, processes, and technology need a leader"*, just as *"an orchestra needs a conductor"*. Emmett, draws a parallel with the performance of an orchestra and states,

" in an orchestra….You've got musicians (people), musical scores (process), and musical instruments (technology). But without a conductor, they're more likely to produce noise than music. Even if everyone in the string section plays the right notes at a relatively similar tempo, creating a symphony requires more than following the sheet music." Therefore *"…..An orchestra needs a conductor"*

The same analogy can be applied to the adoption and implementation of new and innovative technologies within construction companies. The "conductor" in this case is the management. To successfully implement and use any new technology it requires management buy-in and belief in order to plan and drive policies and strategies. The research findings from an industry-wide survey (Paper 2, Appendix B) and case studies (Paper 4, Appendix D; and Ruikar, et al., 2004), complement this view. The adoption of any new and innovative technology (e.g. e-commerce) within an organisation, department, or work-group requires total commitment from the management (or group leader). It is important for the management to buy into the technology so that they can lead the business into successfully implementing and adopting the technology, i.e. the management needs to be e-ready. Thus a fourth category, "management" is necessary. Taking this into account, the VERDICT Model has been so structured that for an organisation to be e-ready it must have:

- *Management* that believes in the technology and takes strategic measures to drive its adoption, implementation and usage in order to derive business benefits from the technology;
- *Processes* that enable and support the successful adoption of the technology;
- *People* who have adequate skills, understanding of, and belief in, the technology; and finally
- *Technology* tools and infrastructure necessary to support the business functions (e.g. processes and people).

All four categories are considered important for an organisation to be e-ready (see Figure 4.8). A company cannot be e-ready if it satisfies the requirements of just one category and not the others. For example, even if the management, processes and people are e-ready, the fact that the technology infrastructure is inadequate will affect the overall e-readiness of the organisation. This example indicates that the company will need to address its technology issues in order to be e-ready. Drawing from the orchestra analogy, *"a memorable symphony performance doesn't happen when the players just assemble with their instruments and scores."* and, *"the orchestra with the most violinists isn't necessarily going to sound the best."* Similarly, all four categories - management, processes, people and technology - need to work hand-in-hand and symbiotically.

Figure 4.8 Four Key Elements for an E-ready Organisation

Many organisations fail to realise that if they install a system without first achieving universal buy-in and changing business processes, they will have a software installation, not an implementation of a comprehensive solution to business problems. According to Larkin (2003), if an organisation merely completes an installation by automating inefficient processes, it will not realise long-term positive impact. A successful company-wide rollout includes more than simply buying and installing software. It requires the management to align people, processes, and technology to implement a solution that meets business needs. The result is the ability to capitalize on the full potential of the technology investment. Thus, the implementation of new technology needs to be carefully managed and orchestrated. Companies should recognise that in order to successfully implement and benefit from new technologies such as e-commerce, it is essential that the *people* (who are the ultimate users of the technology) and the *process* are given due consideration. The *technology* within the company also needs to be assessed in order to ensure that the company has the necessary infrastructure (ICT infrastructure) to use existing and new or emerging technologies successfully. Furthermore, the company needs clear leadership and direction that is provided by the *management* in order to successfully implement the technology. These four categories are discussed in detail in Paper 5, Appendix E.

The next section highlights some of the aspects considered for developing the e-readiness assessment questionnaire (Appendix F). The questionnaire is divided into four sections: management, process, people and technology.

Management

Management is an important factor that leads and governs the adoption, implementation and use of technology within organisations through the careful orchestration of business strategies in order to derive definite business benefits. This

can be achieved by defining specific business strategies for technology adoption and by ensuring that adequate resources are available in terms of funds, time and man-power. It is important that the management does not lose sight of its ultimate vision and aim in using the technology (e.g. to derive business benefits). To quote Paul Nitze, a famous American diplomat and strategist, “One of the most dangerous forms of human error is forgetting what one is trying to achieve” (Hill, 2004). In business terms this can have dire consequences.

Process

It is important to consider the process factor as the adoption of new technology will directly affect an organisation’s processes and vice-versa. Therefore, companies will need to ensure that the new technology either complements their existing processes or that the existing processes are flexible enough to accommodate the technology. In order to gain maximum benefits from technology adoption (e.g. increased transparency, reduced response time and improved integration of activities across the supply chain) organisations need to examine and map their existing processes. This will help in identifying the bottlenecks and devising measures to remove such bottlenecks or process inefficiencies.

People

The people factor is important and can affect an organisation’s overall e-readiness, because the introduction of any new technology (or change) will affect the workforce within that organisation. The people factor accounts for the social and cultural aspects related to the people within an organisation. It takes into account the attitudes, outlook, and feelings of staff within an organisation towards change brought about by technology adoption. People make organisations and are important to its success. No matter how carefully the management has geared the business to successfully adopt new technology, it is less likely to succeed to its full potential, if the people are not ready. The people, who are the ultimate users of the technology, need to have the appropriate skills and competencies, functional expertise, the right attitudes, a positive mindset, and the culture to adapt and adopt.

Technology

The final category to consider is technology. The technology factor covers all aspects related to IT and communications technologies (e.g. Internet technology), which include both the hardware and software usage and its availability within a company, department or workgroup. Also important are the aspects related to the performance of the technology – thus, even if the technology infrastructure is adequate and available, it is of no consequence, if it cannot efficiently perform the required functions. Technologies such as e-commerce allow project teams to communicate and exchange data in a collaborative environment. Thus, if one company in the chain is ill-equipped, it has adverse effects on the entire chain. ‘A chain is only as strong as its weakest link.’ Thus, this is an important issue that needs to be considered in assessing e-readiness.

4.5.2.2 VERDICT - System Architecture and Operation

VERDICT is built around a three-tier architecture model (adapted from Williams and Lane, 2002). At the top level of the model is the *client tier*, which includes the Web browser software (e.g. MS Internet Explorer) that interacts with the VERDICT application. In between the top and bottom tiers is the *middle tier*, which communicates

data to and from the client and database tiers. The middle tier is contains most of the application logic. The Web server, the scripting engine and the scripts reside in this tier. The base tier of the VERDICT application is the *database tier*, which is made up of a database management system (DBMS) that manages the data that is created, added, modified, deleted and/or requested by the end-user/s.

VERDICT has been developed using PHP (Hypertext Preprocessor) as the scripting language. PHP is an open source[2], server side, HTML-embedded scripting language used to create dynamic Web pages (Webopedia, 2004).The front-end of the VERDICT prototype is designed using Macromedia Dreamweaver and Fireworks (for graphics). The application mainly consists of a series of Web-based questionnaire-forms that can be accessed by the end-user/s using standard Web browsers such as MS Internet Explorer and Netscape. Any information that is added to these forms (i.e. end-user responses) is stored in the MySQL database (situated in the *database tier*). The VERDICT system resides on a server with which the end-user communicates.

Any requests made by the end-users are communicated via the Web server. This action invokes the PHP script code embedded in the Web page to request and retrieve the data from the MySQL database. This data, returned by the MySQL database, is then processed by the PHP script. The processed data is then presented to the end-user on a Web page. A high level view of this process, which includes the operations and the system architecture of the VERDICT application are illustrated in Figure 4.9.

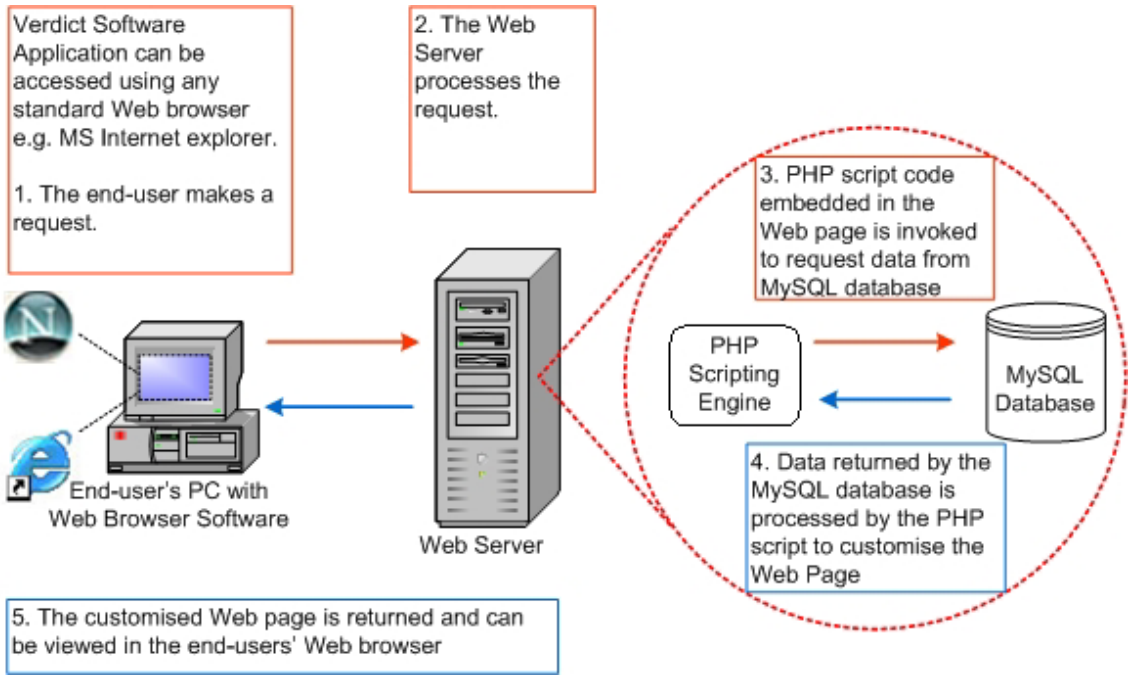


Figure 4.9 Operation of VERDICT (Adapted from Keitz, 2002)

Further details of the VERDICT architecture are included in Paper 5 (Appendix E). End-users can access VERDICT online using the Web-address: http://civil-unrest.lboro.ac.uk/cvkr. It should be noted that the VERDICT questionnaire is required to be completed by appropriate company staff e.g. senior staff with adequate knowledge of the key aspects of the organisation – management, process, people, and

2 Open source refers to a program in which the source code is available to the general public for use and/or modification from its original design free of charge (Webopedia, 2004).

technology.

4.5.2.3 VERDICT Prototype- Features and Working

The VERDICT home page welcomes the user (i.e. respondent) and displays information about VERDICT including its aim and expected outcomes. It also includes some instructions on the basic working of the VERDICT tool. Respondents are expected to read these set of instructions before proceeding to the next page i.e. the Background Information Page. This page requires user input in the areas of company information and employee information. On completion of the required fields in this page, the user begins the e-readiness questionnaire which is distributed over four pages (one page for each category.) A typical page is shown in Figure 4.10.

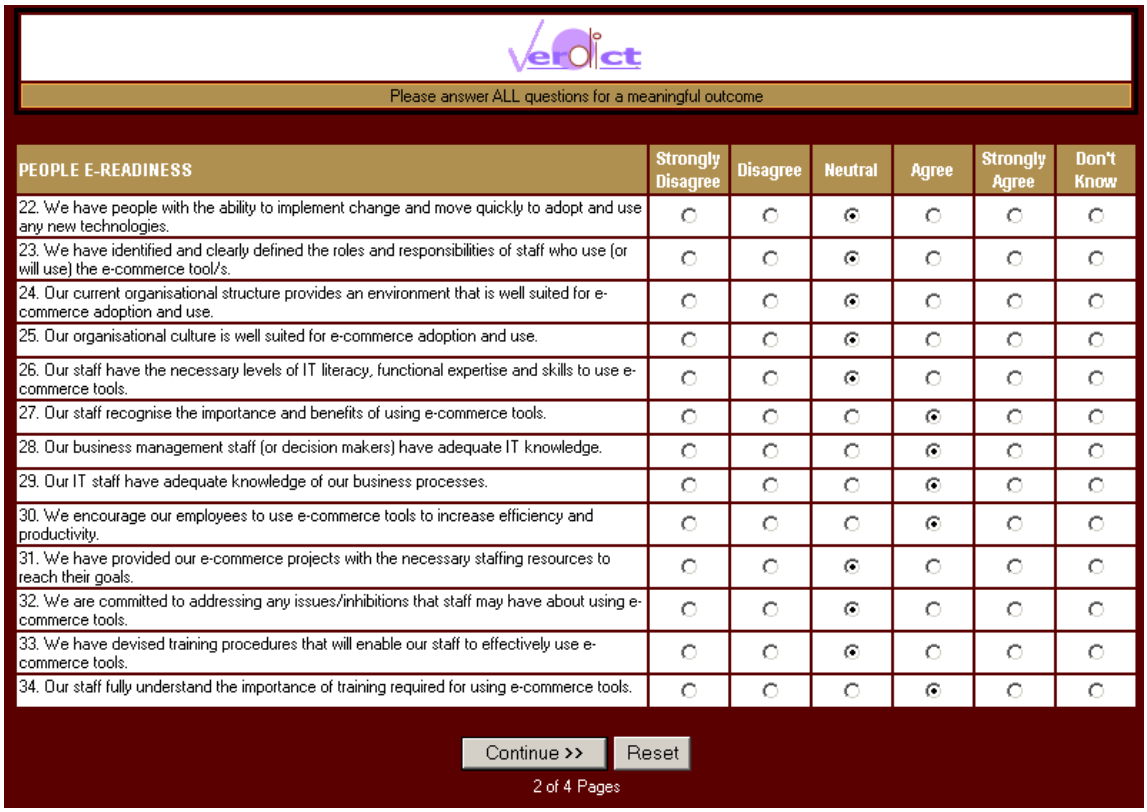


Figure 4.10 Typical E-readiness Questionnaire Page

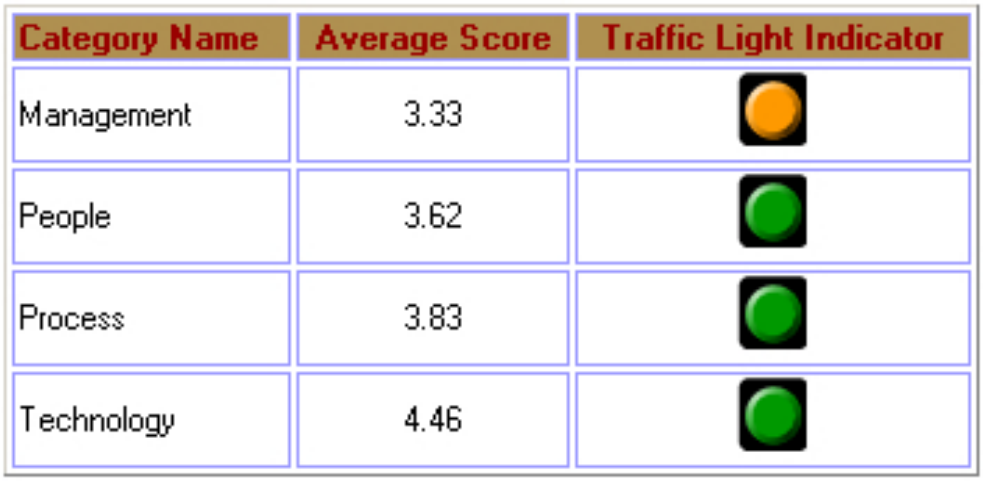
A typical questionnaire page consists of a series of statements relevant to a particular category. The end-users may either agree or disagree with these statements, to varying degrees i.e. Likert Scale. VERDICT relies on the judgement of the respondent (i.e. end-user) as to whether or not he/she agrees with the statement/s in the context of their organisation, department or work group. The respondent(s) need to ensure that their responses are consistent with their assumptions e.g. if the responses are in the context of the department (and not the organisation), then that assumption must be consistently reflected throughout. The extent to which the respondent agrees or disagrees with the statement is graded on a scale of 1 to 5, where 1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strongly Agree. A 'don't know' option is also included (where don't know = 0 score). The statements are so orchestrated that a response of strongly agree will generate the highest score of 5 points. An average score is calculated for each category. The higher the average score the more likely it is that the end-user company is 'e-ready'.

On successful completion of the questionnaire, users are presented with a report that summarises their overall e-readiness. This e-readiness assessment report includes data in textual and graphical formats and is divided into the following three sections:

- Table summarising average scores in each category (with 'traffic light' colour coding to indicate e-readiness);
- Radar diagram of overall scores in comparison to the 'best-of-breed' in the construction sector; and
- Summary of all responses highlighting areas that need attention.

Table Summarising Average Scores In Each Category

This section summarises the responses in each category i.e. Management, People, Process, and Technology and records the average score in each category (see Figure 4.11).



Category Name	Average Score	Traffic Light Indicator
Management	3.33	
People	3.62	
Process	3.83	
Technology	4.46	

Figure 4.11 Typical Table Summarising Average Scores in each Category with Traffic Light Indicators

The minimum score that can be obtained for each category equals ‘zero’ where the respondents ‘don’t know’ the answers to any of the questions, and are therefore not ‘e-ready’. The scores are averaged, and depending on the average score, the respondents are presented with ‘traffic light‘ indicators i.e. red, green and amber lights, to visually indicate their e-readiness in each category, where:

- An average score greater than or equal to zero and less than 2.5 is red. Red indicates that several aspects (within a category) need urgent attention to achieve e-readiness;
- An average score greater than or equal to 2.5 and less than 3.5 is amber. Amber indicates that certain aspects (within a category) need attention to achieve e-readiness; and
- An average score greater than or equal to 3.5 is green. This indicates that the end-user organisation has adequate capability and maturity in these aspects and therefore is e-ready (in those respects).

The choice of these boundaries is based on simple percentage scores and there is

scope for further normalising the scale once the best-of-breed is established. (For details on how the best-of-breed can be established read the following section).

Radar Diagram

Average scores obtained in each category are also plotted on a radar diagram as illustrated in Figure 4.12. A radar diagram includes 'spokes' which represent dimensions or criteria, scores on which are joined up (Chambers, 2002). This gives the respondents a visual representation of their overall e-readiness (shown in blue) in comparison to the best-of-breed in construction (shown in red). For this project, data for the 'best-of-breed' is for illustration purposes. This can be achieved by following the example of Cisco Systems (2004), who have based their 'best-of-breed' sample on information from Fortune 1000 executives.

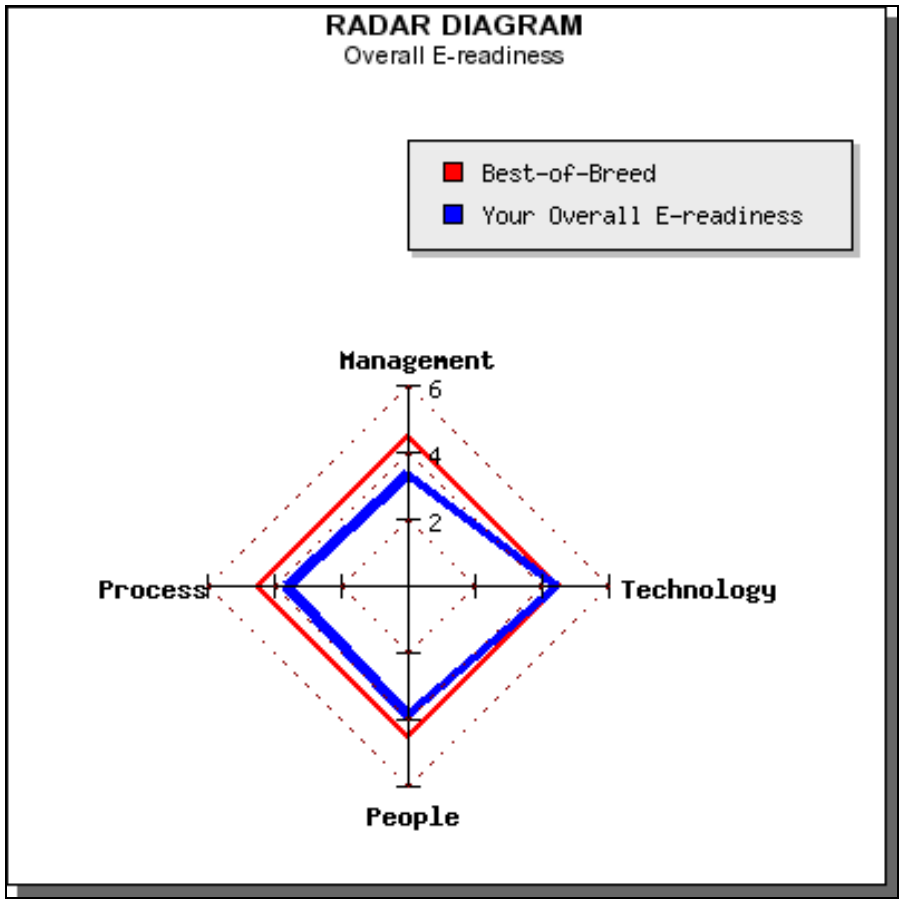


Figure 4.12 Radar Diagram Illustrating Average E-readiness of Respondent Companies as Compared to the Best-of-Breed

Summary Report of All Responses

A summary of responses to all statements is also included in the final e-readiness report (see Figure 4.13). This includes a list of all the statements included in each category and the corresponding score of each response. This summary section also highlights specific points within each category that need attention to achieve e-readiness. These are highlighted as red or amber, depending on the level of urgency. This allows companies to focus on, and improve on, those specific aspects within each category, even if they may have achieved e-readiness in that category.

Process Readiness	Your Score
35. We have analysed our current business processes.	4
36. We have identified the bottlenecks and inefficiencies in our current business processes.	4
37. Our existing processes are flexible enough to accommodate e-commerce tools.	4
38. We have designed new Web-enabled processes.	5
39. We usually work with the same companies within the supply chain.	2
40. We use email for exchanging all our drawings and documents, both internally and externally, with members of the supply chain.	3
41. We have adopted e-commerce tools to overcome current process inefficiencies (e.g. removal of redundant processes).	4
42. We have adopted e-commerce tools to automate our existing processes.	4
43. We make changes to current processes (where necessary) to facilitate the adoption of e-commerce tools.	4
44. Our use of e-commerce tools will facilitate faster and more cost-effective business processes.	4
45. Our use of e-commerce tools will improve integration of activities across the supply chain.	4
46. We have used Web-based tools to support different construction processes (e.g. procurement, project management, facilities management, etc).	4
Average Score	3.83
Technology Readiness	**Your Score**
47. We have a well defined IT policy.	4
48. We have adequate IT support (in-house or external).	4

Figure 4.13 Summary Report of All Responses Highlighting Aspects that Need Attention

4.5.2.4 VERDICT EVALUATION

The VERDICT prototype was evaluated using the methodology described in Section 3.3.4. Evaluation was based on the functionality of the prototype application, its user-friendliness, errors, and its relevance to its target audience i.e. construction companies. The evaluators were given a standard evaluation questionnaire covering these areas (see Appendix F) and were encouraged to include any additional suggestions for further enhancing the application.

The peer review was conducted by a selected panel of eight researchers with experience in the use of ICT and e-commerce applications within the construction sector. The industry sample comprised of five construction industry practitioners who are current end-users of e-commerce applications. The findings of these evaluations are presented in Section 5.2.2.

4.6 SUMMARY

This chapter discussed the research undertaken to meet the aim and objectives of the EngD project. It also highlighted the main results of the research undertaken including the e-readiness model and implementation of the VERDICT prototype. This application was evaluated using the approach discussed in Section 3.3.4 (Chapter 3). The results of this evaluation and the conclusions of this research work are presented in the next chapter.

CHAPTER 5 KEY RESEARCH FINDINGS AND CONCLUSIONS

5.1 INTRODUCTION

This chapter presents the key findings of this research project, including the evaluation results of the prototype application. The chapter discusses the impact of the research on the industrial sponsor and its implications for the wider construction industry. Recommendations and further work are also discussed. Finally, the chapter critically evaluates this research project and presents the final conclusions.

5.2 KEY FINDINGS OF THE RESEARCH

5.2.1 CASE STUDY FINDINGS

This section presents the findings of case studies conducted to examine the impact of specific construction e-commerce applications on the business processes of the end-user companies. The case study methodology adopted was discussed in Chapter 3 and details of the work undertaken presented in Chapter 4. The findings of these case studies are discussed in detail in Paper 5 (Appendix E). They are classified under several headings namely: the drivers to the adoption of e-commerce tools, process implications, and benefits and barriers to e-commerce adoption.

5.2.1.1 Drivers for E-commerce Technology Adoption

Different factors can influence the adoption of technologies such as e-commerce within construction organisations. From the case studies it was seen that:

- Technology adoption can be either management-driven, client-driven, market-driven or project-driven;
- Case study end-user companies fall within the early adopters category of the technology adoption bell curve (see Figure 5.1);

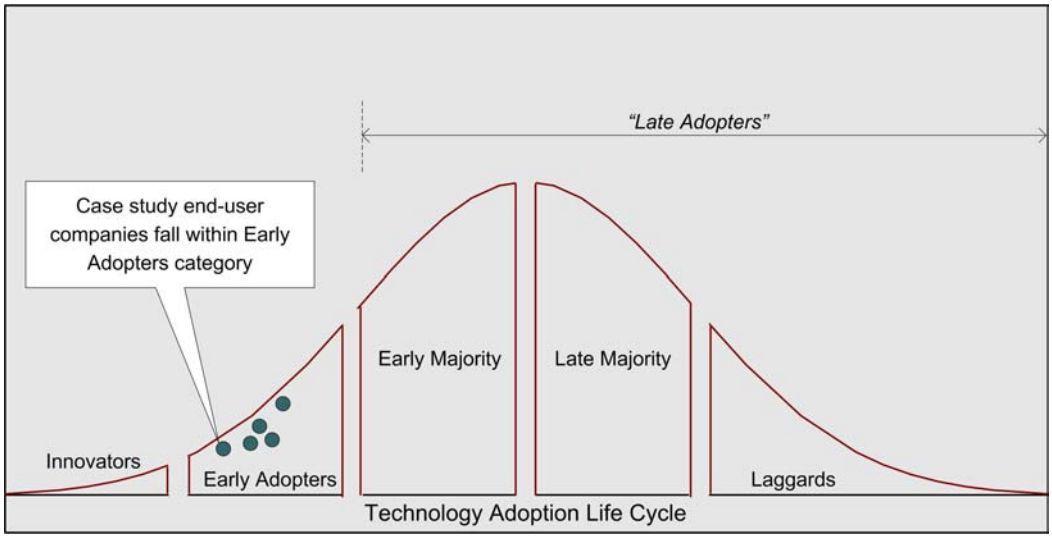


Figure 5.1 Technology Adoption Life Cycle (adapted from Moore, 2003)

- In the majority of the case study companies, the use of e-commerce tools was driven by the company's management as a strategic decision to improve business performance and support innovation, except in supplier companies where the use was driven by the main project contractor;
- Case study end-user companies believe that e-commerce tools are the way forward;
- Innovative technologies such as e-commerce are viewed as the primary differentiators that set companies apart from their competitors reflecting their drive towards innovation;
- The competitive edge that early technology adoption offers can be beneficial especially for prospective or future construction projects where clients are seeking expertise in that area (i.e. previous experience in using e-commerce tools);
- One of the case study companies, believes in the early adoption of technology and it is company policy to always be at the cutting edge of 'whatever'; and
- Factors such as client needs and market conditions, although important, are not directly influential in the implementation of e-commerce tools.

From the case study findings it was evident that management buy-in is a key factor influencing the adoption of any technology within a company and consequently the wider industry. This was viewed as a challenge, but not an impossible task. It requires open-minded management who are not nervous about change. Quite often companies (especially within the 'early majority' category) are reluctant or cautious in the use of new technologies. This is because being new, the technologies have not been previously reviewed for their usefulness and effectiveness. Thus, there is an element of risk involved which most construction companies are not willing to take. For the benefit of the wider construction industry, more needs to be done in the areas of documenting and publicising previous experiences (i.e. success stories and failures) of using e-commerce applications.

5.2.1.2 Process Implications

The use of any technology can affect the existing processes and result in a change in organisational processes, working methods and culture. According to Laudon and Laudon (2002), these changes can be in terms of process automation or rationalisation, the technology can also lead to process re-engineering and formulation of new processes, which may lead to paradigm shifts within the industry.

From the case studies it is seen that:

- The current use of e-commerce has NOT resulted in process re-engineering, but has facilitated process automation;
- End-user companies have adapted the technology to match their business needs;
- There is evidence of ASPs modifying or 'tweaking' their products to meet end-user business needs;
- Companies are more comfortable with process automation, because of its minimal impact on the organisational culture and its working methods; and

- Use of e-commerce tools has improved the efficiency of traditional construction processes in terms of reduced time and costs (there is documented evidence of this in Section 3.2 of Paper 4, Appendix D).

The end-user companies also suggested that these tools should be developed by staff who have a full understanding of the construction process and its complexities. In their view software tools that 'do too much' or are complex to use, are not easily adopted by the industry. Therefore, ASPs and software vendors must be careful not to develop technology-led solutions that force end-user organisations to drastically change their methods of working. They need to fully understand that the tools they develop are merely facilitators of the process and not the process itself.

5.2.1.3 Benefits and Barriers to E-commerce Adoption

The benefits and barriers to the use of e-commerce tools to facilitate construction processes are well documented in several research projects (Shelbourn, et al., 2002; Steele and Murray, 2001; and Motawa, et al., 2001). For the case studies, the end-user companies were presented with a list of possible benefits and barriers to the use of e-commerce tools. The end-users were required to identify the benefits and barriers from this list. Further, they were also asked to state any additional benefits or barriers not included in the list. The next two sections present these findings.

Benefits

The following are the benefits of using e-commerce tools that were identified by the end-user organisations:

- E-commerce tools such as project extranets enable better communication between project stakeholders and provide an environment suitable for partnering;
- Such tools facilitate faster information flow across the supply chain thereby reducing response times;
- The electronic exchange of project data and documents eliminates the need to physically re-key in information, thereby saving time and making the resulting process more efficient;
- E-commerce tools result in faster and cheaper document processing;
- According to the case study end-user companies, the use of e-commerce has improved their service to construction clients, as such tools increase the possibility that the projects will be completed on time, which in turn benefits the client;
- Using e-commerce tools (such as project extranets), an audit trail that records all project documents and data transactions is created. This leads to increased accountability and transparency which help to resolve disputes;
- E-commerce tools encourage 'openness' amongst project team members and lay the foundations for a better working relationship between the project teams; and
- Using e-commerce tools has led to a 'less paper environment' rather than a paperless environment.

Barriers

The following are the end-user perspectives on the barriers to the adoption of e-commerce:

- Most end-user companies identified issues related to management buy-in and cultural issues as the major barriers to the adoption of e-commerce within the construction industry;
- End-user companies do not consider legal issues and security issues associated with Web-based applications such as e-commerce tools as major barriers to their adoption;
- Although security is high on the agenda for most end-user companies, it does not deter the wider usage of the tool, and concerns are often based on long-standing misconceptions rather than reality;
- The current lack of standards for interoperability and version control problems are classified as medium level barriers by end-user organisations;
- For the case study organisations cost is not a major concern, as these companies view themselves as forward-thinking visionaries and market leaders, who want to keep abreast with technology, whatever the cost;
- Cost was identified as a possible deterrent for adoption amongst SMEs (Small and Medium Enterprises);
- The sheer magnitude of e-commerce tools available in the market is considered an issue as each of these tools have different interfaces, functionalities and may also use different terminology. This poses the end-user companies not only with the problem of getting acquainted with multiple interfaces, but also understanding the different terms and functions of each application;
- The 'immediacy' that the Web demands is an issue that can put undue pressure on staff e.g. most e-commerce applications such as project extranets, have a project page that alerts staff to take action (sometimes immediate), however, it is not always possible for staff to address these issues instantly (even though the system may prompt them to do so);
- Connectivity issues such as network connection failures are viewed as low level barriers that can cause frustration to the users; and
- Technology issues such varying levels of IT infrastructure amongst supply chain members are viewed as barriers that can affect project performance. This problem arises when the end-user with a older version of a software solution tries to save a file prepared in a newer version (most software solutions are backward compatible but not forward compatible).

Documenting and disseminating the information about the potential benefits and barriers to using new and innovative technologies such as e-commerce can be especially useful for those companies that have not previously used it. This also increases their awareness of the potential risks and rewards of using these technologies. As stated in Section 4.5 (Chapter 4) it is also important for companies that seek to adopt e-commerce tools to measure their 'e-readiness' for adopting e-commerce tools to ensure a productive and beneficial implementation of these tools. To address this need an e-readiness assessment model for construction organisations and a prototype application that assesses e-readiness were developed. The prototype

system was then evaluated using the methodology stated in Section 3.3.4 (Chapter 3). The next section presents the findings of these evaluations.

5.2.2 EVALUATION FINDINGS

The VERDICT prototype was evaluated by an independent panel of reviewers including academic researchers and industry practitioners. Out of a total of eight academic researchers and seven industry practitioners who agreed to evaluate the prototype, twelve returned their completed evaluation forms (seven academic researchers and five industry practitioners).

Figure 5.2 presents the results of the evaluation in the areas of prototype use, understanding, navigation and errors.

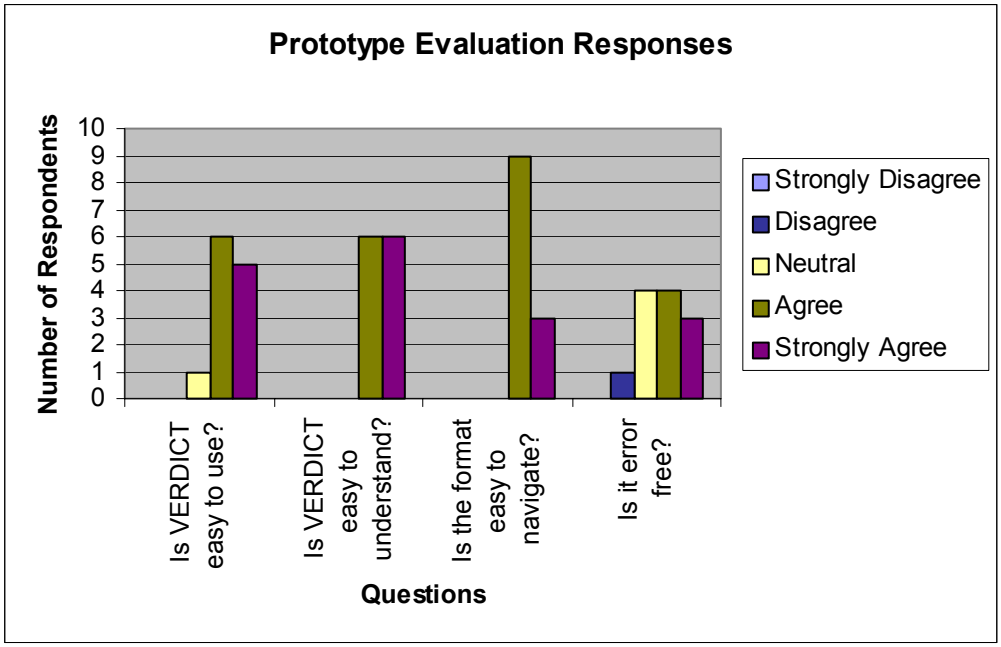


Figure 5.2 VERDICT Prototype Evaluation Responses

- Ease of use: All reviewers (except one) either agreed or strongly agreed that the VERDICT prototype was easy to use. The one remaining reviewer held a neutral view;
- Ease of understanding: All the reviewers either agreed or strongly agreed that VERDICT was easy to understand;
- Ease of navigation: Majority of the reviewers strongly agreed that the format of the prototype was easy to navigate ; and
- Presence of errors: Although a majority of the reviewers agreed that the prototype was error-free, one reported an error in its operation. The error reported was rectified by adjusting the browser settings of the end-user.

Reviewers were also asked to highlight aspects of the prototype that impressed them most or fell short of expectations. All the reviewers were impressed with the presentation of the e-readiness reports and thought that the VERDICT reports were easy to understand and effectively highlighted the areas of e-readiness that companies needed to address. In their view the user-friendliness and the simplicity of the

application would make it acceptable for use in the industry. To quote one of the industry reviewers' comments, 'the report generated from the questionnaire and the traffic light indicators give a high level view of which of the four areas need improving and then a more detailed view based on all the questions. The questions are generally quite comprehensive and well structured'. Further, the evaluation findings highlighted that the prototype application addresses all aspects that construction companies need to consider to achieve e-readiness, and then gives a rapid appraisal of where an organisation is in respect of its e-readiness. The overall evaluation results show that none of the evaluators thought that there were any parts of the application that fell short of their expectations. However, a few suggestions were made to further improve the application. These suggestions are included in the recommendations section of this chapter (see Section 5.6).

Reviewers were also asked their opinion about the appropriateness of the questions in each category and were encouraged to suggest additional questions. All the reviewers thought that the questions were comprehensive, well structured and needed no changes. Some suggestions were made to reduce the number of questions or to classify the questions by identifying themes within the four categories. In their view, this would further enhance the structure of the questionnaire. This suggestion has not been taken up and could be implemented as part of further work.

The prototype was also evaluated for its benefits. The next section states the evaluators perspective on the benefits of using VERDICT:

5.2.2.1 Benefits of VERDICT

According to the evaluators the following are the benefits of using VERDICT:

- VERDICT flags-up the critical issues that companies need to address to achieve e-readiness;
- It gives a clear result of an organisations' strengths and weaknesses regarding their readiness for using e-commerce tools;
- Being Internet-based, the system is platform-independent and provides all the benefits of using the Internet e.g. flexibility, accessibility, portability, device independence, no need for specialist software, economical, etc; and
- The capability that VERDICT provides for benchmarking against the best-of-breed allows companies to gauge where they are (in terms of e-readiness) with respect to their competitors.

On the whole the response was enthusiastic for future use of VERDICT and most evaluators stated that they would recommend the use of the application for assessing e-readiness. Some of the industry evaluators used VERDICT in-house to formally evaluate their company's e-readiness. One of the industry evaluators' had a meeting with their staff (i.e. e-commerce application users) and senior management to review their poor performance in using e-commerce tools. According to this evaluator, the results from VERDICT helped them focus this discussion on the areas that needed attention (i.e. those highlighted in their VERDICT report).

Besides assessing the prototype, the industrial evaluators also used VERDICT to assess the e-readiness of their companies for e-commerce. The next section presents the findings of these e-readiness evaluations.

5.2.2.2 E-readiness Assessment of Industry Evaluators

The industrial evaluation was conducted by managerial staff (e.g. senior project manager, project director, senior systems manager, etc) of leading UK construction organisations, which included consultants, contractors and project managers. A total of ten construction companies were approached to evaluate the prototype. Out of these ten, seven confirmed their willingness to evaluate the prototype and six of these actually used the prototype to assess their e-readiness.

This section presents the findings on the e-readiness of these companies based on their responses. Table 5.1 includes the average scores of each company in the categories of management, people, processes and technology. These scores are also plotted on the radar diagram to give a visual dimension to the data (see Figure 5.3).

Table 5.1 Category-wise Comparison of E-readiness Average Scores for End-user Evaluation Companies

	Average Scores in Each Category							
	Management		**People**		**Process**		**Technology**	
Company 1	3.48		3.46		3.83		3.54	
Company 2	3.48		3.62		3.50		3.85	
Company 3	3.33		3.62		3.83		4.46	
Company 4	3.52		3.54		3.58		4.69	
Company 5	3.33		3.85		3.42		4.00	
Company 6	2.29		2.54		3.17		3.62	
Average	**3.23**		**3.44**		**3.55**		**4.02**	

From the table it is seen that:

- Management in all the companies is the least e-ready with the lowest scores compared to the other three categories;
- All the companies have a high level of e-readiness (i.e. have a score >=3.5) in the technology category;
- Company six is the least e-ready and has the weakest level of e-readiness in the management category; and
- Most companies are e-ready in the people and process categories, however, they need to address some aspects to achieve e-readiness.

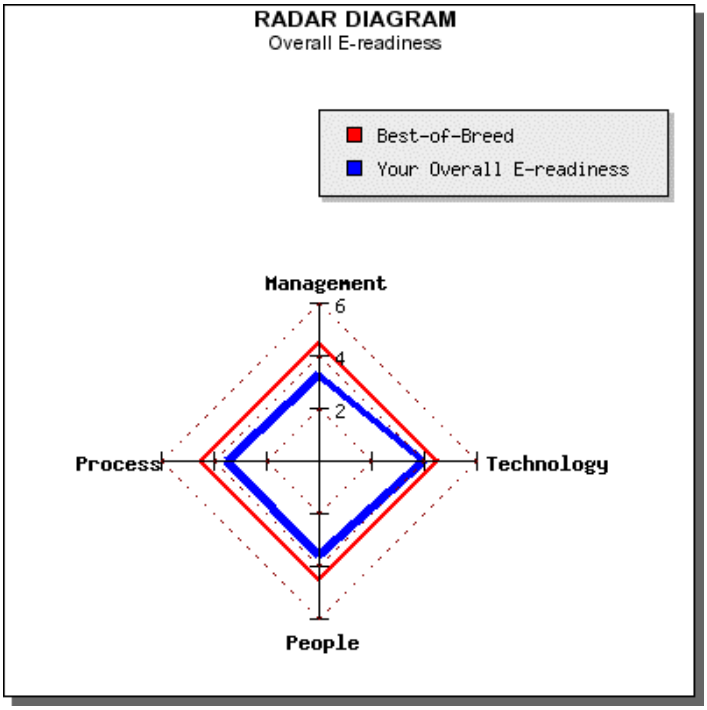


Figure 5.3 Category-wise Average E-readiness Scores of Industrial Evaluators

5.3 IMPACT ON THE SPONSOR

This research assessed the impact of e-commerce on the business processes of end-user construction organisations. An e-readiness model that assesses the readiness of construction organisations to successfully adopt, use, and benefit from e-commerce tools was also developed. The technique to assess e-readiness was demonstrated through the development of the VERDICT prototype software.

This research project was initiated by the industrial sponsor, BIW, but midway through the EngD project the industrial sponsor withdrew (following a re-organisation). This had little impact on the overall aim and objectives of the project, but it impacted on the project scope. The focus was now not just on the industry sponsor (an e-commerce ASP), but on the industry it represented.

This research showed that the use of e-commerce tools is on the increase and that the technology is ‘here to stay’. These are encouraging findings for software vendors and solution providers. ASPs should be aware that the construction industry is a conservative industry and does not welcome change easily. Thus any change must be introduced gradually. ASPs should understand that any future tools should be developed by staff who have a full understanding of the construction process and its complexities. These tools should also be easy to implement and use. At present software tools that ‘do too much’ or are complex to use, are not easily adopted by the industry. Therefore, ASPs and software vendors must be careful not to develop technology-led solutions that force end-user organisations to drastically change their methods of working. They need to fully understand that the technology tool they develop is merely a facilitator of the process and not the process itself. Collaboration tools such as the ones used in the case studies work well because of their minimal impact on individual businesses and the companies have achieved measurable benefits from using these tools.

As seen from the evaluation results, the VERDICT e-readiness tool can help ASPs judge the readiness of construction companies to use their applications. It can also flag-up those issues for which the companies are not e-ready. There is scope for developing strategies focused on addressing those specific issues highlighted in the e-readiness report. Strategies can be tailored to individual company needs.

5.4 IMPLICATIONS FOR THE WIDER INDUSTRY

There are two main areas in which this research project has implications for the wider industry. The findings of these two areas will assist the wider industry in:

- Assessing the impact of e-commerce tools on their day-to day working; and
- Assessing their readiness to effectively use e-commerce technologies.

The case study findings have shown that construction organisations are increasingly using e-commerce tools such as Web-based collaboration tools for managing construction projects. All end-user companies that have used e-commerce tools have incurred benefits in terms of improved project performance and process improvement. The case studies also highlighted that management buy-in is an important driver for technology adoption in construction. Findings suggest that e-commerce should not be viewed as a 'passing phase', it is 'here to stay' and it will not be long before it becomes an industry-wide norm. Success stories such as those demonstrated by early adopters (like the case study organisations) for using e-commerce tools can act as drivers for their adoption amongst the late adopters. Such examples also contribute to increasing awareness of the potential risks and rewards of using e-commerce technologies and allow companies to assess the impact of these technologies on their business processes.

The e-readiness assessment model can be used as a mechanism to gauge the readiness of construction organisations for e-commerce. The model is based on the premise that for any company to be e-ready, its management, people, process and technology have to be e-ready. All four categories are considered important for an organisation to be e-ready. Construction companies can not only use VERDICT to gauge their overall e-readiness, but also use it to periodically review their progress in achieving e-readiness by using the four categories as KPIs (Key Performance Indicators).

The prototype application has impacted on the industry in more ways than were initially foreseen. This can be illustrated by reiterating the example discussed in Section 5.2.2.1, where one of the industrial evaluators used their company's e-readiness reports as a guide for invoking discussion within their organisation by focusing on the issues highlighted in the report and devising measures to overcome those issues.

5.5 CRITICAL EVALUATION OF THE RESEARCH

This project was initiated with the aim of studying the business process implications of e-commerce in construction organisations. Considering that this is a rapidly evolving field within the construction sector and that the research was conducted over a period of four years, the initial findings needed to be re-affirmed as the project progressed. Some of the limitations of the research are:

Technique Used for Case Studies

- The case study sample was limited to two main e-commerce ASPs and their

respective construction end-user organisations. Although this sample was adequate for this project, if time and access to other construction ASPs were available, it could have further enriched the data.

E-readiness Assessment Model

- The current e-readiness model highlights critical areas that need consideration to achieve e-readiness. However, it does not state the steps that need to be taken to address these. This could be addressed by providing guidance to the companies in achieving e-readiness by setting short-term achievable targets that lead to e-readiness.

E-readiness Prototype

- Although the prototype demonstrates the concept of benchmarking against the best-of-breed in construction. More needs to be done as discussed in Section 5.6.2, to establish how best to operationalise the concept of 'best-of-breed'.
- When the prototype was evaluated by different management staff within the same company there was a slight variation in the final e-readiness results. This may be because different individuals within an organisation have different perceptions of their own business based on their experience and role. There is scope to develop VERDICT further to get a more objective assessment of company's e-readiness. Representatives from the different departments, e.g. IT department, senior management, site staff, etc could use the VERDICT tool to eliminate the bias or subjectivity of individuals. The final e-readiness report could be based on the averages of these individual responses.

5.6 RECOMMENDATIONS AND FURTHER WORK

This section makes recommendations for further research and also proposes further improvements to the existing prototype application based on self-evaluation and the comments made by the evaluators.

5.6.1 RECOMMENDATIONS FOR FURTHER RESEARCH

Some of the recommendations for further research are as follows:

- The typical business process model presented in Section 4.3 (and Paper 3, Appendix C) of this thesis used the principles of BPR to illustrate how the current working of the construction supply chain could be improved by using the IC - an e-commerce tool developed by the industry sponsor. It also highlighted the possible business benefits to different members of the construction supply chain. This was done by focusing on the specific process of managing and finalising architectural detail design drawings (for door designs). The model illustrated the iterations involved in finalising the detailed architectural design drawings (for doors) and demonstrated how, using the capability of the IC, the final set of drawings could be linked to (door) suppliers database to search for doors based on specific criterion such as door prices, specifications, availability, and other aspects could be compared. Using this information the door supplier could be finalised, selected and payments made electronically. While this model focused on one building component – a door, there is scope for further research in the

development of similar business process models for different building components. It would also be beneficial to pilot a project that uses such a re-engineered model and documents its implications for different members of the construction supply chain. This can not only help to test and validate the re-engineered processes, but can also help to establish the *actual* benefits and drawbacks from an end-user perspective;

- In the construction industry, even though there is a high volume of information transfer between project partners, access to files and records is relatively poor. To improve the exchange of information between construction disciplines, the IAI (International Alliance of Interoperability) has developed the Industry Foundation Classes (IFC) standard. IFCs facilitate the creation and maintenance of a single repository for a project, that is a 'Single Project Model'. Using the IFCs project teams can create a project model (possibly a 3D model) that allows them to store and retrieve project information. Such a single project model will enable project teams to work closely in order to achieve benefits such as efficient development of design solutions, integrated cost planning, installation scheduling, etc. Information can be extracted and added to such a model using the interface provided by e-commerce tools such as project extranets. There is scope for conducting further research to investigate the use of single project models for information management; and
- Existing e-commerce tools have done much to address collaboration issues of construction project teams. However, these systems still do not adequately support the information and knowledge requirements of mobile project team members. Emerging technologies such as Wi-Fi, Web services and the Semantic Web have the potential to overcome some of the shortcomings of current ICTs by providing support to the mobile project team members. While Wi-Fi increases the possibility of accessing information from anywhere and at anytime, the Semantic Web has the potential to provide contextual meaning to this information. Together these technologies have the potential to facilitate the construction workers' work practices by allowing them to access a wide range of data and services on an as-needed basis. There is scope to conduct further research that looks into integrating such services with existing e-commerce tools.

5.6.2 FURTHER IMPROVEMENTS TO VERDICT PROTOTYPE

Currently, the VERDICT prototype flags those issues that organisations need to consider to achieve e-readiness. However, it does not indicate 'how' this can be done. There is scope for addressing this current limitation by providing consultancy services that give expert advice on how e-readiness can be achieved. This will require further research in the development of strategies that outline the measures that organisations will need to take to achieve 'total' e-readiness and hence best practice.

Further work on improving the VERDICT model and prototype application include a continuous improvement plan, making cosmetic changes, classifying questions into sub-categories and weighting the questions in order of importance.

The continuous improvement plan includes periodic reviews of the prototype application for its appropriateness and regular updates (whenever necessary) to meet the changing industry needs and to keep abreast with the technological developments. Further work also includes addressing suggestions made by the evaluators, most of which are currently beyond the scope of the project, but can be implemented in future

as a part of the continuous improvement plan. Based on these suggestions, the following recommendations are made for future versions of the prototype application:

- Adding a 'save' function that allows users to save their responses (page-wise) will enable the users to return to the questionnaire and continue from that point forward, if they are unable to complete the entire questionnaire in one sitting; and
- The user-friendliness of the prototype may be further improved for example, current operation of the VERDICT prototype prevents users from returning 'back' to the previous page by using a browser's 'back' button. Clicking on this can result in loss of data and the users have to re-start the questionnaire. The next version of the prototype could be designed to allow users to 'freely' navigate back and forth before finally submitting their responses.

Some additional recommendations include:

- There is scope for further research into establishing 'best-of-breed' e-readiness levels for construction organisations. This can be done by following the example of Cisco Systems, who have based their best-of-breed sample on information from Fortune 1000 executives (Cisco Systems, 2004). A similar approach can be adopted in construction.

Cosmetic changes that were suggested to improve the aesthetics of the prototype front-end have already been addressed and the current version of the prototype reflects these. However, some of other issues highlighted by the evaluators, that were not as straightforward were considered, rationalised, rejected or accepted. These included identifying 'killer' questions in each category to give users an instant snapshot of their overall e-readiness. However, this suggestion was rejected as it can undermine the importance of other questions in each category. There may also be a danger in that the organisations may assume that they are e-ready based on the 'snapshot' findings and therefore not address the issues that may be flagged-up in the more comprehensive questionnaire version.

Another recommendation made by the academic reviewers was the possibility of classifying the questions in sub-categories and weighting them according to their level of importance to achieve e-readiness. However, this is a complex process. The relative importance of the criteria for e-readiness of organisations may vary according to the nature of the end-user organisation and its discipline. What is a priority for one organisation may not necessarily be for another. Also, the questions may be weighted differently by different construction organisations. Research by Nardo (2004) in the merits and demerits of using different weighting techniques for questions in questionnaires suggests, that whatever method is used to assign weights, no consensus is likely to exist. This does not mean that weighting should be disqualified, but is indicative of the dangers of being 'objective' and therefore avoiding assignation of generalised weights to questions. There is future scope for identifying and prioritising questions in order of their importance for each construction organisation. Based on these findings the VERDICT prototype can be developed such that when users input their organisation's details in the background information page, VERDICT automatically presents the appropriate (weighted) questionnaire that is tailored to their needs. Alternatively, provision can be made for end-users to assign relative weights to the four categories and/or to the individual questions.

5.7 SUMMARY AND CONCLUSIONS

The research has shown that the use of e-commerce tools is still within the early adoption phase in the construction industry and management buy-in is vital for implementation of e-commerce technology within construction organisations. Cultural issues associated with technology adoption are one of the major barriers to implementing e-commerce within construction. Software tools that 'do too much' or are complex to use, are not easily adopted by the industry. It is important that ASPs and system developers recognise that their tool is simply an enabler in a bigger process.

Currently, there is evidence of process improvement resulting from automation of processes and removal of bottlenecks leading to rationalisation of procedures. However, there is no evidence of process re-engineering or development of any new processes that have led to paradigm shifts within the construction process. Such a practice may work in the short term, but has certain limitations in that the end-users are not necessarily making full use of the technology and hence not deriving full benefits from it. Instead of regarding e-commerce as an extension of IT and fitting it into the existing business processes, construction companies need to recognise that it is a radically different approach to conducting business and therefore should explore new processes and opportunities, which may only be possible because of e-commerce. Changes that occur in the construction business process due to the adoption of e-commerce need to be continually monitored and documented so that a best practice strategy for e-commerce adoption in construction can be formulated.

The research has also shown that, currently, ASPs provide applications that support individual processes e.g. design management, procurement, trading, etc. Thus, the processes, although automated, are still fragmented. Existing technology has the capability of providing a 'single' solution that encompasses the project lifecycle - from inception to completion including the facilities management phase, thus in effect overcoming the fragmentation issue. However, the industry itself is still not ready to accept the radical changes required to implement such a solution. At present the industry has accepted and adopted e-commerce tools that are easy to implement and use. Such tools facilitate the construction process and increase the probability that the project will meet its target cost and time schedule. In this respect, e-commerce tools contribute towards improving project performance.

To gain maximum benefits from the adoption of e-commerce tools the right strategies and implementation plans have to be developed, communicated and implemented. Taking this into account, construction companies who are currently using, and those who have yet to use, e-commerce tools need to take measures to successfully adopt, use and benefit from this technology. This was demonstrated through the development an e-readiness model and an e-readiness assessment prototype for the construction sector - VERDICT. The model is based on the premise that for any company to be e-ready, its management, people, process and technology have to be e-ready in order to derive maximum business benefits. From the implementation and evaluation of VERDICT it can be concluded that VERDICT can be used as a self-assessment tool by organisations to gauge their e-readiness. The tool can also help in highlighting areas that need to be addressed to achieve e-readiness.

In conclusion, the following are the main contributions of this research:

- Identification of the main drivers, benefits and barriers to the adoption of e-commerce tools within the construction sector;

- Development of a re-engineered business process model that highlights opportunities for the use of innovative e-commerce tools within the construction process;
- Documentation and dissemination of the impact of e-commerce tools on the business processes of end-user organisations;
- Development of a model to assess e-readiness of construction for e-commerce; and
- Implementation of a new and innovative prototype application that assesses construction e-readiness for e-commerce.

From these main contributions it can be seen that the primary objectives (Section 2.3) of this research are satisfied. The early stages of this research project (objective one) investigated the current working methods within the construction industry and the evolution of e-commerce. This led to the identification of the main drivers, benefits and barriers to the adoption of e-commerce tools within the construction sector. Objective two involved investigating the potential impact of e-commerce on construction business processes. To satisfy this objective a re-engineered business process model that highlights opportunities for the use of innovative e-commerce tools within the construction process was developed. To satisfy objective three, case studies were undertaken to document and disseminate the impact of specific e-commerce applications on their end-user business processes. Findings of each of these stages led to the development of an e-readiness model and a prototype e-readiness application to demonstrate innovation in the application of knowledge to the engineering business environment. The development of this e-readiness model and the prototype application satisfy objective four.

This research has demonstrated that clearly, there are numerous benefits for construction organisations that chose to adopt e-commerce. This adoption has to be well planned and all the key enabling factors – management, process, people and technology – must be geared to ensuring beneficial outcomes. The model and e-readiness assessment prototype developed as part of this study will enable construction organisations to successfully adopt e-commerce.

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APPENDIX A PAPER 1 (JOURNAL)

Anumba, C.J and **Ruikar**, K., (2002). 'Electronic Commerce in Construction – Trends and Prospects', *Automation in Construction*, Elsevier Science B.V. Vol.11, pp. 265-275.

ELECTRONIC COMMERCE IN CONSTRUCTION - TRENDS AND PROSPECTS

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ABSTRACT

There is growing interest in the conduct of business transactions by electronic means through the Internet and/or dedicated networks; this is often referred to as electronic commerce. This paper reviews developments in electronic commerce, with a particular focus on its applicability and uptake within the construction industry. Electronic commerce business models are reviewed and the enablers and barriers to their uptake in the construction sector presented. The paper concludes with future trends in electronic commerce and the need for construction organisations to make the necessary investments that will enable them to take advantage of these.

KEYWORDS

Electronic Commerce, Internet and Dedicated Networks

1. INTRODUCTION

The Internet has revolutionised the way in which information is stored, exchanged and viewed. It has opened new avenues for businesses, which were only a decade ago almost inconceivable. Businesses have recognized the possibilities such a revolution has opened and have plunged into the global race to take advantage of the opportunities offered by the new ICT (Information and Communications Technology). This sudden recognition of the need to adopt new measures has some immediate consequences. There arises a need for businesses to shift from their traditional, tried and tested methods if not radically alter these methods to embrace new technology. Such changes can prompt businesses to improve traditional business processes, innovate their products and services, and develop strategies that are flexible to incorporate new technologies as and when they emerge. The boom in the electronic ways of conducting business, or electronic commerce, as it is commonly referred to, has had knock on effects on virtually every business sector. The construction industry is no exception.

The construction industry's need to adopt innovative ideas and methodologies such as electronic commerce in its operation has been expressed in the Egan (1998) report, which is one of the major drivers for innovation in the construction industry in UK. The Egan (1998) report states that the construction industry is an important pillar of domestic economy in UK, contributing to about 10% of the total revenue. It further states that the construction sector is simply too important to be allowed to stagnate. Stagnation of any industry can be prevented by researching into the amalgamation of new and revolutionary technologies such as electronic commerce into the industry's day-to-day working methods.

This paper reviews developments in the adoption of electronic commerce in construction. It presents a taxonomy for electronic commerce and briefly discusses the different developments in electronic commerce both within and outside construction. It then reviews electronic commerce trends in construction including the barriers and enablers for electronic commerce in construction. Finally it discusses future trends for electronic commerce in construction.

2. OVERVIEW

Electronic commerce can simply be defined as doing business by electronic means, typically over the Internet. The definition of electronic commerce is not static (Kosiur, 1997) and depends on the adopted perspective. From a *communications* perspective, electronic commerce is the electronic delivery of services and information. From a *business process* perspective, electronic commerce is the automation of business transactions and workflows. Broadly defined, however, electronic commerce is a modern business methodology that addresses the needs of organisations, merchants and consumers to cut costs while improving the quality of goods and services and increasing the speed of service delivery (Kalakota and Whinston, 1997). The Organisation for Economic Cooperation and Development (OECD) defines electronic commerce as 'the electronic exchange of information that support and govern commercial activities including organisational management, commercial management, commercial negotiations and contracts, legal and regulatory frameworks, financial settlement arrangements and taxation (OECD, 1999).

Electronic commerce has been around in various forms such as EDI (Electronic Data Interchange) (Kosiur, 1997) since the late 1960s (Trepper, 2000). With the advent of the World Wide Web and Internet browsers in the early 1990s, Internet electronic

commerce has flourished (Black, 2000). The Forrester research group has projected that business transactions over the Internet will have a value of $7000 billion US dollars amounting to 8.6% of the global sales of goods and services by the end of 2004 (Sanders and Temkin, 2000).

3. TAXONOMY FOR ELECTRONIC COMMERCE

Electronic commerce can be broadly divided into four main categories (European Commission, 1999):

- Business-to-Business (B2B)
- Business-to-Consumer (B2C)
- Business-to-Administration (B2A)
- Consumer-to-Administration (C2A)

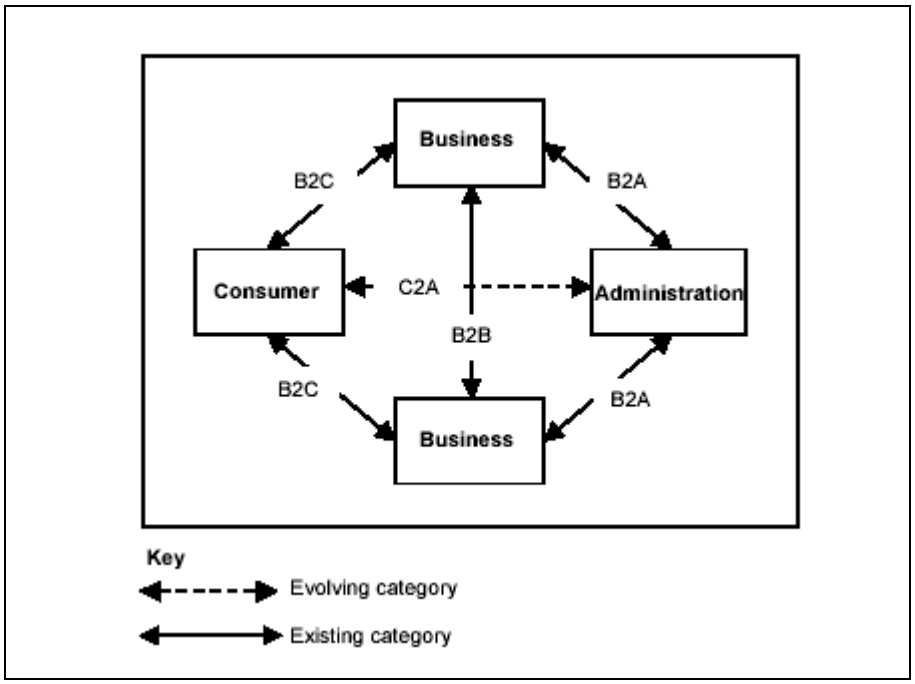

Figure 1. Categories of Electronic Commerce (adopted from European Commission, 1999)

3.1 BUSINESS-TO-BUSINESS (B2B)

Business-to-Business (or B2B as it is commonly referred to) is an electronic means of carrying out business transactions between two or more businesses. B2B incorporates everything from manufacturing to service providers. An example of such a method of carrying out business would be a company that uses the Internet to place an order from the suppliers or retailers, receive electronic invoices and make payments electronically.

3.2 BUSINESS-TO-CONSUMER (B2C)

Business-to-Consumer is similar in concept to the traditional method of retailing, the main difference being the medium used to carry out business - the Internet. Such a

method of carrying out business transactions assumes that the consumer has access to the WWW. By selling direct to customers or reducing the number of intermediaries, companies can achieve higher profits while charging lower prices (Laudon & Laudon, 2000). This removal of intermediary organisations or business process layers is termed disintermediation.

3.3 BUSINESS-TO-ADMINISTRATION (B2A)

This category covers all the transactions that are carried out between businesses and government bodies. Currently, this category is in its infancy, but it has the potential to grow with government initiatives (European Commission, 1999). Government initiatives could help publicise the awareness and growth of electronic commerce in various sectors e.g. DETR's (Department of Environment, Transport and the Regions) Web site (2001) for construction includes UK government initiatives with key players from the construction industry. It gives details of government policies, initiatives and other information relevant to the UK construction sector.

3.4 CONSUMER-TO-ADMINISTRATION (C2A)

This category has evolved over the last couple of years. According to the European Commission (1999), 'the category C2A has not yet emerged'. Since the time the article was written, new developments have taken place. The C2A category is starting to emerge, and governments in general are pledging to do much more about it through initiatives such as UK Online, which is a joint venture of the UK government with the industry, voluntary sector, trades unions and consumer groups to facilitate Internet access to UK citizens by year 2005 (UK online, 2001). Some of the government initiatives are the eEurope initiative at European level and C2A applications such as e-democracy, e-voting, information about public services, and e-health (Timmers, 2000).

3.5 OTHER CATEGORIES

The European Commission cited the above categories in 1999. Since then, however, trends have changed and newer categories such as Consumer-to-Consumer or C2C have emerged. Examples include, consumer e-auctions and Web applications such as Napster. Although there may be no financial transaction, there is still an exchange of value and these are economic activities and could be referred to as peer-to-peer Internet transactions (Timmers, 2000). In line with current trends, there is a possibility that a new category such as Administration-to-Administration (or A2A) might emerge, where governments of different countries may exchange documents and data or conduct business transactions electronically.

3.6 INTERNET BUSINESS MODELS

Laudon and Laudon (2000) present another useful classification of business models for Internet-based electronic commerce. This is summarised in Table 1 and includes examples in each category. These business models are more appropriate for some of the above categories of electronic commerce than others, and organisations have to decide on which model is best suited to their needs.

Table 1: Internet Business Models (from Laudon & Laudon, 2000)

Category	Description	Examples
Virtual Storefront	Sells physical goods or services on-line instead of through a physical storefront or retail outlet. Delivery of non-digital goods and services takes place through traditional means.	Amazon.com Virtual Vineyards Security First Network Bank
Market Place Concentrator	Concentrates information about products and services from multiple providers at one central point. Purchasers can search, comparison-shop, and sometimes complete the sales transaction.	Internet Mall DealerNet Industrial Marketplace InsureMarket
Information Brokers	Provide product, pricing and availability information. Some facilitate transactions, but their main value is the information they provide.	PartNet Travelocity Auto-by-Tel
Transaction Brokers	Buyers can view rates and terms, but the primary business activity is to complete the transaction.	E*Trade Ameritrade
Electronic Clearinghouses	Provide auction-like settings for products here price and availability are constantly changing, sometimes in response to customer actions.	Bid.com OnSale
Reverse Auction	Consumers submit a bid o multiple sellers to buy goods or services at a buyer-specified price.	Priceline.com
Digital Product Delivery	Sells and delivers software, multimedia, and other digital products over the Internet.	Build-c-Card PhotoDisc SonicNet
Content Provider	Creates revenue by providing content. The customer may pay to access the content, or revenue may be generated by selling advertising space or by having advertisers pay for placement in an organised listing in a searchable database.	Wall Street Journal Interactive Quote.com Tripod
On-line Service Provider	Provides service and support for hardware and software users	Cyber Media Tune Up.com

4. DEVELOPMENTS IN ELECTRONIC COMMERCE

Electronic commerce has been in existence for a very long time in the form of EDI, which is the computer-to-computer exchange of routine business documents in a standard format, between companies (Sharda, 2000). EDI opened new avenues for businesses to communicate and exchange documents with several advantages such as paperless offices, faster communication and reduced costs compared to traditional methods. Despite the advantages of EDI one of the factors that prevented wider use of EDI was that it could not be incorporated into existing company networks and the participating organizations had to agree on a standard format in order to communicate electronically with each other. This problem grew in complexity as organizations became bigger and more and more trading partners had to be added to the network.

Often each individual trading partner was required to contract in advance for a tailored software program (Bryan, 1998).

For every new sender or receiver (trading partner) added to the client list, a new translation program would be needed so as to format their data to conform to the standards of the other participants (Webber, 1997). This made the original process very rigid and expensive. This drawback could be overcome with the help of Value Added Networks or VAN.

VAN is a third party network, with the aid of which the sending partner can electronically transmit data to the receiver via a modem or phone lines. The VAN receives transactions, sorts them by receiver and stores them in the receiver's mailbox until they are picked up (Sharda, 2000). The authors have illustrated this in Figure 2.

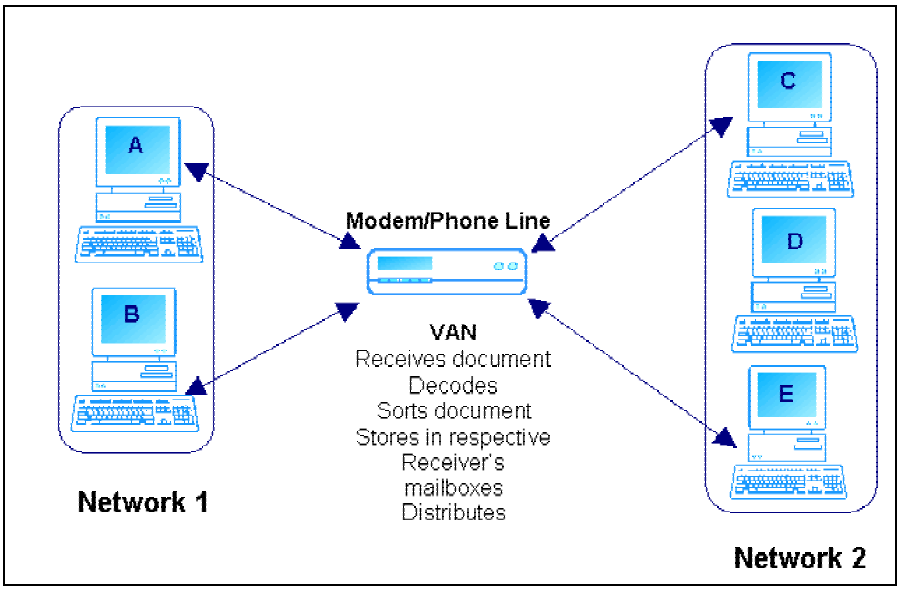

Figure 2. Value Added Networks

The use of electronic exchange technologies was popularised during the late 1980's and early 1990's in construction. The increased use of CAD to produce drawings, development of STEP (Standard for Exchange of Product data) and the formation of the EDICON organisation provided a platform for developing awareness and commitment to electronic exchange and gave direction for further development of technologies to achieve greater business benefits (Lewis, 1999). EDICON viewed the evolution of EDI as providing a means of improving interdisciplinary communications within the construction industry using a set of messages developed for industry specific applications. This lead to the development and ratification of the bill of quantities message set. Lewis (1998) has, however, pointed out that its use has not proceeded beyond the test stage. A survey undertaken by O'Brien and Al-Soufi (1994) established that the early use of EDI in construction was for trading cycle information and that there was no practical implementation of industry-specific EDI. Another survey undertaken by Akintoye (1997) noted that EDI exchange formats were predominantly used for pilot projects. This survey also indicated that the number of contractors had not increased since the survey undertaken by O'Brien and Al-Soufi (1994), thereby confirming that the application of EDI in the construction industry was limited.

Prior to the initiation of the Internet, data transmission for EDI was conducted either through dedicated phone lines or third-party value added networks (VANs). A

survey conducted by DTI (Department of Trade and Industry, 1998) indicated only 33% of firms in the UK construction industry use EDI. This was particularly prominent among SMEs (Small to Medium Enterprises) with only 19% using EDI applications. Low and Sloan (1999) state that the high development and utilization costs, technological limitations and low critical user mass are the main barriers to the uptake of EDI in construction.

In recent years the growth of the Internet has been exponential and it has affected all aspects of life. In business, this has been demonstrated through the increased uptake of Internet technologies, such as e-mail and Internet access. Low and Sloan (1999) state that while the Internet has generated significant impacts on various parts of the business value chain, it also introduces newer ways for implementing EDI. Instead of the private VANs, data can now be transferred over the Internet. Using the Internet, information can be transmitted and exchanged in a much more dynamic manner. New technologies such as the eXtensible Markup Language (XML) have now emerged and will be the norm for future exchange of information. Their main objective is the development of a system that is not only extensible enough to meet future requirements but is also adaptable and flexible enough to incorporate new innovative technologies of the future as and when they emerge (Bryan, 1998).

Such developments will make it possible to combine old technologies such as EDI with relatively newer technologies such as XML to broaden the scope. However, XML/EDI involves much more than just dropping EDI into an XML wrapper[3]. XML/EDI provides 100% backward compatibility to the existing EDI transactions and at the same time moves EDI forward to the next generation of technologies. With the use of XML/EDI, businesses will not have to discard the investments they made in existing EDI systems (Bryan, 1998).

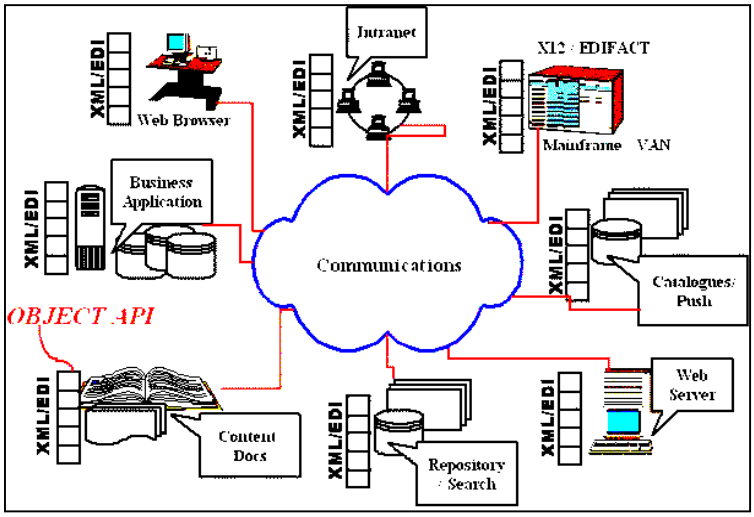

Figure 3. Possible impact of XML/EDI on Future Electronic Transactions.

This figure illustrates how, in the future, different platforms and applications (such as Web servers and intranets) will be able to communicate with each other for data exchange through a common XML/EDI interface.

[3] Legacy systems can be integrated into software architectures via the process of wrapping. Wrapping involves mapping an existing system interface to another (Anumba, et al., 2000)

5. ELECTRONIC COMMERCE IN CONSTRUCTION

The uptake of electronic commerce in the construction industry has been relatively limited and ineffective as compared to other engineering sectors such as the automotive or the aerospace industry. One of the reasons for this could be the fragmented nature of the construction industry and the one-off nature of the product.

A construction project is a complex activity involving several participants; for example, the client, architect, structural engineer, fabricator and the contractor. It is a team effort, involving several, inter-organisational activities and dialogue. Currently, information flow in the construction industry is mostly manual and hence slow. The traditional means of communication involves producing numerous paper copies of documents and drawings. Management of these loose documents is often very time-consuming and tedious. Libraries of documents need to be maintained to effectively access data as and when required by the user. “A lack of a clear audit trail causes delays in communicating with other members of the team” (Needleman, 2000). The reliance on third parties such as courier services, can sometimes lead to delays. There is also a high amount of added expense incurred in the delivery of project documents to project members who are geographically distributed. Many organisations that offer electronic commerce services and solutions are trying to exploit these current inefficient methods of communication and data exchange within the construction industry. This is made possible through the use of Web-based solutions for communication and project management. The use of Internet services may lead to considerable savings in terms of time and money for construction projects. This increased efficiency in terms of project communication may lead to lower building costs.

5.1 UPTAKE OF ELECTRONIC COMMERCE IN CONSTRUCTION

To date the construction sector has made use of Internet tools in several different ways. Some construction companies may be ahead of others in the level to which they have embraced this new technology. Depending on the level of involvement in adopting new technologies such as electronic commerce, the benefits may differ. Some of the current trends of electronic commerce in construction industry are as follows:

- **Company Promotion**: The Internet is being used to promote companies by the dissemination of company information. Architects, designers, fabricators contractors and other members of the construction sector are using the Web to promote their companies and inform people about the services they have to offer. The main idea behind such a site is to promote the company, its products and the services it has to offer to its targeted market.
- **Product Promotion**: The Internet is used for the purpose of increasing product sales through online promotion. Product promotion is done either through an independent Web site or through an online vendor. Such a product promotion site displays all product specifications that can include manufacturer details, product availability, quality assurance, cost and mode of delivery. This information is stored categorically and is regularly updated.
- **E-Procurement through Web Directories and Search Engines**: Some of the principal methods of locating information on the Web are with the help of search engines, Web directories and broadcast or ‘push’ technology (Laudon and Laudon, 2000). Search Engines search documents for specified keywords and return a list of the documents where the keywords

were found (Webopedia, 2000). The Web can be used as a tool to procure or obtain information about construction related suppliers and their products. Several Web sites provide a search tool for the user to access varied information about the construction industry. Information may be varied and can range from items such as jobs and products to specific information about bidding processes.

- **Project Management**: Some Web sites are designed to streamline the construction business process. These sites look into how the Internet can be used to improve and integrate the process of design and management of a construction project. Such a project management site may yield several benefits to its users. It can result in speeding up the process of communication between different parties involved in a construction project and thus avoid any unnecessary delays that are often a direct result of miscommunication.
- **Project Collaboration**: The Web can be used as a tool to facilitate online collaboration for project partners, which allows project partners to collaborate and communicate with each other in real time. The concept of online collaboration defies the boundaries of time and geography and allows construction stakeholders to among other things, exchange ideas and make comments no matter where they are located. There are several online project collaboration tools available for construction project teams.
- **Online Tendering**: The Internet has now made it possible to have online tendering services. With this facility it is possible to provide tendering information online along with project specifications.

5.2 ELECTRONIC COMMERCE ENABLERS

The emergence of electronic commerce has revolutionised the way in which companies trade and conduct business. Some of the advantages of previously discussed electronic commerce applications in the construction sector can be summarised as follows:

- **Company/Product Promotions**: Using the Internet to promote a company or its products can facilitate a reduction in advertising and marketing costs, provision of company information (products and services) through a Web presence, easy access to target audiences from the construction sector, and transparency with customers.
- **E-procurement through Search Engines and Web Directories**: Internet-based construction search engines can allow several advantages. These include quicker access to construction-related information, up-to-date product and industry information, simplified procurement business processes, cost savings through disintermediation and quicker product comparison in terms of price and quality.
- **Project Management/Online Project Collaboration**: Online collaboration tools can facilitate easier management of construction projects, easier access to project information from anywhere at anytime, faster transaction time, better transparency in the exchange of project information, better collaboration between construction project partners, time savings for communication of project information, savings on project cost, and streamlined construction business processes.

- **Other Benefits**: In addition to the benefits cited above using electronic commerce applications in construction can reduce paperwork, reduce re-keying of information (thereby reducing errors) and provide wider market reach.

5.3 BARRIERS TO ELECTRONIC COMMERCE

In spite of all the benefits electronic commerce provides, there are some major concerns that need to be addressed in order to increase public confidence in adopting electronic commerce applications. The barriers to electronic commerce can be classified into two categories, namely barriers that are common to all industry sectors including the construction sector and barriers specific to construction electronic commerce applications.

5.3.1 General Barriers to Electronic Commerce

The general barriers to electronic commerce mainly fall into three categories, namely issues related to infrastructure, trust and reliability and regulatory issues. Within each of these categories there are issues that need to be considered for governments, users and consumers alike (Thorbjornsen and Descamps, 1997).

- **Infrastructure**: The Internet is a global phenomenon, however, the telecommunications infrastructure of several developing countries is not sufficiently developed to handle the advances in electronic commerce technologies and to compete at par with their developed counterparts.
- **Trust and Reliability**: Confidentiality of data must be maintained, as data must not be visible to 'eavesdroppers'. It is also important that communicating parties are able to authenticate the identity of the other party, and know when data integrity has been compromised. In addition, once an exchange is complete, it must be possible to prove that a transaction has taken place.
- **Regulatory Issues**: Companies see unclear regulatory issues (such as tax issues, legal issues, ethical issues etc.) as major deterrents in adopting e-measures. Electronic commerce analysts suggest that security is the most important factor that is preventing companies from adopting electronic commerce measures. There are several initiatives that governments are taking to combat these common fears. The US government has addressed these issues concerning global electronic commerce in a paper 'A Framework for Global Electronic Commerce' (Clinton and Gore, 1997). Some of the issues addressed in this paper are:
    - Financial Issues such as customs, taxation and electronic payments.
    - Legal Issues such as 'Uniform Commercial Code' for electronic commerce, intellectual property protection and privacy/security issues.
    - Market Access Issues e.g. Telecommunications infrastructure and information technology.

5.3.2 Construction Specific Barriers to Electronic Commerce

There are several factors that have limited the uptake of electronic commerce in construction including the high cost of initial investment associated with building the required infrastructure and training of personnel, quantifying the return on investment (ROI), security of data in online transactions, integration with legacy systems and

interoperability of distributed software applications over the Internet (Ugwu et al., 2000).

Furthermore the construction industry operates using “arms length contractual relationships” that does not encourage unnecessary risk (Lewis, 1999). For most construction projects teams are formed for the duration of the project and these last only as long as the project itself. This temporary nature of relationships provides little incentive for investing into innovative technologies such as electronic commerce. Another major barrier to the implementation of electronic commerce in the construction industry relates to the investment justification for construction firms especially SME’s. Elliman and Orange (2000) state that SME’s simply do not have the capital needed to implement electronic commerce technologies to support their business and project activities. The reason being payback from investment in such technologies can extend beyond a twelve-month period. Consequently, the money invested for initial set-up becomes dead investment for this period. Most SME’s are unable to sustain this investment.

The barriers to the effective use of electronic commerce can be overcome if the infrastructure for electronic commerce use is properly created. Security issues can be handled through firewalls and secure encryption technologies. Currently most of the communication, both within and outside construction organisations takes place by exchanging e-mails. Most of the e-mail messages are routed between the Internet service providers over public telephone networks and therefore are no more (or less) secure than the conventional telephone calls. The public trust is more biased towards telephone calls than electronic mails. Therefore it is essential to build consumer confidence in electronic means of communication and data exchange. Consumer confidence can be addressed with the help of secure trading standards and updated consumer laws. Security issues concerning organisations are partially addressed by the Electronic Commerce Bill. This bill will ensure that data is encrypted in order to guarantee confidentiality. One of the measures taken to combat trust and reliability issues is the Data Protection Act 1998, which gives consumers the right to object to the use of their personal data for direct marketing (Rimmer, 2000).

6. FUTURE TRENDS

Electronic commerce technology is changing at a rapid pace. Companies will have to devise new measures and strategies to automate their current business processes to incorporate electronic commerce applications in their day-to-day business processes. The construction industry will be influenced by these developments. These influences will be both cultural and technical. The growth of electronic commerce is exponential; therefore it is difficult to predict the future trends of electronic commerce. However, some of the emerging trends of electronic commerce that could be used in the construction industry are:

1. M-Commerce: Since it is possible to connect mobile devices such as mobile phones and PDA’s (Personal Digital Assistant), new research is being taken up to explore the opportunities in mobile electronic commerce or m-commerce. Research in this field is in its infancy and therefore it is difficult to establish if this trend will take off (Dr. Ecommerce, 2000).
2. Wireless Communications such as Bluetooth: Bluetooth is a form of wireless technology that will remove the need for cables connecting computer equipment. It operates by means of low-cost short-range radio links that can be between mobile and stationary PCs, mobile phones and

other peripheral devices. The possible uses of such a system are infinite as they speed up the distribution of information and allow increased mobility e.g. staff on construction sites will be able to communicate, collect and distribute data/information electronically (Fleming, 2001).

3. Ubiquitous Computers: It may become possible for more and more household and office appliances to be connected to the Internet resulting in these devices making transactions on behalf of people. Such intelligent devices can open up endless possibilities, which are difficult to predict. (Dr. Ecommerce, 2000).
4. Agent-based Procurement of Goods and Services: Procurement is now possible through intelligent autonomous software agents (Obonyo, et al., 2001), this being a shift from software-as-tool to software-as-assistant. The user informs the software agent about the various tasks to be performed. The software agent then acts in a proactive manner by accomplishing tasks such as monitoring incoming mail, comparing price lists of construction material, and organizing agenda when the user is not present (Kalakota and Whinston, 1996).

7. DISCUSSION AND CONCLUSIONS

It is evident that the use of electronic commerce in construction can yield several benefits. Electronic solutions will enable more people to be reached with much less effort than it currently takes to reach a single customer. It will be possible to reach thousands at the same time and will cost only a fraction of what it costs today. The use of electronic commerce is still in its infancy in the construction industry; with the main barrier being that the use of the Internet is not ubiquitous. In spite of being relatively slow in adopting this new technology, the construction industry is beginning to recognise the potential advantages that electronic commerce solutions have to offer.

Currently, the trends in the market are mixed. On the one hand there are companies that offer purely electronic online services for tasks such as finding jobs and doing e-business, while on the other hand, there are those who have yet to accept the Internet as a tool to improve the traditional, tried and tested methods of carrying out business and managing construction projects. However, there are positive signs that the industry is moving towards the adoption of Electronic commerce. For example, even those companies that are sceptical about electronic commerce are online and have a Web address. Some clients are also beginning to put tender information on the Internet and requiring bidders to submit their tenders electronically.

More work is required to encourage the construction industry to adopt this new way of conducting business. ‘The critical element is getting people to understand and buy into the system’ (Russell, 2000). This will be easier if it is client-led, as clients have the clout to insist that their projects are procured in a certain way, particularly if there are demonstrable benefits for all participants. However, these new ways of working will work best if team members embrace them whole-heartedly.

‘Recent industry research suggests that half of all construction transactions will be conducted online by 2005’ (Russell, 2000). A number of research institutes and companies in the construction industry are investigating the Internet and the possible benefits it has to offer. This will further stimulate the adoption of Electronic commerce, as new tools and business process models become available. Some of the big players in the construction industry have already realised the potential that this revolutionary technology has to offer.

The nature of the construction industry is such that project communication is a complex activity. Projects involve a large number of organizations that may be geographically dispersed. Electronic commerce is seen as the solution to project communication and information dissemination problems. Electronic commerce is changing the way in which projects are managed and implemented. It offers several benefits to the construction industry in terms of greater collaboration, efficient dissemination of project information, and cost reduction (as the electronic exchange of documents offsets printing, copying and transport costs). The barriers to electronic commerce such as security and privacy issues are being addressed through the introduction of new legislation and data encryption standards. Some of the other barriers are being addressed by research projects in the UK and elsewhere. The research at Loughborough University is focusing on three key areas:

- Investigating the business process implications of electronic commerce in the construction industry (Ruikar, et al., 2001).
- The development of intelligent product libraries to facilitate automatic storage and retrieval of product information from manufacturer's databases.
- The use intelligent agents to automate aspects of the electronic transactions and business processes involved in electronic commerce.

Clearly, the construction industry needs to make the investments necessary to reap the benefits of electronic commerce and overcome the current barriers. This will entail investing in the enabling technologies, exploring new ways of working with the available technologies, and contributing to the development of customised solutions that meet the industry's needs.

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APPENDIX B PAPER 2 (REFEREED CONFERENCE)

Ruikar, K., Anumba, C. J., and Carrillo, P. M., (2002). 'Industry Perspectives of IT and E-commerce', *Proceedings of the 3rd International Conference on Concurrent Engineering in Construction*, at University of California, Berkeley, July 2002, pp. 26 – 40.

INDUSTRY PERSPECTIVES ON THE IMPACT OF IT AND E-COMMERCE

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ABSTRACT

In recent years several new IT-based technologies such as e-commerce have been developed, which if applied to the construction industry can prove beneficial. Before the implementation of new technologies and applications, it is essential to identify the factors that the industry perceives as being the enablers and barriers to the uptake of these applications for greater effectiveness. This paper presents the results of a survey undertaken to establish the views of industry practitioners on the uptake of IT (and e-commerce in particular) within the UK construction sector. The survey explored attitudes, current usage, barriers and enablers amongst other things. The findings of the survey are briefly discussed and outline ideas for more effective deployment of IT and e-commerce in construction organisations presented. The paper also tries to outline some future prospects for using e-commerce in the UK construction industry, based on responses to the survey.

KEYWORDS

Information Technology, E-commerce, Construction Innovation, UK Construction, E-commerce Barriers and Enablers

1. INTRODUCTION

It has been well documented that the construction industry is characterised as being both fragmented (Anumba and Evbuomwan, 1999; Egan, 1998; Lottaz et al., 2000) and information-intensive (Thomas et al., 2001). A considerable degree of information flows between disciplines including client, architect, structural designer, quantity surveyor, services engineer, fabricator, subcontractors, contractor and material suppliers. A construction project is a team effort, which involves several inter-organisational activities, dialogues and data flows, making it a highly complex process (Egan, 1998). Currently, the information flow in the construction industry is mostly paper-based and hence slow. Also there is the likelihood that there will be increasing amount of communication blockages as the projects grow larger and more complex (Thomas et al., 2001). Conventional paper-based methods of communicating information are grossly inadequate particularly in collaborative/concurrent engineering settings where the project team members may be geographically distributed. It is therefore very important for construction project teams to look at alternative and more effective ways of communicating through the project lifecycle. Construction projects can incur considerable savings in terms of time and money by adopting dynamic methods of information exchange and communication facilitated by IT and e-commerce tools. The exponential growth of the Internet and the growing use of IT have accelerated the pace of change, and demand more flexible and adaptive organizations (Malone and Crowston, 1991). Construction organisations that decide to enhance their business processes using IT and the Internet should recognise that adopting such 'innovative' methods will facilitate in integration of the entire management process for construction projects. The flow of information in such a system will be electronic and hence interactive. It will make use of the Internet as a 'medium' for data storage, data transfer, communication, conferencing, dialogue and decision-making and acquiring information. All these tasks would be carried out in a monitored and secure environment.

With developments in IT, the construction industry is adopting new and innovative tools to overcome the current inefficiencies in its project processes; these are mainly through facilities for exchanging and organizing project information (Lottaz et al, 2000). A survey of the UK construction industry, undertaken by the Construction Products Association (CPA, 2000), predicted that by 2005, 50% of the industry's business activity would be undertaken using e-commerce. However, another survey carried out a year later by the same organisation (CPA, 2001) indicated a considerable reduction in these projected figures to 22%. The construction industry stepping back from the initial 'dotcom fever' was seen as the main reason of this change. This paper presents selected results from a 2001 survey on Information Technology and E-commerce in Construction that was carried out to establish the current usage of IT and e-commerce in the UK construction sector. This survey has been carried out as a part of a broader research project on 'Business Process Implications of E-commerce in Construction' at Loughborough University. The primary objectives of the survey were:

- To establish the readiness of UK construction industry to adopt IT and, in particular, e-commerce technologies and;
- To identify the barriers and enablers to the implementation of these technologies in the day-to-day construction processes.

The paper gives background information about the survey questionnaire and objectively analyses the results using illustrative charts and statistical data as appropriate. Finally, the paper discusses the future prospects for using e-commerce in UK construction, based on the survey results.

2. SURVEY BACKGROUND AND METHODOLOGY

Several surveys have been conducted in the past couple of years to determine the impact of IT in the construction industry worldwide (Rivard, 2000). In the UK surveys have been conducted to gauge IT usage within the construction sector by DETR in 1999 and by the CPA in 2000 and 2001. The data used in the DETR survey is already three years old, while the CPA survey concentrated on e-commerce transactions within the construction supply chain, and particularly with respect to construction product suppliers. The survey conducted by the authors mainly focuses on the uptake of e-commerce and IT within the construction industry and identifies the main barriers and enablers. It is vital that the barriers, enablers and the potential of using technologies such as e-commerce are identified, examined and analysed in order to make recommendations for an effective uptake of these technologies within the construction industry. The findings of this survey will be used as one of the sources to formulate an effective strategy for development and uptake of new e-commerce applications in the construction sector. In order to benefit fully from such technologies will require changes to the existing business processes (Howard and Andresen, 2000). This is one of the key objectives of the research project that looks into re-engineering the current construction business processes with particular focus on suppliers and end users.

The survey was carried out in the first half of 2001. The questionnaire occupied four sides of A4 paper. Paper copies of the survey questionnaire were distributed by post to a random sample of 145 construction organisations encompassing various construction disciplines including architects, engineers, contractors, manufacturers and suppliers within the UK. Each respondent was given the opportunity to respond anonymously, however, a high percentage of all the respondents provided contact details to receive a copy of the survey results. The findings presented in this paper are based on an overall response rate of 22%.

3. SURVEY ANALYSIS AND RESULTS

Selected results from the survey are presented in this paper and include computer usage (hardware and software), communication networks (inter and intra-disciplinary levels), information technology, and e-commerce technology within the UK construction sector.

3.1 COMPUTER USAGE

This section considers the level of computer usage and includes the use of different types of operating systems, office software applications and specialist applications performing specific business operations. The survey results indicate that the type of operating system used varies from company to company, with the Microsoft Windows being the most commonly used.

Effective communication is key to the success of any construction project. It has been well documented that a wide array of communication problems, ranging from delays to distortion of messages, can impose strains on overall construction project management and project performance. The prohibitive costs of making long distance calls, facsimile transmission etc, have made the project management community in construction look for more viable alternatives (Alshawi and Ingirige, 2002). The survey results have shown that the use of e-mail as a mode of communication is common and almost all companies surveyed use e-mail. Continuing the trend of dominant usage of Microsoft applications, it is seen that MS Outlook (73%) is the most commonly used e-

mail application.

There are several specialist project management software applications available in the market and the survey results show that a high percentage of responding companies use project management software applications to manage projects. 53% of the respondents use MS Project as a project-planning tool while 27% used Primavera (www.primavera.com). Other planning tools namely, PowerProject (www.astadev.de) and SureTrak (www.primavera.com/products/sure). are also used.

The survey also investigated the types of database systems used in the industry and the results suggest that the use of these systems is relatively common amongst participant construction organisations. The use of MS Access (65%) is higher than that of other database systems such as Lotus Approach (5%), dBase (5%) and SQL (15%). The remaining 10% use other database programs (e.g. Oracle).

The main output of any architectural and engineering firms is drawings and these drawings are now mostly generated using computers (Rivard, 2000). The survey results indicate that CAD (Computer Aided Drafting) packages are widely used throughout the industry. While 100 % of the architects use CAD packages for design drawings, the average percentage of CAD usage in the industry (including manufacturers and contractors) is 87%. CAD in this context refers to 2D(two-dimensional) CAD drawings.

3.2 COMMUNICATION NETWORKS FOR CONSTRUCTION

The efficiency with which information is communicated between different project partners of a construction project will depend on the communication systems that are being used by each individual organisation involved in the project. The survey tried to establish the percentage usage of different communication media including mobile phones, personal email, pagers and Internet, amongst office and on-site construction staff. Amongst construction companies, over 65% of *office staff* are connected to the Internet and over 85% have access to e-mail (see Figure 1). In contrast, only 40% of *site staff* has e-mail access. The use of mobile phones is twice as high for on-site staff (approx. 60%), as for office staff. This suggests that there is a high percentage of use of communication media within UK construction supply chain.

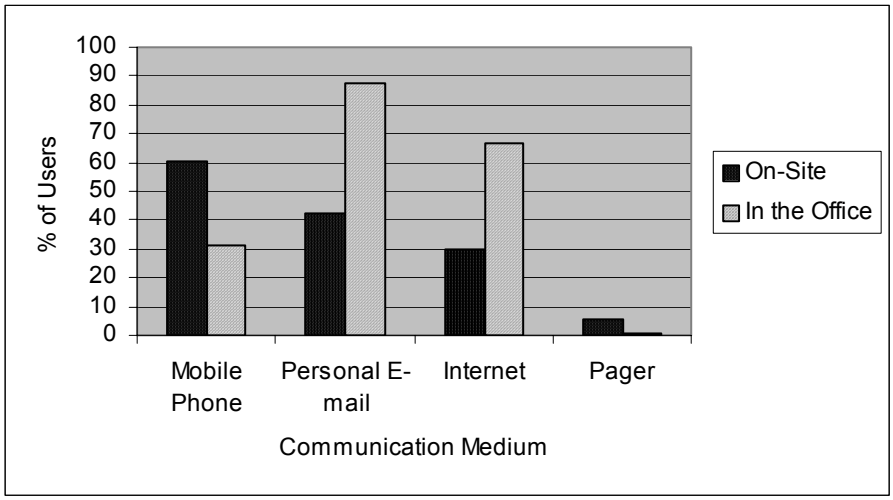

Figure 1. Percentages of Staff With Access to Communication Media

In recent years an increasing number of companies make use of the Internet to advertise and market their products and services (Ruikar, 2001). The survey results confirm this trend and figures show that 90% of the responding companies have company Web sites that advertise the company's products and services.

Intra-disciplinary mode of document exchange in construction organisations: Any construction project involves the production and exchange of a large number of documents and drawings at both inter- and intra- organisational level. A high percentage (73%) of the respondents said that e-mail is the most popular medium for the exchange of documents internally within their organisation, while FTP (File Transfer Protocol) is the least likely. It can be seen that the method for exchange of documents/drawings internally, largely depends on the size of the organisation itself. While larger organisations use e-mail as the preferred choice, SME's (Small to Medium-sized Enterprises) exchange documents by hand.

Interdisciplinary mode of document exchange: The survey findings show that e-mail, fax and post are the most popular methods of exchanging information between construction disciplines (see Figure 2). However, the most preferred method of communication could not be conclusively derived from these results. This could be because; depending on the document type, the preferred medium for inter-disciplinary document exchange may vary. For example, most companies' exchange documents such as specifications and project drawings electronically, while the exchange of documents such as Bills of Quantities and technical calculations is seldom done in an electronic format.

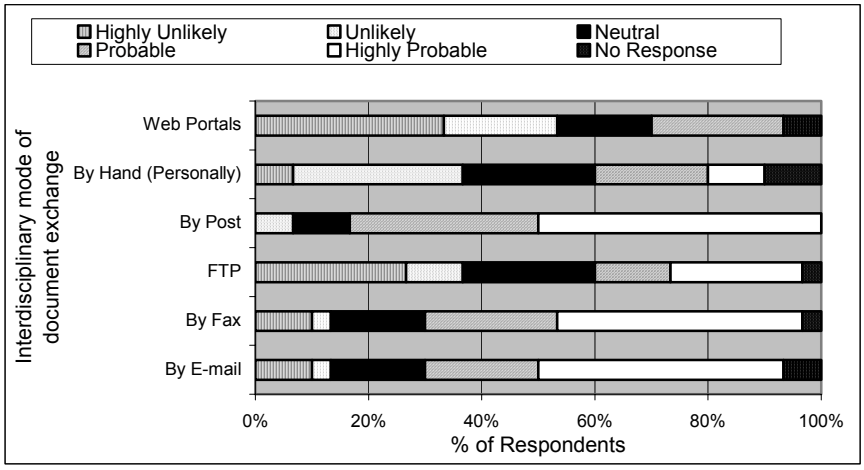

Figure 2. Interdisciplinary Mode of Document Exchange

3.3 ROLE OF IT WITHIN CONSTRUCTION COMPANIES

The main focus of this part of the survey was to examine the role of IT within the surveyed construction organisations and to establish the impact of IT on the organisation's day-to-day activities. Of the surveyed organisations it can be seen that 73% of architectural and engineering firms have a dedicated IT department and a definitive IT policy. It is evident that majority of the responding contracting companies, have IT managers, but no well-defined IT policy.

The successful introduction of any new technology depends upon the receptivity of the staff (Rivard, 2000). The results have shown that the overall attitude towards the implementation of IT is generally positive. In order to establish the attitude of

construction disciplines towards implementing IT measures, it was necessary to examine the most common factors that influence investments in this area. The need to improve the efficiency of office administrative work and demands from clients, are rated as the two most likely factors influencing IT investments. Additionally, a high proportion of the respondents (60%) also rate the need to be at the forefront of technical innovation, and demands from staff/employees as factors influencing IT investments. Some contracting organisations are hesitant to invest in IT and even suggested that their company would only be pushed into making IT investments, only if it is a client requirement or they can see quantifiable gains from it, in terms of improved business processes.

The survey questionnaire also tried to establish the extent to which the use of IT can improve the design or construction processes. Figure 3 shows the viewpoint of the respondents regarding the influence of IT in areas such as document quality, document errors, speed of work, interdisciplinary communication and construction business processes. More than 80% of the respondents regard increased speed of work, and improved interdisciplinary communications as the key influences of IT on design and construction processes. The response suggests that IT is currently being used to facilitate faster distribution of construction information. Every time data is re-keyed, it can become a potential source of error. Also each time data is transferred from one document to another, or entered into an electronic repository, there is a good probability that errors will be introduced into the data (Sharda, 2000). Some research studies suggest that businesses can eliminate errors that are caused due to data re-entry using technology tools (Watson and Anumba, 1991; Anumba, 1996); however, from the survey findings there is little evidence to suggest that the use of IT can reduce construction errors.

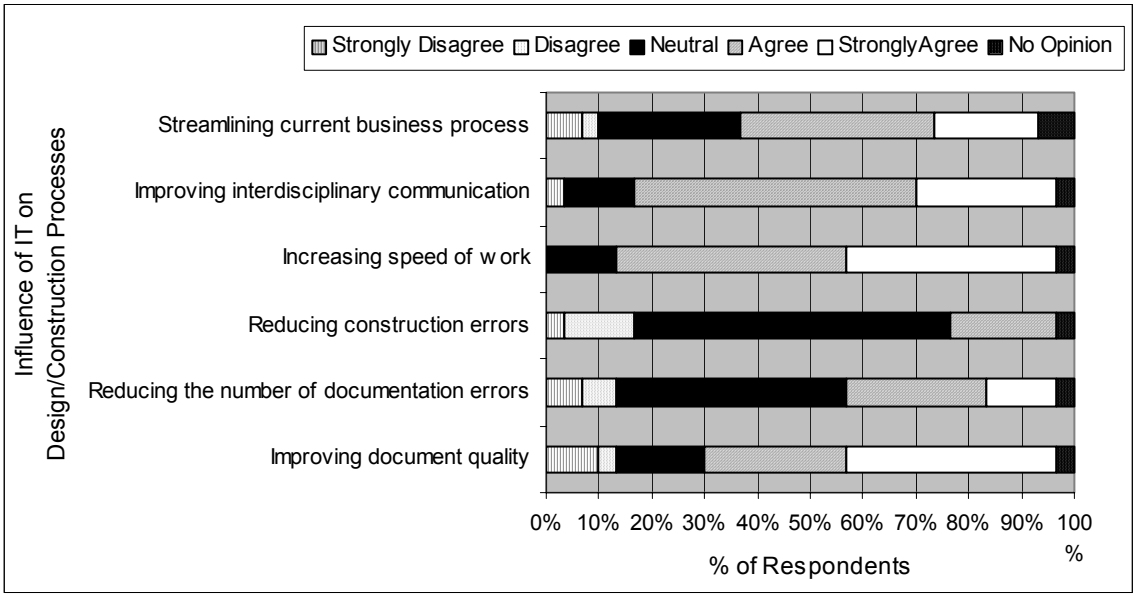

Figure 3. Influence of IT on Design and Construction Processes

Members of the construction industry need a sound understanding of the potential of advanced IT systems in construction if they are to gain business benefits from their use (Construct IT, 1996). From the survey results, it is possible to establish the key areas in which productivity has increased because of IT use among the participating companies. By productivity the authors mean an increase in the throughput. When asked whether the introduction of IT has lowered or increased productivity in areas such as company administration, project management and coordination, design and

site management and interdisciplinary communication, 93% of the respondents said that efficiency in the area of company administration has increased (see Figure 4). The responses also suggest that areas of management such as site management have shown little change in productivity due to IT implementation (67% of contractors reported either very little change or no change).

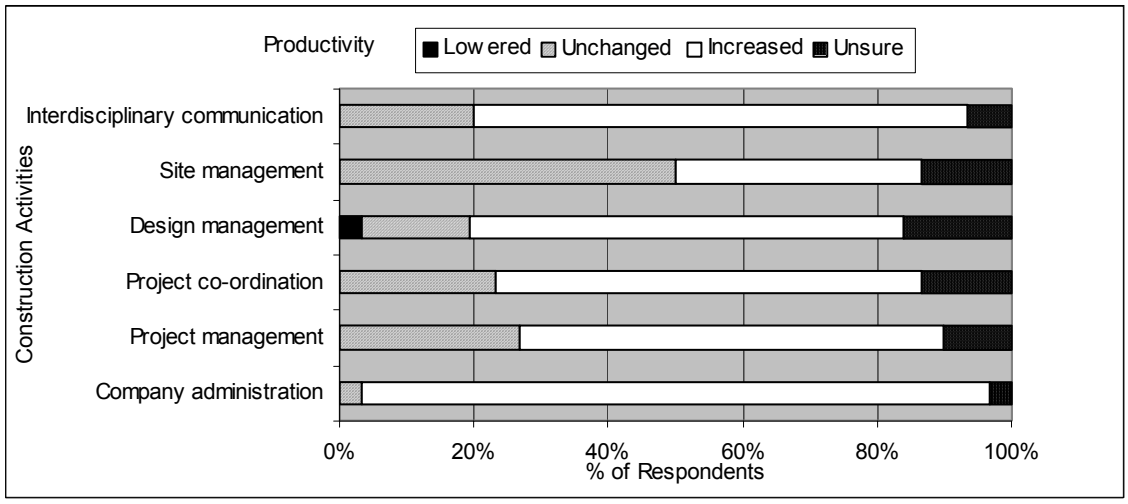

Figure 4. Influence of IT on Productivity

To establish in which areas future IT investments are most likely, respondents were asked to prioritise the possible IT areas in which their respective organisations are planning to invest within the next two years. Among the possible six choices included (see Figure 5), investment in CAD (Computer Aided Design) applications has the highest priority rating. Web collaboration portals, design and document management tools are also amongst the most popular IT systems for future investments, while investment in Virtual Reality (VR) applications has been given the least priority. Previous research studies in the area of VR state that the requirements of specialist skills, dedicated staff, cost of implementation and lack of integration between application packages (e.g. integration between CAD and VR software), are the major barriers to the implementation of Virtual Reality systems in construction (Issa, 2002); the industry needs to take these issues on board to encourage wider usage.

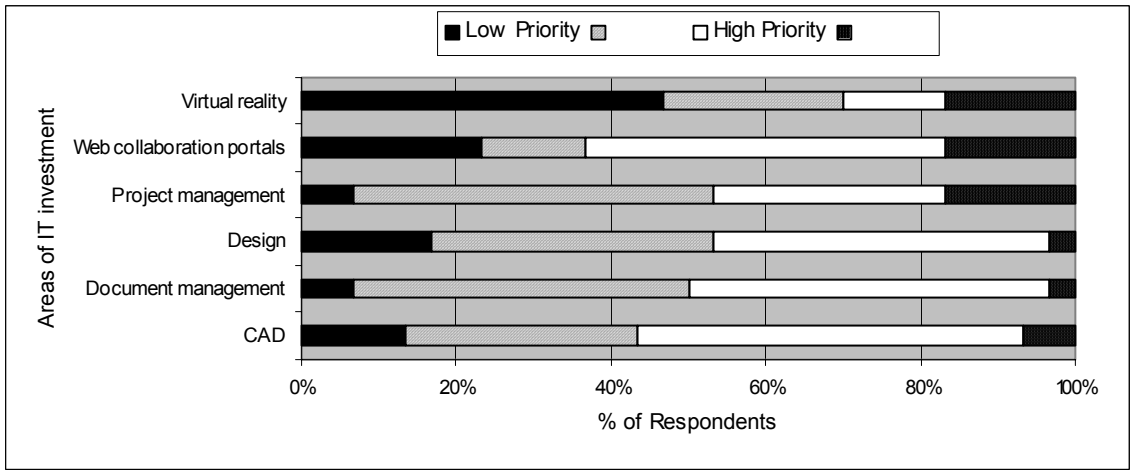

Figure 5. Future Investments in IT

In order to take on board new technologies it is vital that the benefits of and barriers to the use of these technologies are carefully examined and analysed. A

majority of the respondents consider the use of IT applications to be beneficial for different tasks in the construction process (see Figure 6). In the view of more than 50 % of respondents, use of IT has helped in improving interdisciplinary communications and financial control, speeded up work and increased the possibility of sharing information. Implementing IT to facilitate better management of project data/documents and streamlining the business process are also seen as benefits. A report by the UK Task Force (Egan, 1998) has stated that technology alone cannot provide the answer to the need for improved efficiency and quality in construction. The survey results support this, as more than 60% of respondents do not agree that the use of IT can improve the quality of work.

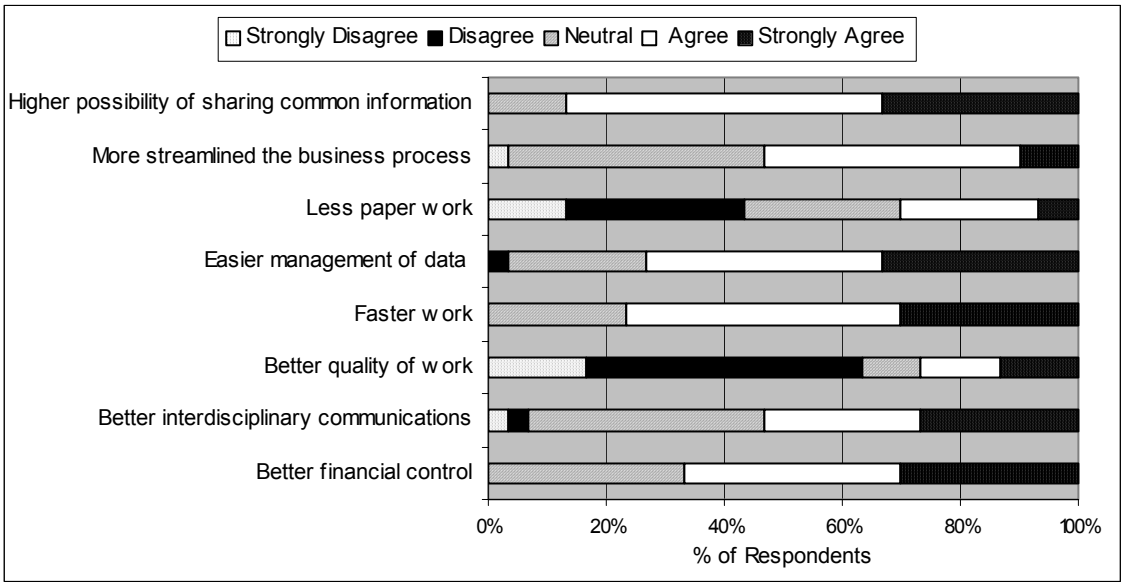

Figure 6. Possible Benefits of Implementing IT Measures

To establish the barriers to the implementation of IT measures, the respondents were asked to rank the barriers, which in their view are preventing wider implementation of IT within the construction sector. Barriers listed in the questionnaire were collated after a thorough literature review carried out by the authors (Ruikar, 2001). The respondents were invited to suggest/specify additional barriers. The results suggest that factors such as high cost of initial investment, lack of commitment from management in implementing IT and a lack of interest from company decision makers, are seen as the main barriers to IT implementation. Also, the low profit margin of construction companies is regarded as a barrier to the adoption of IT tools. Majority of respondents do not regard IT-related security issues, regular upgrades of software or hardware, and possible information overload as major barriers. The following section explores the uptake of e-commerce applications in the construction sector, the associated benefits and barriers.

3.4 E-COMMERCE IN CONSTRUCTION

By establishing the extent to which the Internet has influenced the construction industry and examining areas in which e-commerce is currently being used, it is possible to gauge the industry's changing attitude towards using technology. The section on computer usage in construction companies has shown that a high percentage of staff has access to e-mail. Also, the most common use of the Internet is for the exchange of information using e-mail services (Figure 7).

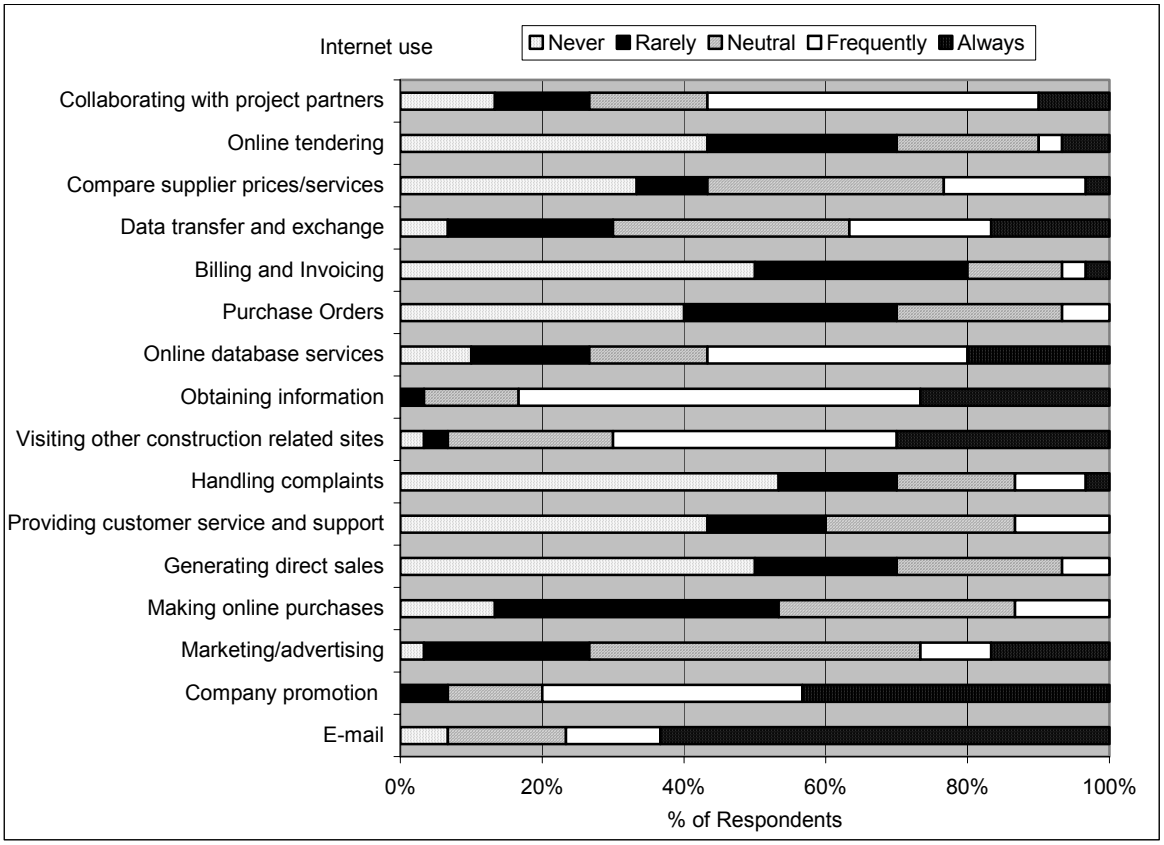

Figure 7. Use of Internet in Construction

The Internet is an efficient medium to promote a company's products and services. A majority of the companies (80%) have a dedicated company Web Site and use the Internet for company promotion. The survey outcome also suggests the Internet is being widely used for retrieval of construction-related information. About 50% of the respondents also use Web-based collaboration tools. An interesting observation is that a high percentage of the responding manufacturing companies do not use the Internet for strategic activities, such as customer relationship management (CRM). Also, very few firms use the Internet for financial transactions such as billing and invoicing (6%), online tendering (10%) and purchase orders (7%).

According to many leading experts (Anumba et al., 2000; Elliman and Orange, 2000; Alshawi and Ingirige, 2002), the Internet has the potential to transfer complex information accurately, speed up transactions and provide instant access to information from anywhere and at anytime. One section of the survey questionnaire was therefore aimed at establishing the industry's view of the potential benefits of e-commerce. The questionnaire presented ten possible benefits and encouraged the respondents to include additional benefits. The results indicate that most respondents have a neutral view of the benefits of e-commerce to construction (Figure 8), with a majority of respondents unsure of the exact benefits of e-commerce to their respective organisations.

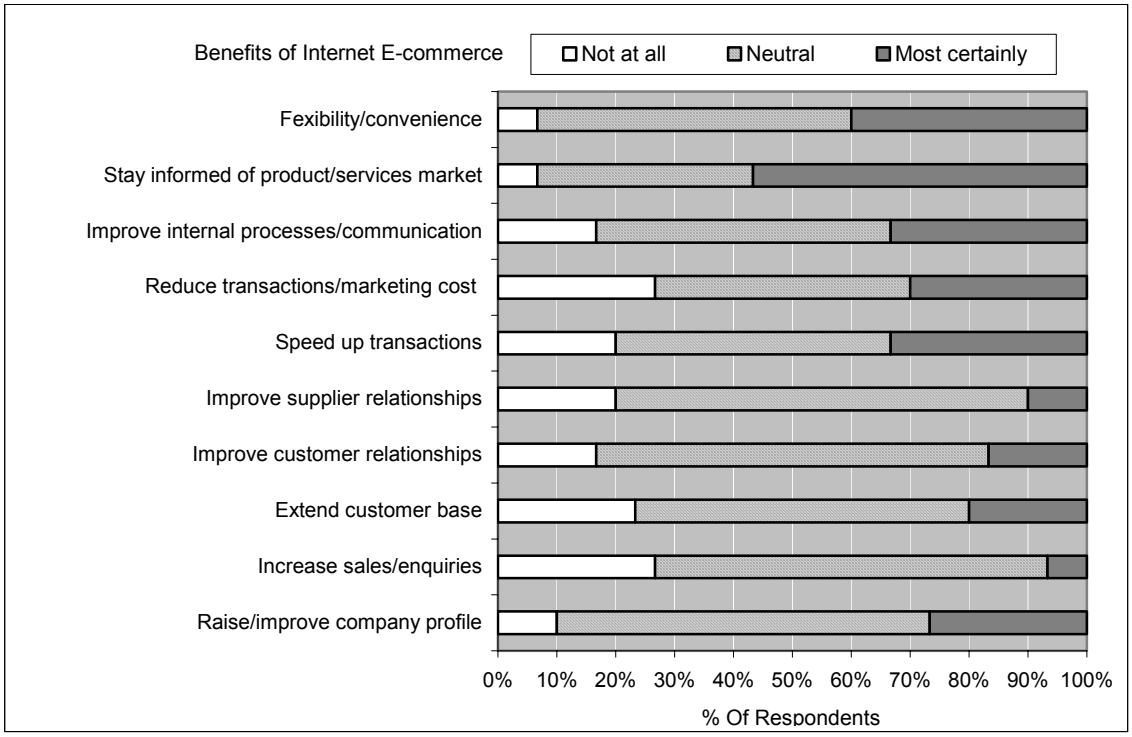

Figure 8. Benefits of Internet E-commerce

Unlike other industries, the construction industry has been relatively slow in the uptake of e-commerce. It was therefore essential to obtain the industry's viewpoint on the main barriers to e-commerce in construction. Issues related to Internet security and a lack of standards for information exchange across networks, as the two main barriers for using e-commerce. This could be one of the main reasons for the limited use of the Internet for financial transactions such as billing and invoicing, online tendering and purchase orders. Although security issues have been considered as a top priority at cross-disciplinary level, these are not viewed as high priority in IT implementation, which is usually within the organisation itself. Cultural issues, associated with the transition from traditional methods to the use of new tools, are also seen as a major barrier. Other issues associated with using the Internet, such as the invasion of privacy and unsolicited mail are, however, not seen as major deterrents for e-commerce adoption.

4. CONCLUSIONS AND FUTURE WORK

The survey results revealed that there is a considerable usage of IT applications in the day-to-day working of most UK construction organisations and the level of IT investments largely depends on the size of the organisation. The results show that most firms use email as a vehicle to communicate with peers. It has also shown that although the Internet is being used to obtain construction related information and data, the construction industry has been relatively cautious in the use of the Internet as a mechanism to conduct day-to-day business. Many in the construction industry believe that the future of e-commerce in construction is still quite unclear and the objectives for using e-commerce technologies in construction have not been clearly defined. This may be due to the lack of a well-defined business process model that integrates e-commerce with the existing infrastructure of construction companies. In order to adopt IT and e-commerce strategies into the day-to-day working of construction projects, companies will have to radically alter the traditional processes of managing

construction projects and also the way in which project partners collaborate and communicate with one another. It is therefore, essential to study and examine the effects of incorporating e-commerce and IT based applications into the construction business process. One of the benefits of adopting e-commerce can be a streamlined and more efficient construction business process that uses electronic tools for information exchange and data flow. There is potential for research in the area of development of business strategies for the effective adoption of new technologies such as e-commerce in construction.

Although e-commerce and IT usage can be beneficial to construction there are several outstanding issues such as security that need to be addressed. Reliance on computers requires the working environment to be secure. The high degree of computer dependence and newer systems such as networking and the Internet have made it essential for organisations to invest in computer security systems. Organisations must develop policies to detect computer attacks and prevent computer-related crimes. Barriers to electronic commerce such as security and privacy issues are being further rectified through the introduction of new legislation and data encryption standards. When projects are managed using on-line collaborative tools a huge database of information is created. On completion of the project the data needs to be archived (currently on CD-ROMs). There are concerns about future accessibility of this data when current technologies become obsolete. Thus construction-sector organisations should take measures to ensure continued access to project information (Berning and Diveley-Coyne, 2000).

The following recommendations can be made based on the study presented:

- There is potential for conducting future research in the area of development of business strategies for the adoption of e-commerce, including the most appropriate e-commerce business model(s) for the construction industry.
- Construction organisations need to explore the new opportunities offered by e-commerce and re-engineer their business process to maximise the benefits.
- Changes that occur in the construction business process due to the adoption of IT and e-commerce measures need to be continually monitored and documented so that a best practice strategy for their adoption in construction can be formulated.
- As e-commerce is still in the early stages of implementation in most construction organisations there are very few performance measurement tools available to quantify the benefits. More performance measurement tools need to be developed as the technology usage matures.

Based on the findings of this survey, literature review and interviews work is currently in progress to propose a representative construction business process model that uses the principles of BPR. This model proposes the use of IT and Web-based tools in the construction business process with specific focus on construction suppliers and end-users. Clearly, the construction industry has much to gain from the adoption of IT and e-commerce. Greater investment in the enabling infrastructure and in staff training is vital if these benefits are to be realized. The survey results indicate that the UK construction industry has an unclear understanding of the possible benefits of e-commerce. Thus, if the short-term and long-term benefits of adopting e-commerce technologies are made clearer and are found to be profitable, then all barriers to its adoption can be more readily addressed.

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APPENDIX C PAPER 3 (JOURNAL)

Ruikar, K., Anumba, C.J., and Carrillo, P.M. (2003). 'Reengineering Construction Business Process through Electronic Commerce', *The TQM Magazine, Special issue: Managing Quality in E-Operations* , Emerald Press, UK, Vol. 15, No. 3, pp 197 – 212.

REENGINEERING CONSTRUCTION BUSINESS PROCESSES THROUGH ELECTRONIC COMMERCE

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ABSTRACT

There is a growing use of electronic commerce in the industrial world. However, its use in construction has been relatively limited and ineffective compared to other industry sectors such as the automotive or aerospace industries. One of the reasons for this could be the fragmented nature of the construction industry and the one off nature of the end product. New research indicates that there is a lack of defined or clear objectives within the construction industry regarding electronic commerce usage. It is also evident that a majority of the industry players are unsure of the exact benefits of electronic commerce applications in construction. This paper tries to address these shortcomings by presenting how the current construction business process can be improved through the use of new and innovative electronic commerce applications. It also outlines some of the benefits these applications have to offer the construction supply chain in delivering a better quality product, namely, the constructed facility.

KEYWORDS

Electronic Commerce, Business Process Reengineering, Construction, Online Collaboration, Supply Chain Integration.

1. INTRODUCTION

The uptake of electronic commerce in construction has been relatively slow compared to other industries. The reason for this could be the fragmented nature of the construction industry and the one-off and changing nature of the construction end product. Traditionally, new teams are formed for every new project and these teams disperse once the project is complete, thereby, contributing to the fragmentation. Also a construction project itself is a complex activity involving several multi-disciplinary participants, typically the client, architect, structural designer, quantity surveyor, services engineer, fabricator, subcontractors, contractor and material suppliers. It is a team effort, which involves several inter-organisational activities and dialogues. Currently, information flow in the construction industry is mostly paper-based and hence slow. Such traditional means of communication involve producing numerous paper copies of documents and drawings. Management of these loose documents is often a very time-consuming and tedious process. Libraries of documents need to be maintained to effectively access data as and when required by the user. Thus, the conventional methods of communicating information are proving to be outdated. The reliance on third parties such as courier services and postal services, can sometimes lead to delays. Additional expenses are also incurred in the delivery of project documents to project members who are geographically distributed.

The need for the construction industry to adopt innovative ideas and methodologies in its operation has been emphasized in several research initiatives and government reports such as the Egan report (1998), Latham report (1994), etc. However, according to recent research there is a lack of defined or clear objective within the industry regarding electronic commerce adoption (Ruikar, et al., 2001). It is seen that a majority of the industry players are unsure of the exact benefits of electronic commerce applications in construction. In order to take on board new technologies and avail of the benefits technologies such as electronic commerce can offer; it can sometimes become essential to change or even reengineer the current business processes.

This paper proposes the use of IT (Information Technology) and Web-based collaboration tool, in construction business processes. The Information Channel has been used as a specific case study example of Web-based collaboration tools. The rationale behind this business process model for electronic commerce in construction is discussed. The paper explains how such a business process can deliver a better quality product, namely, the constructed facility. Finally, it states the benefits and discusses the effects an electronic commerce application can have on the working of the construction supply chain.

2. THE NEED FOR A NEW COMMUNICATIONS MODEL

The construction industry involves several disciplines with a complex network of communications between these disciplines (Egan, 1998). Currently, all the stakeholders in a construction project communicate with one another individually with faxes, telephone networks and in some cases via electronic mail (Hibberd, 2000). This kind of one-to-one correspondence can make the communication network very complex resulting in a ‘spider-web’ network (see Figure 1).

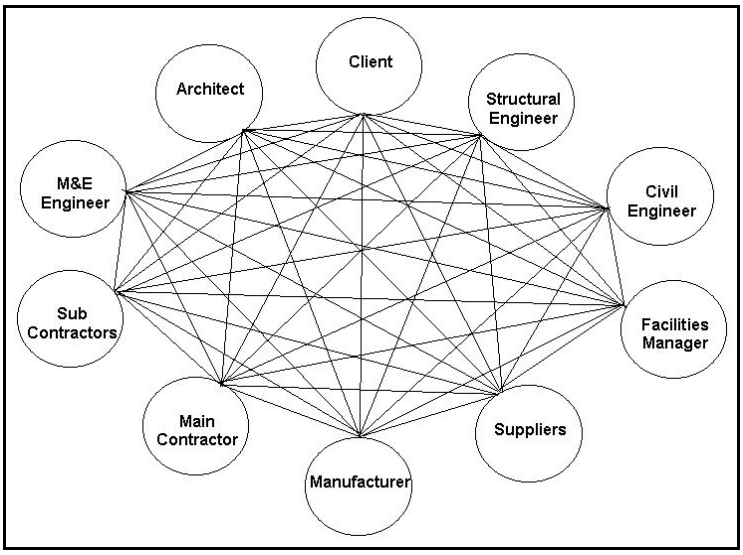

Figure 1. Spider Web Communication Network

The construction industry has taken several measures to overcome these communication problems. For example, the use of electronic technologies for data exchange was popularised during the late 1980's and early 1990's in construction. The increased use of CAD (Computer Aided Design) to produce drawings, development of STEP (Standard for Exchange of Product data) and the formation of the EDICON (EDI in Construction) organisation provided a platform for developing awareness and commitment to electronic exchange and gave direction for further development of technologies to achieve greater business benefits (Lewis, 1999). EDICON viewed the evolution of EDI (Electronic Data Interchange) as providing a means of improving interdisciplinary communications within the construction industry using a set of messages developed for industry specific applications. In spite of several efforts to improve communication through the use of EDI, research has shown that its use has not proceeded beyond the test stage in construction (Lewis, 1999). A survey undertaken by O'Brien and Al-Soufi (1994) established that the early use of EDI in construction was for trading cycle information and that there was no practical implementation of industry-specific EDI. Another survey undertaken by Akintoye and McKellar (1997) noted that EDI exchange formats were predominantly used for pilot projects. This survey also indicated that the number of contractors had not increased since the survey undertaken by O'Brien and Al-Soufi (1994), thereby confirming that the application of EDI in the construction industry was limited.

In recent years there has been a growth in the use of Internet and Internet-based technologies in construction. In order to maximise the benefits of using such technologies, it is important to develop a communication model that incorporates these technologies into the construction business processes.

3. ELECTRONIC COMMERCE IN CONSTRUCTION

Effective communication is vital for the success of collaborative and concurrent engineering in construction (Anumba and Evbuomwan, 1999). Many organisations that offer electronic commerce services e.g. extranet companies, are trying to exploit the current inefficient methods of communication and data exchange within the construction industry. This is made possible through the use of Web-based solutions for communication and project management. These electronic commerce systems are so designed that they act as a central communication base or a central hub. The hub-

centric network uses the principle of a single source and thereby reduces the number of communication passages. Figure 2 illustrates a hub-centric communication network.

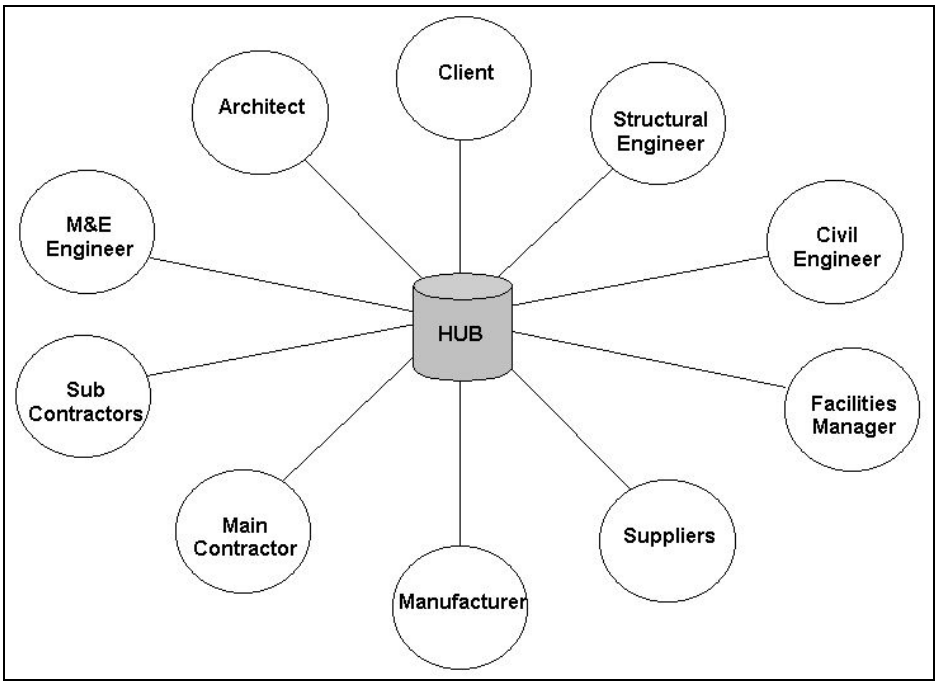

Figure 2. Hub-Centric Communication Network

The central hub enables easier and faster interdisciplinary communication in a secure environment. The result of this can be a simple and efficient form of the communication network. An example of a tool that can facilitate such a hub-centric environment to support collaborative working in the construction industry is the Information Channel developed by BIW Technologies.

4. THE INFORMATION CHANNEL

The research project Process Protocol (1995) specified a need for a project database (or an Information Channel) for construction projects. The main objective being the development of a tool that allows the entire construction supply chain to communicate and archive information (records of what was done, when, by whom etc). BIW Technologies Ltd (BIW) formerly the Building Information Warehouse developed the Information Channel (IC) in response to this need.

The IC is an online project collaboration tool with the help of which building industry professionals can collaborate with their partners and clients using Web technologies. It has been designed to encourage interdisciplinary teamwork during the entire span of a construction project, right from its onset to completion. The IC can help to manage projects, and provide structured access to all project and project-related documents. It also creates a permanent and secure database of all project information that includes drawings, revisions, comments made to prompt such revisions, documents, minutes, progress on site, site photographs and all other related data (BIW, 2000).

With the help of the IC the entire construction supply chain can communicate and archive information (records of what was done, when, by whom etc) throughout the lifecycle of the construction project. Each independent client is provided with a unique

project-specific Web site created around an information database. Using this, all relevant data/information can be made available to every (authorised) project team member – from the earliest concepts and specifications, through detailed design, buildability studies, pre-fabrication, construction, maintenance, operation and improvement, to the eventual demolition or dismantling of the facility (Wilkinson, 2001). The IC also incorporates a feature I-components (Intelligent-components) that will facilitate the capture of 'intelligent' data during the project lifecycle. I-components can provide the same advantages as the IC, but in relation to the content of the documents (BIW, 2001). Being intelligent components, the I-components learn about themselves as the project progresses. They can be programmed to know what they are, where they are and how they should respond to their location in space, functional area or perhaps what they are connected to e.g. a door. I-components can support the use of construction modelling systems by allowing users to exchange design components for the manufactured equivalents that contractors actually purchase - and therefore test for fit/clashes (BIW, 2001).

It is seen that IT and Internet based tools such as the IC and emerging technologies of computer-integrated construction (CIC) and concurrent engineering for architecture, engineering, and construction (AEC) will enable the widespread communication and collaborative use of project information among all project participants and all project life cycle stages using computing technologies (Froese, 1995). The latest drive towards performance improvements has motivated the industry into looking towards IT as a vital tool in improving the construction processes. Moreover, the combination of IT solutions and electronic commerce can together make it possible to manage and run construction projects in an efficient manner. These new possibilities can affect the current methods of doing construction. Thus, it becomes important for today's construction businesses to improve their business processes in order to stay ahead of competitors and derive maximum benefits from innovative IT and Web-based technologies.

5. BPR FOR ELECTRONIC COMMERCE IN CONSTRUCTION

A continuous demand for better services and products from customers and clients has forced industries to continually improve their work methods (ProSci, 2001). This in turn has lead to improved business processes. The construction industry is no exception, in fact, the Egan report (1998) has illustrated the need for the construction industry to shift from its traditional product-oriented approach to a customer-oriented approach, which focuses on delivering a better quality product that not only meets, but exceeds the client's expectations. The quality of the construction project can be improved by completing the project on time, within budget and to the client's specifications. One method of achieving this can be through the reengineering of the current work methods within the construction industry.

According to Hammer and Champy (1993) BPR (Business Process Reengineering) is, 'The fundamental rethinking and radical redesign of business processes to bring about dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed'. The basis for BPR is that a company can achieve improved performance through the rapid and radical redesign of its business processes (Daguerre et al., 2001). BPR can be facilitated through the use of business process mapping tools. In this paper the IDEF0 (Integrated Definition for Function Modelling) methodology is used to represent an electronic commerce construction business process model.

6 RATIONALE BEHIND BPR MODEL

The BPR model presented incorporates the use of the IC into the current construction business processes. The model presented has been decomposed into six levels and aims to give overview of how the current working of the construction supply chain can be effectively managed using the IC.

NODE IC/A0

A0 is the context diagram and represents a top-level process that gives a generic view of managing construction projects (refer Figure 3). In this process the construction team (that forms a part of the mechanism in the process) works with inputs such as the client brief and project details to produce outputs or project deliverables such as project drawings, project documents, contracts etc. This activity is performed while working within project constraints such as project time schedule, building industry regulations, standards and project finance. These act as controls for the project. The construction team is assisted in this process by mechanisms such as support IT tools. The business process model aims at proposing enhancements to the current model to maximise its performance and deliver value to its end users.

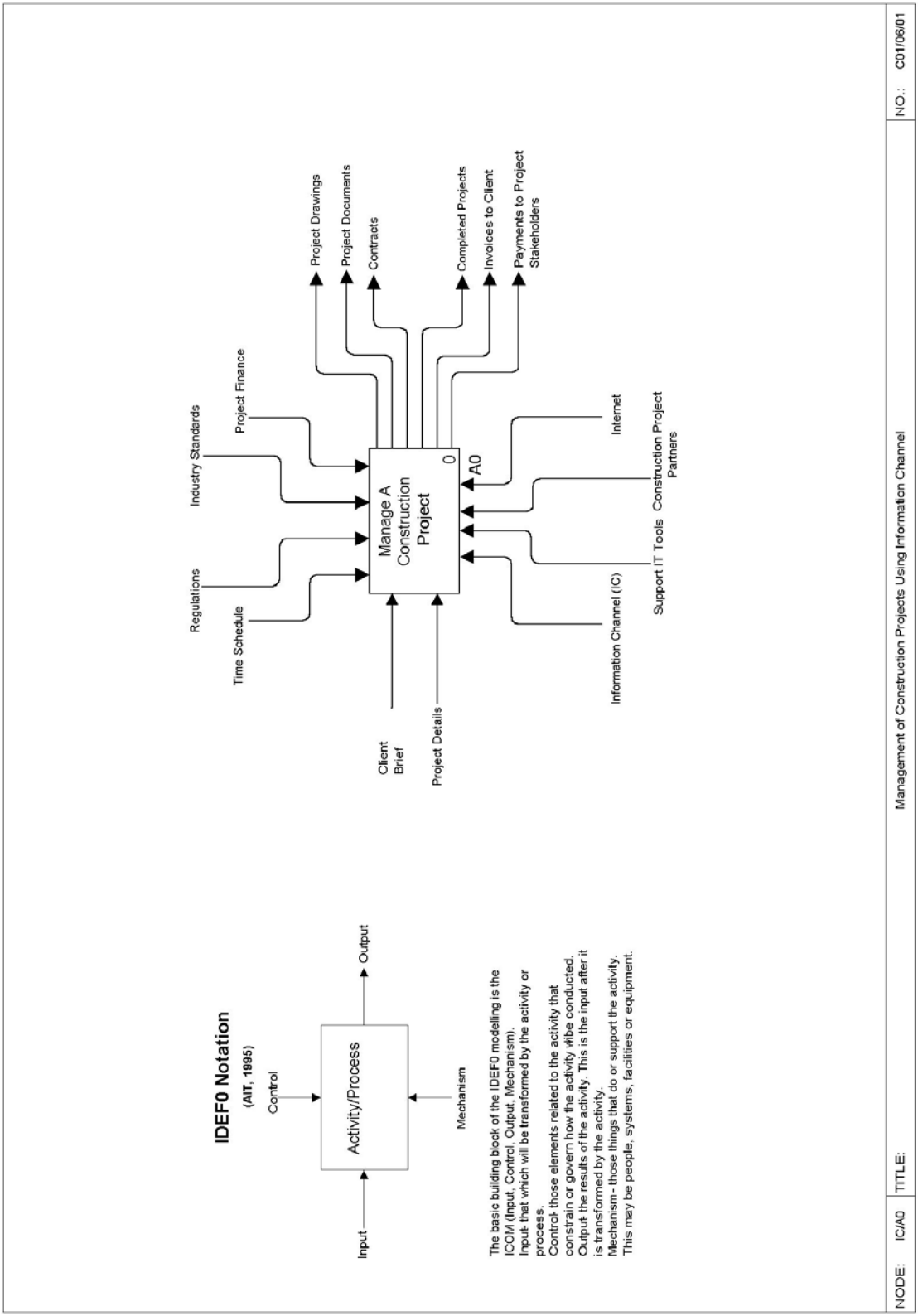

Figure 3. Node IC/A0

NODE A0

The diagram (Figure 4) represents the process of management of project drawings. This process is hierarchical in nature and starts with the overall process of

planning and managing project drawings by the appointed project manager. The process involves input from different construction disciplines. Typically, project drawings may include architectural drawings, structural drawings; building services drawings, fabrication drawings and drawings for on-site work. These processes are interlinked and the diagram tries to represent dependencies and the overall information flow. It also tries to present the information feedback mechanisms and hence the iterative nature of construction processes. The business process model proposes using the IC as a mechanism to improve this process of managing construction project drawings.

As the CAD technician completes a drawing (DWF format) it is passed onto the Company Information Coordinator (CIC). The CIC then uploads these drawings onto the IC for comments e.g. in case of architectural drawings the CIC could be the project architect. The IC has been designed with the assumption that its users will work remotely and may not have access to the special CAD tools that are needed to view project drawings. This drawing management system has been designed such that, any authorised user with access to a standard Web browser can use the system. The IC enables users with appropriate user ID and access rights, to view and comment on project drawings from anywhere and at any time. This encourages real-time, intra-disciplinary communication and hence encourages better project management.

The generally accepted methods for planning and scheduling of construction works are network and critical path analysis. These can be inappropriate for design management because of its ill-defined and iterative nature (Stebbings, 2001). Design managers need appropriate tools to help them plan, manage and integrate with the client, contractor and other parties. By encouraging intra-disciplinary teamwork within the construction team the IC aims to achieve this objective.

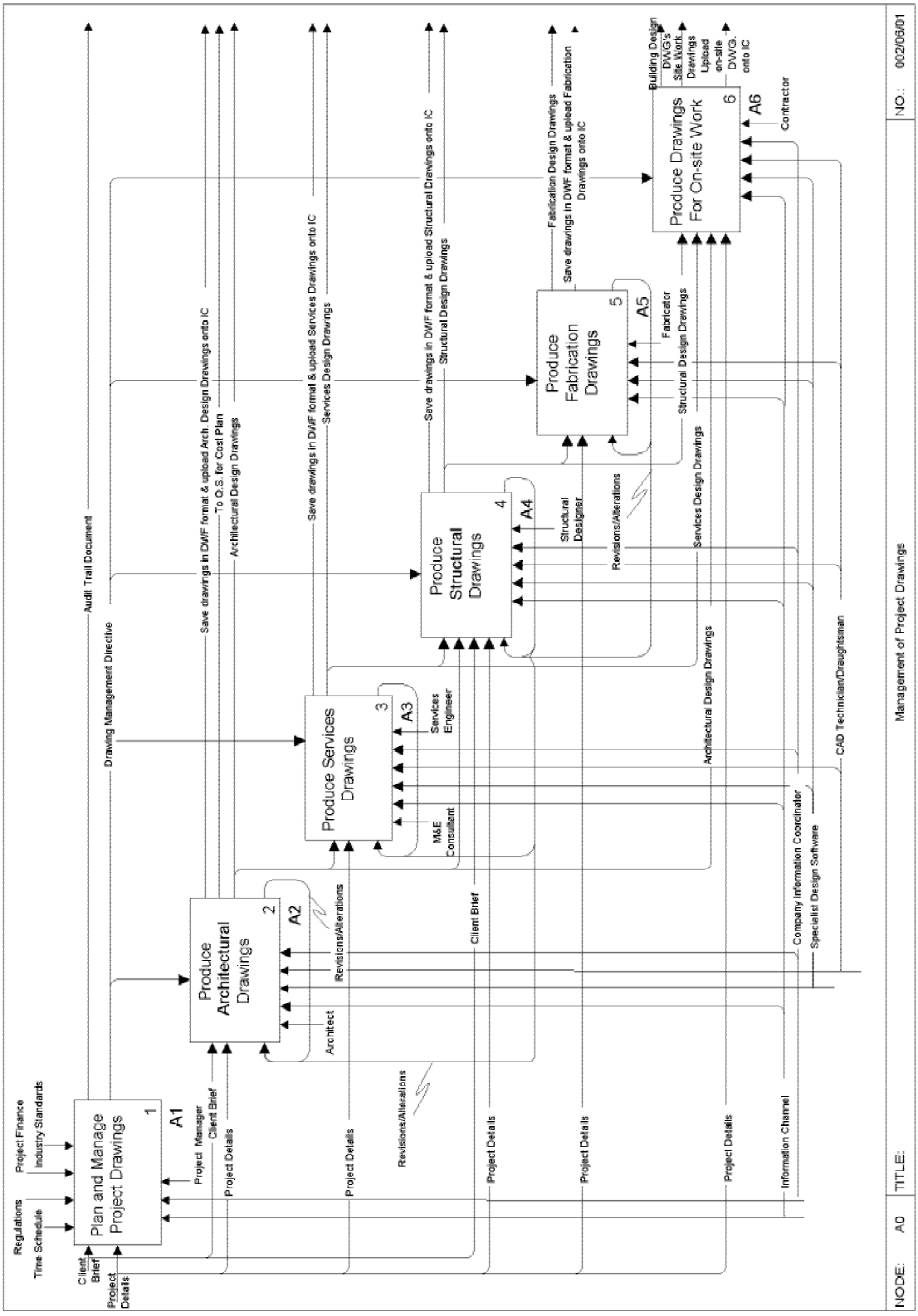

Figure 4. Node A0

NODE A2

This diagram (refer Figure 5) represents the process of managing project architectural drawings. The process is controlled by the activity for planning and

management of architectural drawings prepared during the project's lifecycle. The process proceeds from the preliminary drawing stage onto the preparation of as-built drawings for site work. It encompasses the development, working and detailed drawing stages.

The IC acts as a mechanism for each activity involved in the process. With the help of this tool (IC), the user can be updated with any new drawings (or related documents) that may have been added to/removed from the project. Architectural drawings are prepared using specialist design software such as AutoCAD or equivalent. The CAD technician saves these drawings in DWF format – a web friendly format that enables viewing of CAD drawings over the Internet. These DWF format drawings are uploaded onto the IC with authorisation from the CIC e.g. Architect, for comments from other project partners.

Details of comments made on a drawing can be viewed and responded to. By clicking on the drawing the user can respond to remarks made by other project partners, by adding their own comments e.g. by clicking on a CAD drawing of a door, it is possible to access the changes made to door specifications. Other details such as supplier's product (door) catalogue that includes data such as door specifications, cost, physical properties, availability and quality can also be accessed. Using the IC, authorised users can be updated with the latest comments and changes made to the drawings.

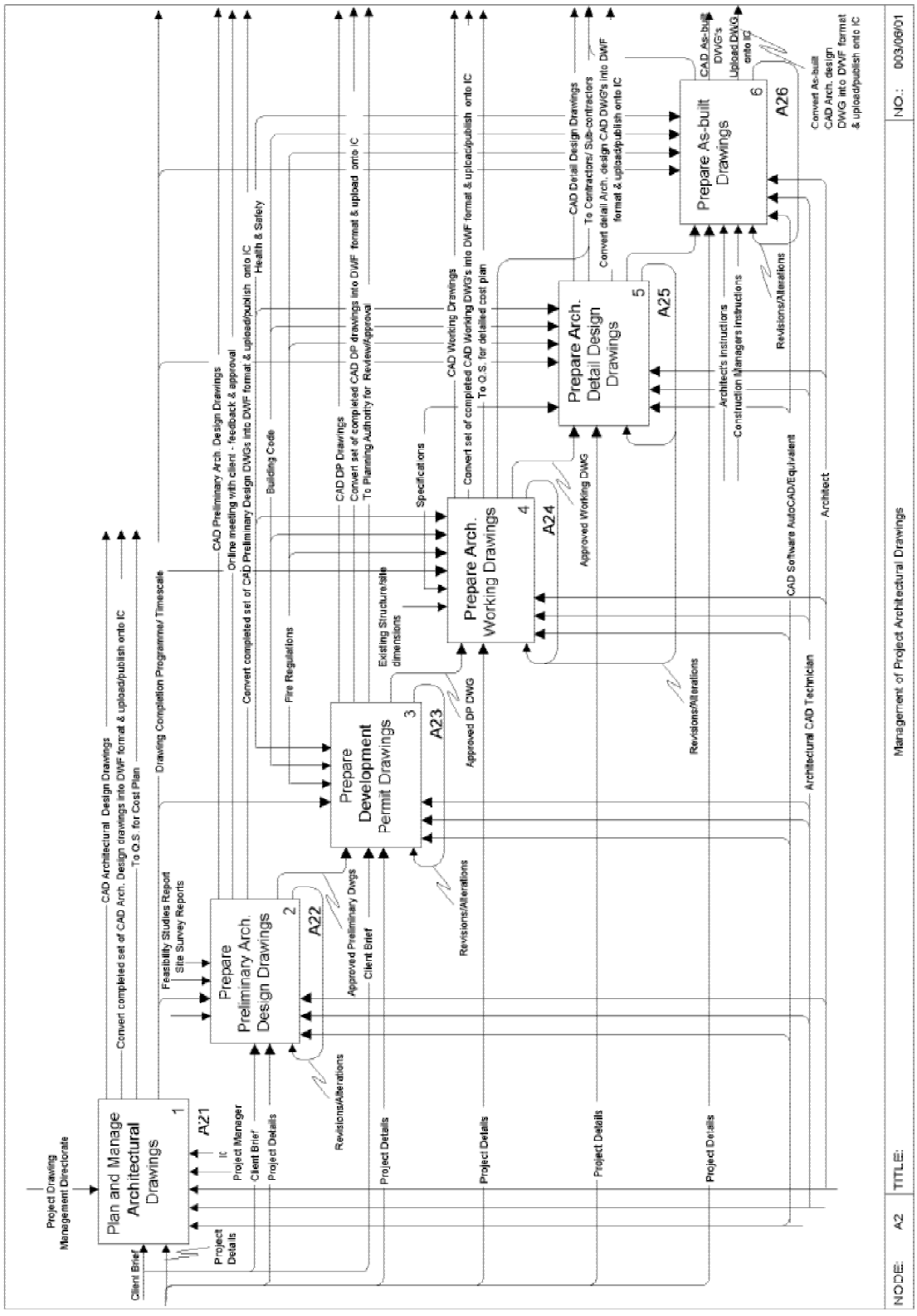

Figure 5. Node A2

NODE A25

This process diagram (refer Figure 6) proposes the method of finalising architectural drawings. The completed/approved detail architectural drawing can be uploaded onto the IC to invite other project partners and the client or client representatives to view and comment on drawings in real time. Using plug-ins such as the Java Viewer or Whip Viewer, authorised project partners can hold virtual meetings online and this entire process of the meeting (minutes and its decisions/outcomes) can be recorded onto the permanent project database. These records can be useful in case disputes occur during the project's lifespan. Project partners may comment on the drawings and such comments may prompt responses from other project partners. This process of comments and counter-comments may continue till a final decision is reached. The fire and building regulations and client brief control this stage of the process. The outcome of such discussions may result in revisions to existing detail drawings. The resulting revised drawings can be uploaded onto the IC for further comments and approval from the relevant project partners. This is an ongoing process that may continue till a final set of updated project detail drawings are produced.

As represented in the process diagram the finalisation of the detail architectural design drawings is an iterative process and the outcome of online discussions, comments and meetings. On approval from the design architect the final set of design drawings can be published onto the IC, so that project contractors can use these for site work. Additionally, the drawings may be submitted/distributed amongst the construction project partners including the services engineering team, M&E (mechanical and electrical) consultants and structural design team. This can lead to the start of the supplier selection process. It can be seen that such a selection process can be used to finalise every architectural detail in the project. This paper will use, the door selection process at the next level as an example.

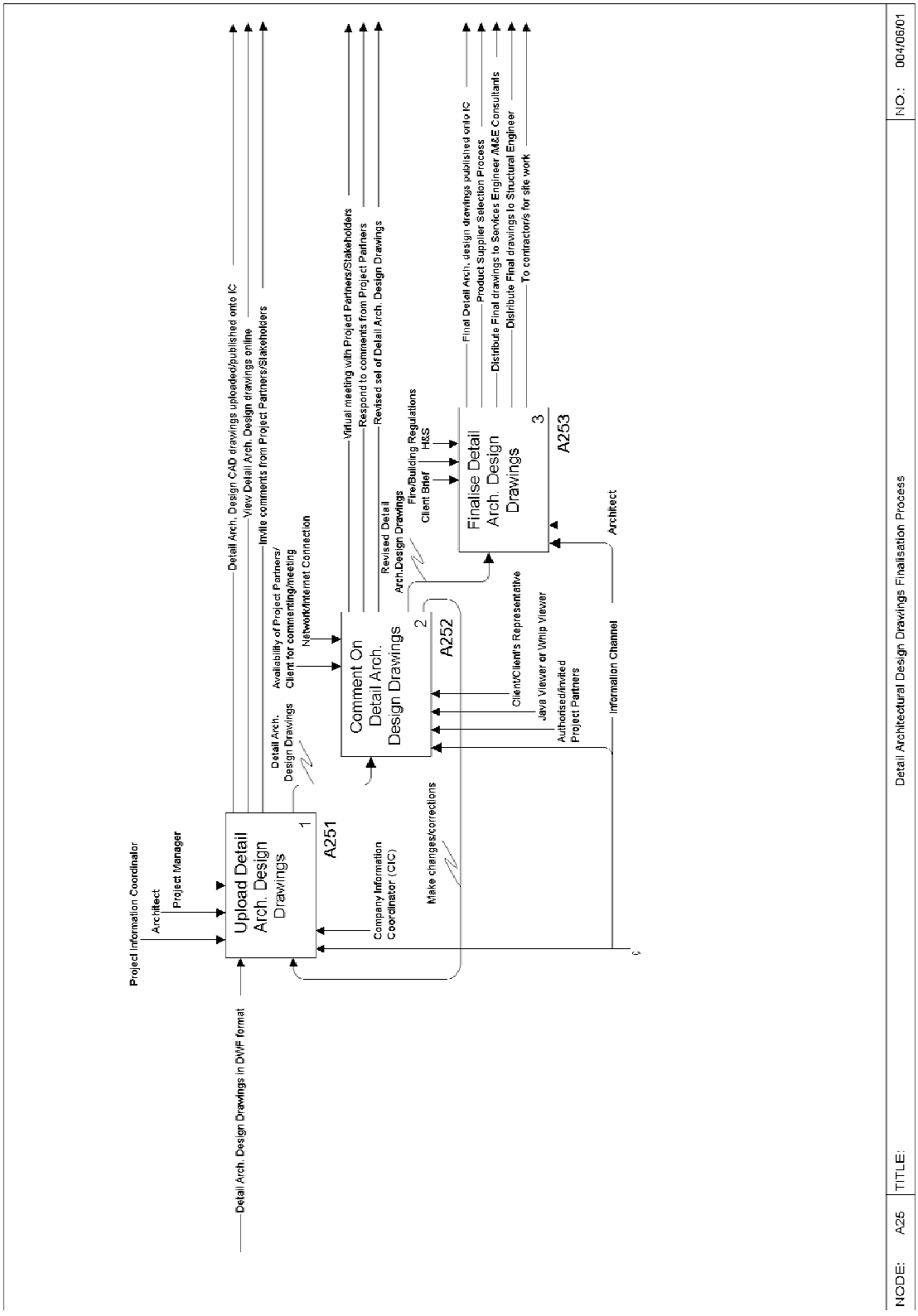

Figure 6. Node A25

NODE A253

The process of selection of the product supplier (in this case the door supplier) will require input from the client brief, the door detail drawings and documents including the

door specifications (see Figure 7). The first step will involve accessing the door supplier's database using the IC. This database is an online interactive database of door supplier's services and all door related information. The suppliers can maintain their product and service data on the Internet to ensure that that only accurate and up-to-date information is available. Using the IC's search engine, the user's can search for relevant door information that meets required product specifications. E.g. a search for a specific door type may list out the door suppliers whose product may match the door specified. The user can then use these search results to compare the different door suppliers for criterion such as cost, quality, availability, delivery time etc. Using the IC, a record of the comparison process can be maintained on the supplier database. Following the comparison process user can then carry out a process of elimination to short list door suppliers. Also the users can view online catalogues from the short-listed door supplier's Web Pages and send tenders by invitation to these door suppliers. Once the tenders are analysed for pricing, the door supplier can then be finalised and selected. This entire process being electronic can be documented to form a part of the project audit trail document.

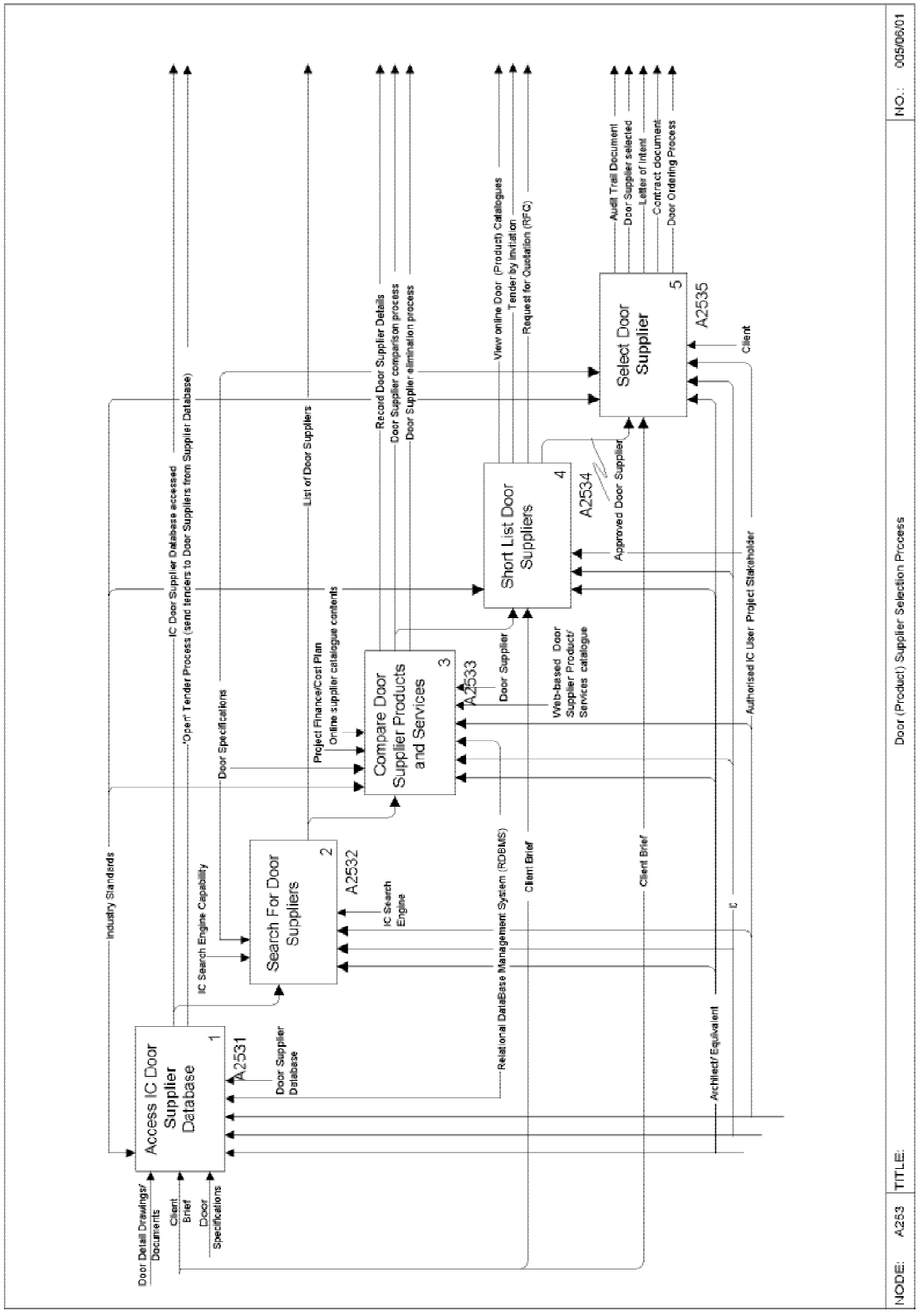

Figure 7. Node A253

The suppliers who advertise their products on this system (IC) can easily update product information. Such information can include product specifications that are defined by the product class and also information such as the cost of the product, its availability and quality assurance as illustrated in Figure 8.

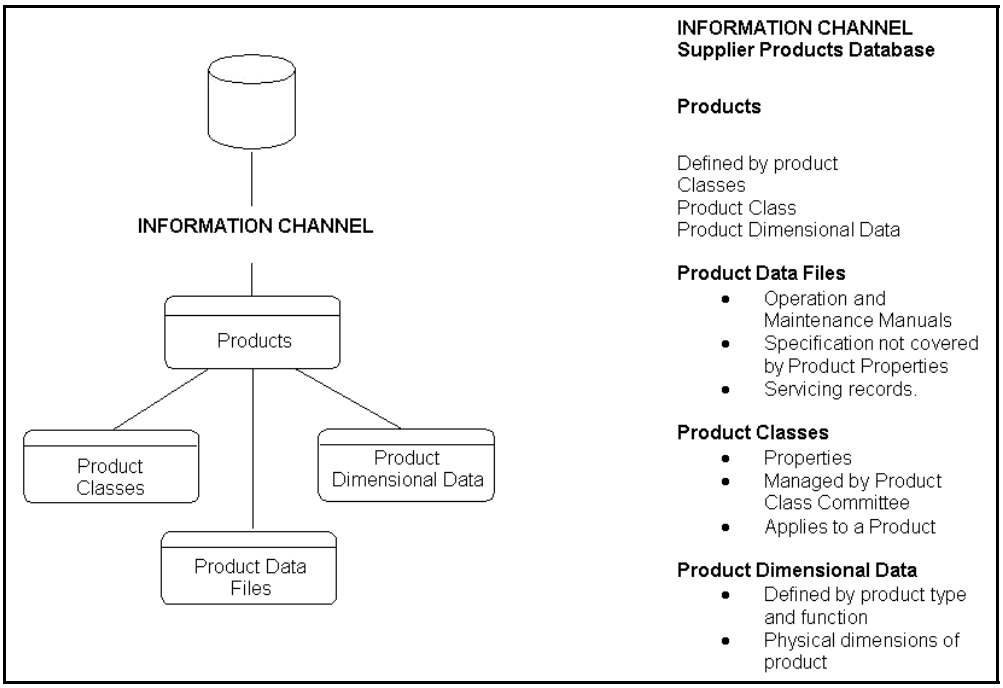

Figure 8. Supplier Product Database

As seen from the Figure 8, for any given product, the typical classification will include product dimensions, finishes, physical properties, its chemical composition and its use. The information stored on such a system will not only be of use to the company that supplies the product, but also the end user who can access accurate, updated product information as and when required. For example, the quantity surveyor (QS) has a better chance of getting an accurate schedule of elements that are involved within the construction project itself and he/she can get the bill of quantities straight out of this supplier database model.

The door (product) suppliers can benefit from such electronic methods of carrying out business transactions as they can have a trail of door orders and keep record of the doors (products) sold. The product sales can be improved by monitoring and co-ordinating the sales inventory and financial data. Such data can help the management with a complete picture of the company's operations on a day-to-day basis. Suppliers can get access to the product and order information and establish product popularity and investigate which products appeal to the user and why.

NODE A2535

This process diagram (see Figure 9) describes a specific product ordering process (i.e. door ordering process) using the IC. Once the door supplier has been approved and selected and the contract document signed, an electronic purchase order is prepared, usually by the accounts department's staff. The contents of the purchase order can be directly (electronically) derived from the documents for door specifications and the bill of quantities, thereby avoiding any duplication/re-keying of information. This electronic purchase order can then be sent to the door supplier using the IC as a tool and the payments for the order can also be made using Electronic Funds Transfer (EFT). EFT is a tool for electronic transfer of value (Sharda, 2000). Encryption software and SSL (Secure Socket Layer) mechanisms can be used to make these transactions secure. EFT can complement the mechanism and working of the IC and allow project partners to improve interdisciplinary financial management.

Traditional approaches of inter-organisational trade payments usually involved sending out cheques through the post. It can take paper cheques approximately two to four days to arrive at the destination, since their date of issue or mailing (Sharda, 2000). With the help of EFT, the payment can arrive at the destination on an agreed date, without reliance on third party and media breaks. The resulting cash flow can be faster, efficient, timely, consistent and reliable.

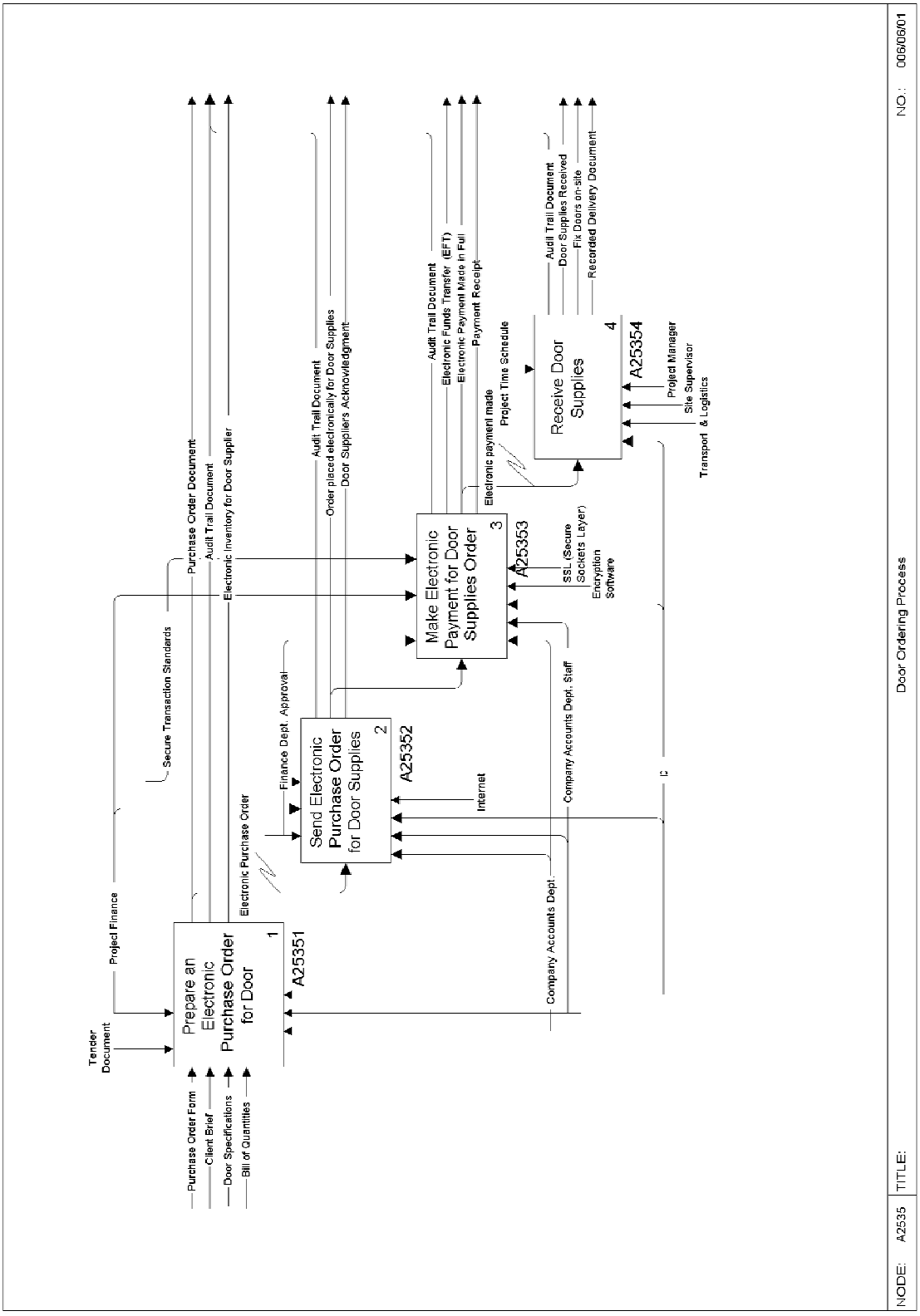

Figure 9. Node A2535

Figure 10 is an illustration of a typical door ordering process using the IC. This process may involve the customer sending out an electronic Purchase Order to the door supplier, who on receipt of this Purchase Order, can acknowledge the order and send an electronic invoice to the customer.

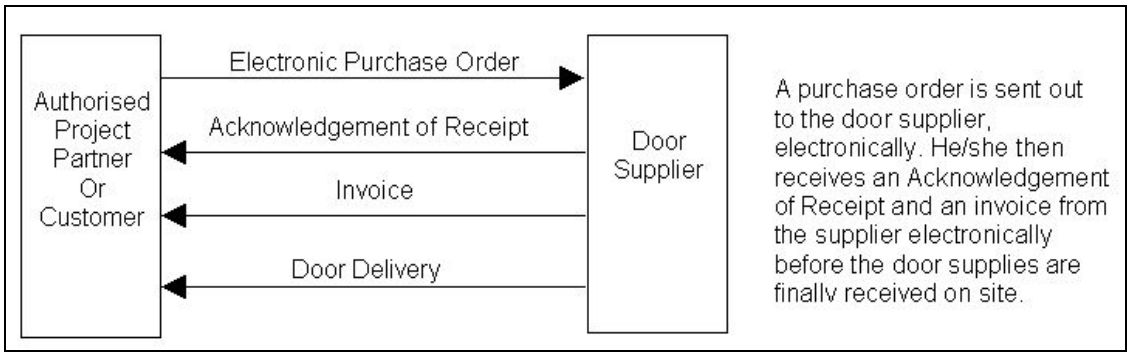

Figure 10. Electronic Door Ordering Process Using Information Channel

7. BENEFITS OF NEW PROCESS MODEL BASED ON THE INFORMATION CHANNEL

Using the IC as a project management tool to facilitate BPR can yield strategic, operational and opportunity benefits to its users i.e. the construction supply chain, as it can overcome most of the current deficiencies that have prevented effective management of the construction design processes. Some of the benefits of using the IC are as follows:

- **Reduced Project Cost**: This system facilitates online viewing, conferencing, reviewing and modifying drawings and documents. Studies have shown that 80% of the project team only view and comment on drawings and documents (BIW, 2000). The IC provides an electronic means of accessing latest project drawings thereby reducing the necessity to print drawings unnecessarily. There is a significant reduction in the production and delivery costs associated with the many drawings created during the project. A study by Gleeds, an international construction management and consulting firm, has confirmed that cost savings of £58, 208 on a £5m, 30 week, retail construction project by using the IC (BIW, 2000).
- **Reduced Time Wastage**: The latest comments and requests are available to the relevant team members immediately on the headlines page. This avoids delays and mistakes often involved in using conventional methods of communication. As the project team members do not have to wait for updated drawings and documents to arrive (by post, courier, etc) the likelihood of delays is further reduced. The IC can be used to host virtual meetings thus allowing project partners to simultaneously view the same drawings and documents, exchange comments/ideas in real time and resolve any issue(s) that may have otherwise caused a delay. Visits to the site and travelling time to the meetings/site can be cut down, since latest progress photographs of the construction project can be accessed from anywhere and anytime using this system.
- **Reduced Errors**: Mistakes and errors can be avoided since all project drawings/documents are regularly updated and instantly available. Therefore, the risk of team members acting off incorrect and outdated information is considerably reduced. Also, reminder emails are sent to project members and managers, if necessary actions are not taken on time.
- **Avoid Disputes**: The IC creates a clear audit trail for the project and therefore increases accountability. It contains all project details such as

meeting minutes, actions, comments, requests, approvals and notifications that are generated during the project. The database maintains records of information such as who has published what and when this information was viewed and by whom. This system is designed to encourage openness and collaboration from all the members of the project team. Thus, time and money spent in resolving project disputes can be significantly reduced.

- **Knowledge Database and Preservation of Corporate Memory**: The IC uses state-of-the-art Web database technology and generates a complete audit trail for the project. The user can view and respond to comments made by other users at the click of a button. These comments are collectively recorded in a structured database instead of being stored in separate drawings or documents resulting in the creation of a knowledge database for the ongoing project. This was previously not possible using the traditional methods.
- **Supply Chain Management**: The cross-disciplinary nature of the IC facilitates easy adoption through the construction project supply chain. Earlier it was seen that one of the main reasons why construction continues to be fragmented is because of the lack of technological alignment of different members of the supply chain. With the help of the IC project members of the supply chain do not have to invest in new applications but can continue to use their existing systems. It also provides a tool whereby project teams can collaborate with one another all through the project's lifespan thereby encouraging partnering.
- **Enables Electronic Commerce**: The project partners for a construction project make use of standard applications to access, manipulate, exchange or receive data (in a structured format) from the IC. Geographically dispersed project partners using other applications access this data using the Web as a platform. Example, the IC allows the user to access real life component data such as cost, availability, durability and specification about a product e.g. door and attach this information to the CAD object for the door. A typical ordering cycle using the IC, may involve the customer sending out a Purchase Order to the product (door) supplier. On receipt of this Purchase Order, the supplier acknowledges the order and sends an electronic invoice to the customer. Hence the basis of an electronic commerce solution.

The BPR model presented here incorporates use of I-components into the existing IC structure. The structure of the system of I-components is such that it is beneficial to every participating team member of a construction project at every phase of the construction process. Some of the benefits of the BPR model presented that are specific to individual construction disciplines involved in a project are discussed below:

7.1 BENEFITS TO THE ARCHITECT

This system can provide CAD benefits to the architect. The example of a door has been presented. The information associated with one particular door type can be displayed in several different documents and drawings. This information may be in the form of:

- Plan of the door say D1.
- Elevations, sections and views of D1.

- Reference to D1 in other drawings, such as working details drawing.
- Door schedule.
- Costing and price list.
- Manufacturer's product data and specifications.
- Supplier's product data and specifications (for door type D1).

Any change or alteration made to any one drawing or document (e.g. a door drawing) can result in all subsequent documents and drawings that are related to the door in question, being automatically revised and updated. Currently, an architectural draughtsman has to make these changes or alterations in each and every drawing. This is a time-consuming, lengthy task and may lead to errors and mistakes. It may also result in modifications being missed out and overlooked. Benefits the BPR model can provide to an architect can be:

- It can cut down repetitive work.
- It can save time in updating and revising documents.
- It can increase efficiency due to reduced effort.
- It can be cost effective.
- It can create a knowledge base of product information.

7.2 BENEFITS TO THE QUANTITY SURVEYOR

The BPR model presented can also be beneficial to the Quantity Surveyor (QS). The system can make it possible for the QS to directly get quantities off the IC.

- Material pricing can be done against information selected from CAD documents.
- It can save on the time and effort to prepare and work out the quantities.
- It can reduce the need to carry out market surveys for the purpose of costing.
- It can help the QS negotiate product prices at a very early stage with either the product manufacturer or supplier.

7.3 BENEFITS TO THE CONTRACTOR AND SUB-CONTRACTORS

The BPR model when used by project contractors and sub-contractors gives them instant access to updated project drawings and documents. Thus, the possible benefits include:

- Delays caused because of miscommunication or lack of communication can be avoided.
- Work can continue on site, uninterrupted.

7.4 BENEFITS TO PRODUCT MANUFACTURER/SUPPLIER

Using this business process model, manufacturers/suppliers can have an opportunity to get involved in the construction project at an early stage, thus enabling

them to plan and manage the product inventory well in advance. It can be possible to easily adapt to new business procedures such as the Just-in-Time (JIT) techniques whereby the product supplies can be delivered for site work just before work actually begins on site. With the help of the IC, product suppliers (or manufacturers) can maintain product-related data/information to ensure that only accurate and up-to-date information is displayed and available to their users at all times. They can maintain their own product or related data in an interactive database. Such a database can contain all relevant information of the supplier's (or manufacturer's) products that may be required by different members of a construction project during the construction process.

Other possible benefits of the new business process model for the manufacturer/ supplier are:

- Gaining prior knowledge of probable product (door) order.
- Stock checking and planning and preparing for delivery in advance.
- Better management of product (door) inventory and therefore a reduced possibility of dead investment (since the possibility of product stock remaining idle in the warehouse can be considerably reduced).
- Managing information and ensuring that accurate information reaches potential clients at all times.
- Disseminating up-to-date product/service information to clients in a faster way.
- Reduction in money spent on training of sales representatives for product or services promotion.
- Advertising of product to relevant and probable customers from the construction industry (target audience).
- Facility management - once the building is completed, the knowledge of the building facility can be passed on electronically. The database for the IC can store crucial building information that can be of use at a much later date when the building may need repairs, refurbishment or may need to be demolished. This sensitive information can be of use for capital management and determining the life expectancy of the building.

8. CONCLUSIONS

From all the facts presented in the paper it can be seen that there is an enormous potential for the development of electronic commerce in the construction sector. One of the main benefits of adopting electronic commerce into the day-to-day working of the construction organisations can be a simplified construction business process that uses electronic tools (such as the IC) for exchange of data and information. In order to adopt IT and electronic commerce strategies into the day-to-day working of construction projects, companies will have to radically alter the traditional processes of managing construction projects and also the way in which project partners collaborate and communicate with one another. Doing so can lead to fundamental changes in the way construction projects are managed and executed. It is therefore, essential to study and examine the effects of incorporating electronic commerce based applications into the construction business processes. There is also potential for conducting future research in the area of development of business strategies for the adoption of electronic commerce in construction.

The exponential growth of the Internet and the growing use of IT into current processes have accelerated the pace of change and demand more flexible and adaptive organizations (Malone and Crowston, 1991). Construction organisations that decide to enhance their business processes using IT and the Internet should recognise that adopting such innovative methods may result in integration of the entire management process of construction projects. The flow of information in such a system will be electronic and hence interactive. It will make use of the Internet as a medium for data storage, data transfer, communication, conferencing, dialogue and decision-making and acquiring information. All these tasks can be carried out in a monitored and a secure environment. As stated earlier the construction industry at present is relatively cautious in the use of the Internet as a mechanism to conduct day-to-day business. Many in the construction industry believe that the future of electronic commerce in construction is still quite unclear and the objectives for using electronic commerce technologies in construction have not been clearly defined. This may be due to the lack of a well-defined business process model that integrates electronic commerce with the existing infrastructure of construction companies. However, as seen in the paper adopting IT and electronic commerce into the working of a construction project can result in some radical changes in terms of traditional methods of management of construction projects (including project-related data/information) and communication between project team members. These new electronic commerce applications have benefits for all the members in the construction supply chain as demonstrated in the paper. These benefits will help deliver a better quality product i.e. the constructed facility.

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APPENDIX D PAPER 4 (UNDER REVIEW)

Ruikar, K., Anumba, C. J., and Carrillo, P. M., (under review)., 'End-user Perspectives on the use of Project Extranets in Construction Organisations', Submitted to *Engineering Construction and Architectural Management*.

END-USER PERSPECTIVES ON USE OF PROJECT EXTRANETS IN CONSTRUCTION ORGANISATIONS

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ABSTRACT

Web-based technologies such as project extranets have introduced a new concept for communication and collaboration during construction projects. Project extranets have been used in the industry for some time now to manage information and document flows throughout the lifecycle of construction projects. Very few end-user companies already using project extranets have documented and disseminated information about the implications of using this technology in terms of the impact on their businesses, benefits incurred and possible drawbacks. Wider dissemination of this knowledge will encourage more construction companies to adopt the technology which has a proven record of success on projects for which it has been used. In order to take on board this issue, this paper presents findings of case studies conducted with end-users of a leading project extranet application in UK. It highlights the drivers for the adoption of this technology and its impact on end-user business processes. It also documents the end-user viewpoint on the benefits and drawbacks of using project extranets. Findings suggest that some of the perceived drawbacks of using project extranets are in fact not viewed as drawbacks by end-user companies. Also, the benefits incurred appear to outweigh some of the issues. The end-user organisations believe that an increasing number of organisations will be encouraged to use project extranets when they see 'visionaries' and 'market leaders' such as themselves, benefiting from the technology and leading the way to its wider adoption.

KEYWORDS

Internet, Project Extranets, Construction Project Management, E-commerce

1. INTRODUCTION

With the proliferation of the Internet, companies across several industries, are increasingly leveraging the Internet to achieve competitive advantage (Cheng et al., 2003). The construction industry is no exception. Web-based tools such as project extranets are being used to manage construction projects. Such tools can be used to monitor, control, manipulate and store project information and to make it available to all participants of the construction supply chain (Alshawi and Ingirige, 2002). Examples of Web-based tools include a computer-mediated tendering system for services or contracts, purchasing of materials via the Internet by a contractor, project extranets for project management and specifying products online by a manufacturer (ITCBP Intelligence, 2002). All these Web-based tools can be encompassed under a single banner of e-commerce tools for construction as they facilitate trading, exchange of data and information and the automation of the business processes and workflows (Kalakota and Whinston, 1996).

Previous research studies (Ruikar et al., 2001; Anumba and Ruikar, 2002) and recent industry and research publications have documented the possible benefits and business opportunities for companies using e-commerce tools such as project

extranets. However, the results of a recent survey (Ruikar et al., 2002) have shown that the construction industry has been relatively cautious in using the Internet to conduct day-to-day business. As with most technologies, it can be difficult to gauge the quantitative Return On Investment (ROI) from using such tools and project extranets are no exception. Also, since the technology is relatively new there is a limited availability of information or feedback on the tools' performance on previous construction projects. Hence, there is an element of risk involved (not knowing what to expect), which most construction companies are not willing to take. However, there are a number of technology-oriented construction companies that have successfully managed construction projects using Web-based project management tools such as project extranets. It is therefore, essential to examine the effects of incorporating project extranet applications into the business processes of these end-user construction companies.

Case studies were conducted to examine the impact of one such project extranet application on the business processes of its end-user companies. The case study application is one of UK's leading project extranet applications and has been identified as Product A in this paper. This paper presents the findings of the case studies and covers the following four topics:

1. Drivers for successful implementation of project extranets within end-user organisations;
2. Effects of project extranets on traditional processes of end-user organisations;
3. End-user viewpoint on the benefits of using project extranets; and
4. End-user viewpoint on barriers to implementation of these tools within the industry.

2. CASE STUDY METHODOLOGY

Currently there are several Web-based project management tools available on the market. These tools have the same primary goal – management of project data and documents. The tool selected for the case studies is amongst the market leaders in UK (Alshawi and Ingirige, 2002) and has a well established end-user base who have used the tool to manage several construction projects. Product A is a project extranet tool that allows construction industry professionals to collaborate with other project partners using Web technologies. The framework of the application is such that it facilitates management of construction projects and provides structured access to all project and project-related documents or information. It also generates a permanent database of all project data that includes drawings, revisions, comments made to prompt such revisions, documents, meeting minutes, progress on site, site photographs and other project-related data. Using Product A, members of the construction supply chain can communicate and archive information (records of what was done, when, by whom etc) throughout the lifecycle of a construction project.

Semi-structured telephone interviews were carried with end-users of Product A. These interviews were based on a structured questionnaire in order to ensure consistency in the type of information obtained. The companies interviewed were selected from a list of end-users provided by the ASP (Application Service Provider). Table 1 gives an overview of the end-user companies.

Table 1. Overview of end-user companies.

End-user Company	No. of Employees	Construction Discipline
Company 1	>500	Q.S. and Project Management
Company 2	>500	Contractor and Facilities Management
Company 3	>500	Contractor and Property Development
Company 4	>500	Construction Management
Company 5	25	Architecture and Interior Design

3. MAIN CASE STUDY FINDINGS

3.1 DRIVERS FOR TECHNOLOGY ADOPTION

Several factors can influence the adoption of technology within construction organisations. Technology adoption can be management driven, client driven, market driven or project driven. According to marketing guru, Geoffrey Moore (2003a), technology adoption within an industry sector is based on a traditional Technology Adoption Life Cycle, represented by a bell curve (see Figure 1). This bell curve comprises of industry end-users, progressing from innovators, early adopters, early majority, late majority, to laggards. While innovators are 'technology enthusiasts', early adopters are visionaries who have the insight to match an emerging technology to a strategic opportunity, and are driven by a 'dream'. Their core dream is a business goal, not a technology goal. The early majority are pragmatists who share some of the early adopters' ability to relate to technology. However, they require well established references, before they invest in such technologies. The late majority have a conservative approach to technology and are pessimistic about the ability to gain value from technology investments and start using it only under duress. Laggards are those who simply do not believe in technology.

This analogy can be used for the adoption of extranet technology within the construction sector. Case study findings indicate that the end-user companies interviewed fall within the early adopters category of the adoption curve as shown in Figure 1. In almost all end-user companies the use of Product A was driven by the company's management. These companies believe that project extranets are the way forward for project management within the construction industry and have adapted the technology to match their business needs. Quoting one response:

"use of innovative technologies such as this, has been a primary differentiator that sets us apart from the rest and reflects our company's drive towards innovation. This is because we fundamentally believe that that's the way the industry is going to go and we would like to be at the forefront of innovation".

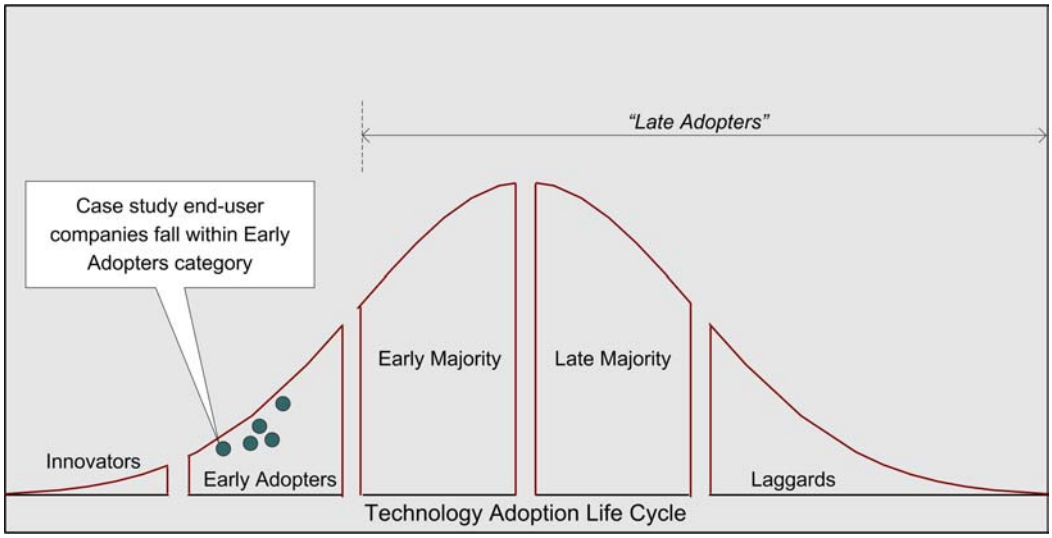

Figure 1. Technology Adoption Life Cycle (adapted from Moore, 2003a)

As the end-user companies interviewed within this case study fall among the early adopter group, it is important to identify the key drivers in their adoption of Web-based project management tools. The identification and dissemination of these drivers are important to promote the ubiquitous use of project extranets for construction management, or as stated by Moore (2003b) for 'Crossing the Chasm'.

For Company 4, it has been a strategic decision to implement Product A, in order to improve business performance. Company 4 had successfully used EDM (electronic document management) tools in the past to manage large construction projects. The company has a policy for continual improvement and innovation, hence it was only natural for them to migrate to the next level i.e. strategic move to use Web-based EDM systems such as project extranets.

After undertaking a review of different market products in terms of their functionality, Company 3 has adopted Product A. According to Company 3, Product A was the best in the market at the time of adoption. They also believe in continuous improvement and have adopted a proactive role in the further development of the tool (e.g. regular feedback meetings with the ASP). The company also believes in early adoption of technology and it is a company policy to always be at the cutting edge of 'whatever' (e.g. technology).

While the others have adopted the technology as a management strategy, Company 2's adoption has been mainly project driven. They were 'pushed into' using a Web-based project extranet applications due to their involvement in some American projects. They saw the benefits of using such tools and recognised that project extranets were the way forward. The company then carried out a market study of similar tools available within the UK market. They selected Product A as its functionality was considered best suited to their current working processes and business needs. Product A vendors were also among the market leaders and this was an important factor that attributed to the selection of this tool. Also, Product A appeared to have the most longevity amongst the available tools. This was a important criterion for Company 2 as some of the ASPs that they had previously used had gone out of business. This had occurred within live projects leading to management problems. It is now a company policy to use Product A for Web-based project management.

The case studies have shown that factors such as client needs and market conditions, although important were not directly influential in the implementation process for Product A. The business strategy to adopt extranet technology (Product A) within end-user organisations has been mainly management driven and has led to business benefits. While some of the benefits can be monetarily quantified others cannot. Quite often in a competitive market, market conditions may also drive the use of technologies since companies are always looking at ways in which they can be ahead of competitors. While this factor was influential in the adoption of project extranets within end-user companies, many believe that it has given them a competitive edge that can be beneficial for future projects. In their view companies that have already used project extranets can market their new acquired ability and strength in this area. Being amongst the early adopters of this technology gives a competitive advantage, especially for prospective or future projects where clients are seeking expertise in this area.

These business benefits as demonstrated by 'early adopters' can act as drivers for the adoption of extranet technology amongst 'late adopters' within the construction industry. The end-user companies identified management buy-in as a key factor to encourage wider adoption of the technology within the industry. It was also viewed as 'a hard nut to crack', but not an impossible task. It requires open-minded management who are not nervous about change. More buy-in can be encouraged through previous examples of success stories. According to Moore (2003b), "part of what defines a technology market is the tendency of its members to reference each other when making buying decisions is absolutely key to its success." Company 3 has documented the business benefits of using Product A and is actively involved in disseminating this information to the wider construction audience. This can encourage wider adoption of the technology amongst construction companies, especially the early majority. Quite often companies (especially within the early majority category) are reluctant or cautious in the use of new technologies. This is because being new, the technologies have not been previously reviewed for their usefulness and effectiveness. Thus, there is an element of risk involved which most construction companies are not willing to take. However, as seen in case of Company 4 the use of Product A was only an extension to the traditional tried-and-tested EDM systems, which had been successfully used before. Therefore the risk was relatively low. Similar may be true for companies that will eventually form the early majority. Buy-in from the early majority is key to the success of any technology as this indicates that the technology has become a widely accepted alternative to traditional methods.

3.2 IMPACT ON TRADITIONAL PROCESSES

The use of technology can impact on the traditional processes of construction organisations and result in change in organisational processes, working methods and culture. According to Laudon and Laudon (2002), these changes can be in terms of process automation or rationalisation, the technology can also lead to process reengineering and formulation of new processes, which may lead to paradigm shifts within the industry. According to one respondent the use of Product A has not resulted in process reengineering, but has facilitated process automation. This has improved the efficiency of traditional processes and resulted in process improvement. Further, it has simplified the communication network of the end-user company with other construction disciplines involved in the project. The impact of Product A on the traditional process can be best described using a generic example as seen in Figure 2.

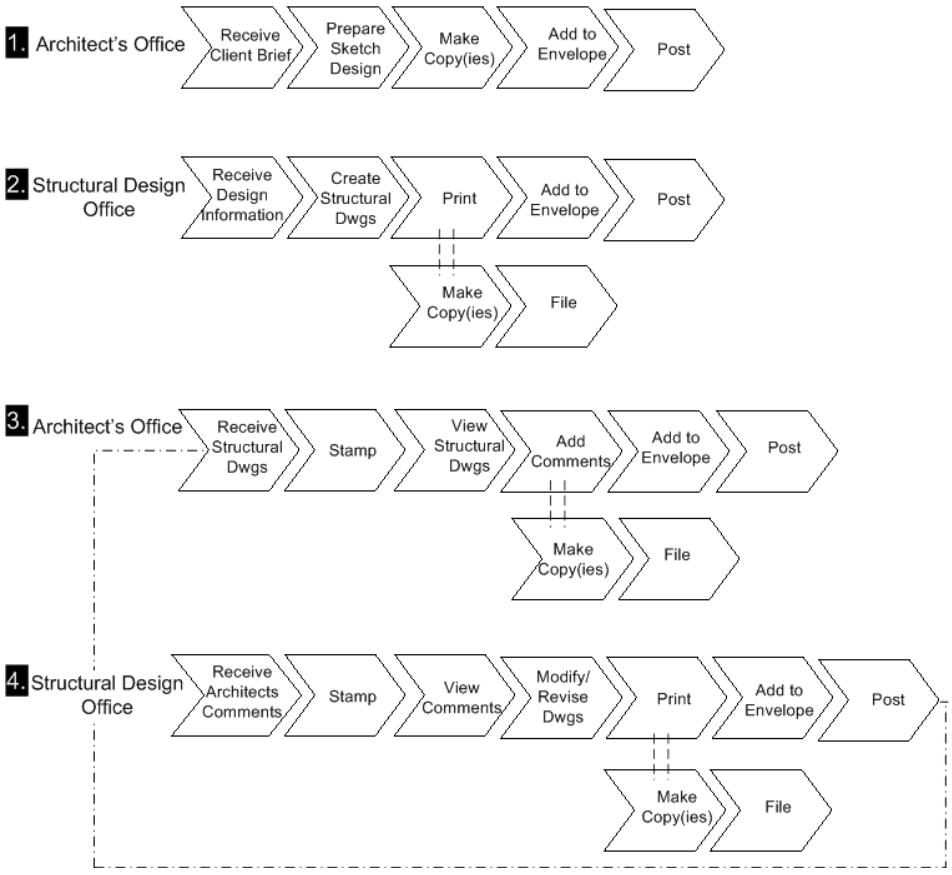

Figure 2. Traditional Processes: A Generic Example

For a given construction project, typically the architect prepares sketch design drawings which are posted to the structural design office. On receiving this design information, the structural designer prepares structural design drawings, prints copies of these, files a completed drawing set for record and posts the other(s) to the architects office for comments/approval.

These structural design drawings are stamped on receipt and then viewed. If the structural drawings are found satisfactory they are accepted and the process can move to the next level (i.e. preparation of detail drawings). However, sometimes comments may be added and changes suggested. Copies of the redlined documents are kept for record and also sent to the structural design office for corrections/modifications. This entire process is iterative and is repeated till the design is finalised.

Similar iterations are involved in the processes between the structural design office and the construction fabricator. As seen from the figure the resulting process is complex and time consuming. Also reliance on third party (postal and courier services) result in delays and affects the overall project cost, timescale and budget.

3.2 MODIFIED PROCESSES

Using Product A, the traditional process can be considerably streamlined. Project drawings/documents can be uploaded onto the main server. Relevant construction disciplines can then be automatically (and instantly) notified/invited to hold online discussions, comment online or respond to comments made by others. The resulting process (as illustrated in Figure 3) while being much more efficient can lead to financial

and time benefits to the end-users. From the figure it can be seen that some of the stages from the traditional cycle have either been completely removed or replaced with new more efficient electronic alternatives. Thus, the resulting modified process combines two aspects of change including process automation and rationalisation of procedures.

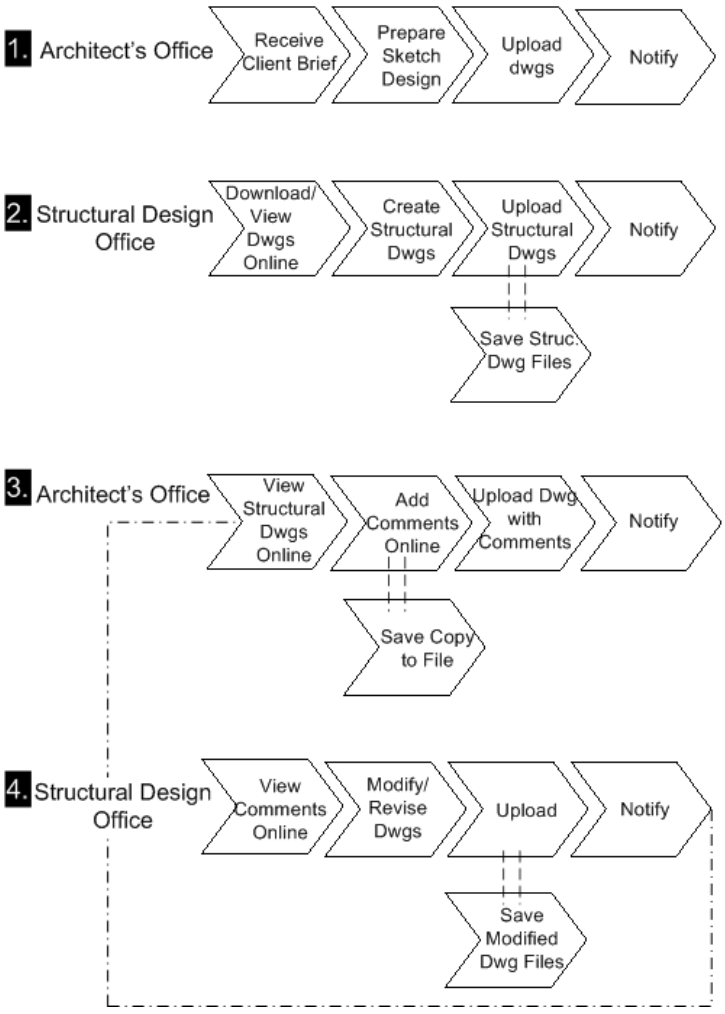

Figure 3. Modified Processes using Product A

A study carried out by Company 1 has indicated that approximately 2% savings in printing and postage costs have been incurred by their firm for a £5m worth construction project using Product A. Company 3 has also documented the cost and time benefits incurred on an £8m retail store project, which met demanding targets set by the client. The team achieved a 10% reduction in overall construction cost, and the construction time was reduced from 17 weeks to 12 weeks. Also, since using Product A, the drawing review process which normally takes 10 days (using traditional methods) is reduced to 2 days.

In Company 1's (a QS) experience the processes of procurement and appointing contractors have improved with the use of Product A. In the traditional process they would prepare tender documents and then either post or e-mail these to individual contractors. Using Product A, tender document files can now be published onto the project Web site, enabling all contractors to access tender documents from a single source thus avoiding any discrepancies. Another benefit of using Product A, is in

addressing individual contractor's queries about the tender/procurement documents. Now, the company can address individual queries and publish this information onto the project Web site for the benefit of all project team members and other contractors. This avoids repetition of queries and reduces the need to address the same query resulting in time savings.

Company 4 has found Product A to be a particularly useful in the construction phase of the project. Traditionally, during the construction phase the trade contractor would submit drawings to the construction management firm for approval, who would then distribute the drawings to the design team. The design team would comment on the drawings and return them to the construction management firm, who would then assign drawings to the standard status A, B or C (where A is approved drawing, B is approved with comments and C is rejected). These would then be sent to the trade contractor. This traditional paper-based process was long drawn out and time intensive. The use of project extranets for document exchange/commenting has resulted in significant time savings (a few days as opposed to weeks it took using traditional processes).

The case study findings indicate that currently there is evidence of process improvement resulting from automation of processes and removal of bottlenecks leading to rationalisation of procedures (Figure 4). However, there is no evidence of process reengineering or development of any new processes that have lead to paradigm shifts.

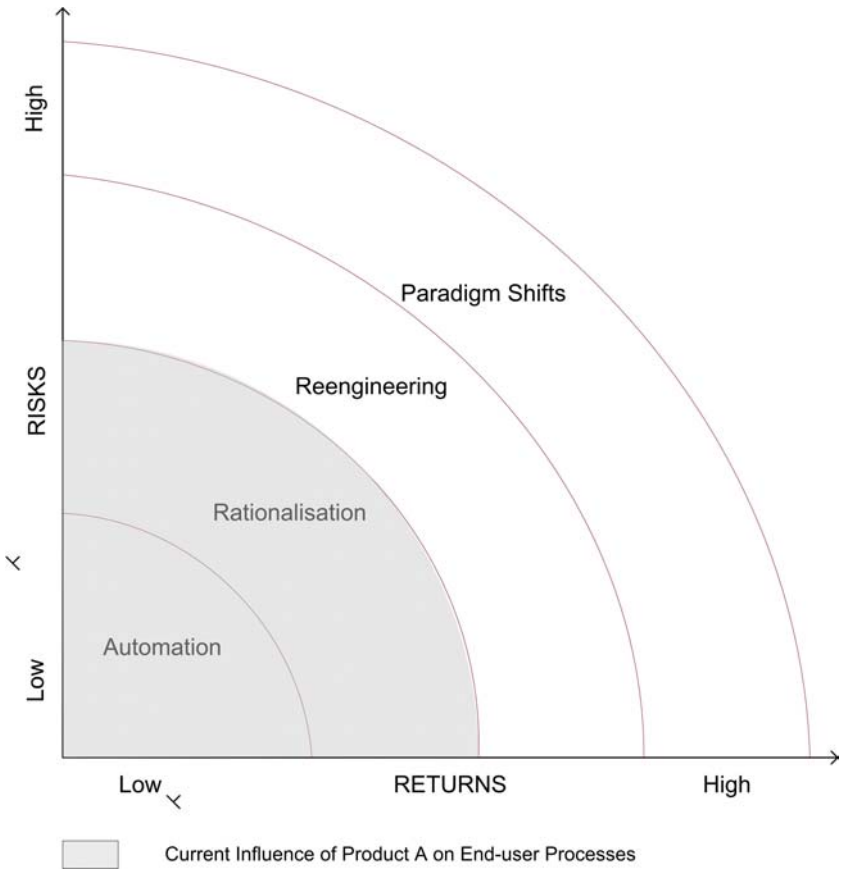

Figure 4. Spectrum of Organisational Change (Adapted from Laudon and Laudon, 2002)

3.3 END-USER PERSPECTIVE ON POSSIBLE BENEFITS OF PROJECT EXTRANETS

The end-user companies were presented with a list of possible benefits of using project extranet applications and asked their views on each. The benefits listed were derived from the literature review and other research studies (Shelbourn et al., 2002; Ruikar et al., 2001; Steele and Murray, 2001; and Motawa et al., 2001). The aim was to gauge the actual benefits as perceived by the end–user organisations. Their responses are listed below.

Improved communication with supply chain members: Respondents believe that project extranets provide an environment suitable for partnering, thus allowing members of the construction supply chain to work with other project team members and establish contacts with members belonging to other construction disciplines. Thus in their view, the tool acts as a facilitator for better communication.

Reduced response time across the supply chain: Respondents believe Product A facilitates faster information flow across the supply chain. As seen in the process example (Figure 5) when using the tool it is possible to comment on, update and distribute drawings/documents electronically, thus saving on time otherwise required for posting and printing.

Faster and cheaper document processing: Respondents believe that the use of Product A has resulted in faster and cheaper document processing. In their view document processing is cheaper since people only print paper copies if it is absolutely essential. Company 3 has seen a £31,000 saving in architect's print costs alone. For Company 4, there has been a 25% reduction in the cost of reprographic printing.

Eliminates manual re-keying: Most end-user companies have benefited from the reduced need to manually re-key in information. Company 1, has seen benefits in terms of time savings and reduced errors due to the elimination of the manual re-keying process, especially at the tender stage. Prior to using Product A, the company would prepare tender documents electronically, print copies and post the printed paper documents to potential bidders. Bidders would return the completed paper documents and on receipt, Company 1 would re-enter the figures into their electronic files. Product A enables electronic publishing and receipt of documents. This eliminates the need to physically re-key in information, thereby saving time and making the resulting process more efficient.

Creating a greater level of trust among supply chain members: Product A facilitates and encourages 'openness' amongst project team members and lays the foundation for a better working relationship. There is an increased level of transparency because information about documents/drawings that are posted/received/downloaded to/from the system, is visible to all project team members. This practice increases accountability and creates a greater level of trust amongst team members. A majority of the end-user companies agreed that the trust issue is important to construction, as quite often the success of a construction project depends on the working relationships between disciplines. A good working relationship can be especially useful in situations of conflict. According to Company 2, "if you win the trust of your fellow team members it is almost certain that you will find yourself working with them again".

Increased client involvement: In theory, most end-user companies agreed that using Product A construction client(s) can access all project files/data and therefore be more aware of the project status. However, in their view this is not entirely true in

practice. This is because, the tool only allows access to project information and does not force the client to be involved. Thus, it is entirely up to the client whether or not to use the facility.

Improved service to client: The end-user companies agreed that use of Product A has improved service to client. According to Company 5, the tool facilitates on-time delivery of the project, which in turn benefits the client. Also, because of the constant availability of information it is possible to respond to client needs quicker.

Knowledge database and preservation of corporate memory: Product A maintains a record of project lifecycle information including all document/ information exchanges between construction parties, project highlights, problems faced, how these were resolved, etc. These records can be very valuable to end-user companies as they can be used to resolve future issues of similar nature e.g. lessons learnt from previous project(s) or stages of the same project can be applied to latter projects/stages. The end-user companies acknowledged that a knowledge database can be useful, however, none of the companies have taken measures to benefit from it.

Avoid disputes: Product A creates an audit trail of the project including details such as meeting minutes, actions, comments, requests, approvals and notifications that are generated during the project. It also maintains records of information such as who has published what, when information was viewed and by whom. Company 1 has benefited from this on several occasions. Each time users disputed the receipt of certain documents, it was possible for them to prove when that the document had indeed been issued to the user. This practice has led to increased accountability and transparency. Therefore issues can be resolved much quicker, saving on time and money.

Paperless environment: All end-user companies agreed that the use of paper has reduced since using Product A. In their view, it is a 'less paper environment' rather than a paperless environment. Even though most end-user organisations are driving down the use of paper, those interviewed beleive that it is virtually impossible have a paperless office. The reason being that people are more comfortable in a paper environment as they have used it over several years. Company 4 has a strategy to cut down on the use of paper. The company policy strictly disallows the use of the paper documents as the primary source, especially when the projects are managed using electronic tools.

From the benefits it is seen that reduction in response time and faster and cheaper document processing are two main benefits of project extranets. The others are ancillary benefits that most end-users of project extranets will benefit from.

3.4 END-USER PERSPECTIVE ON POSSIBLE BARRIERS TO IMPLEMENTATION OF PROJECT EXTRANETS

End-user companies were presented with a list of possible barriers to implementation of project extranet applications and were asked to present views on each giving examples wherever possible. Their responses are discussed below:

Security issues: Although security is high on the agenda for most end-user companies, it does not deter the wider usage of the tool, and concerns are often based on long-standing misconceptions rather than reality. Company 5 points out that the tool is probably more secure than a site office where important project drawings, documents and equipment are stored. According to Company 3, Web-based tools such

as Product A do not compromise their security. In their view, “the issues of confidentiality, authentication, etc have always been there regardless of the medium of communication used”.

Multiple-vendor issues: Currently, there are several ASPs that offer extranet solutions to the UK construction market. In many cases a single construction organisation may be using several different extranet applications on different construction projects. This can be a problem especially for SMEs (Small and Medium Enterprises) and other companies that are not project leaders, who are not always in a position to choose which application to use and often end up using more than one tool. The tools that are currently available in the market each have different interfaces, functionalities and may also use different terminology. This poses the end-user companies not only with the problem of getting acquainted with multiple interfaces, but also understanding the different terms and functions of each application.

Cost issues: The issue of implementation cost and ROI can be a major barrier in the adoption of any technology. However, for the respondent companies cost is not a major concern. These companies view themselves as visionaries, forward thinking and market leaders, who want to keep abreast with technology, whatever the cost. In their view extranet technology is here to stay. These organisations also have dedicated IT (Information Technology) departments and specific budget allocation for new technologies. According to Company 2, the benefits far outweigh the cost incurred, therefore it is not an issue. Respondents have pointed out that cost can be an issue with some of the SMEs in the supply chain, as usually they are forced to use such tools due to market forces that are outside their control.

Cultural issues: Adoption of any new technology can result in changes in the day-to-day working of individual staff members and hence is likely to meet with resistance. Most end-user companies witnessed some resistance from staff when the tool was first introduced, mainly from senior members of staff who have established a certain work culture over the years. According to Company 1, change cannot be forced onto anyone, but has to be introduced gradually to be effective. All staff members need to fully understand why the change is important not just to the company, but to the individual as well. For successful implementation of any tool it is important for the organisations to get full staff commitment. This can only be achieved if individual staff fears and reservations are fully understood and addressed. Such a proactive practice helps build confidence amongst the end-users and they are more likely to accept the change without resistance. Cultural issues can also arise when there is a lower level of IT literacy in an organisation. In the experience of one respondent they have met resistance (for implementing the tool) from the sub-contractor and supplier disciplines who have relatively lower levels of IT literacy.

Legal issues: Since project extranets are relatively new, some legal aspects remain unclear. Many end-user companies view such unclear regulatory issues as deterrents to the adoption of such tools. Recent research by CICA (Construction Industry Computing Association) (Hamilton, 2004) states that it is common industry practice for ASPs to have their own standard terms and conditions of business and for end-user companies to accept vendor’s conditions. All end-user companies have taken necessary steps (e.g. appointing legal advisors) to address such issues. The end-user companies suggest that others who wish to use tools such as Product A should also clarify the legal issues such as ownership of data, legal admissibility of electronic documents, loss of data due to server breakdown, etc prior to signing contracts.

Connectivity issues: Company 5 pointed out that it is sometimes not possible to

access the project Web site due to network connection failures. Such eventualities can be frustrating to the end-users as they usually do not have any control over such situations and often have to wait till the problem is rectified. Such occurrences can disrupt the schedule of staff members (or sometimes the project schedule) especially when they have planned online meetings with other project partners.

Technology issues: In the construction industry different construction companies have varying levels of IT infrastructure. Also, each office (sometimes within the same company) may have different versions of the same software. Although, most ASPs provide plug-ins for viewing drawings/documents, the problem arises when the end-user with a older version of a software solution tries to save a file done in a newer version (most software solutions are backward compatible but not forward compatible). This leads to problems of integration with existing backend systems.

Softer issues: Through the end-user feedback, some softer issues associated with project extranets were brought to light. Company 1, regarded the 'immediacy' that the Web demands as an issue that can sometimes put undue pressure on staff. Even though most project extranet applications have a project page that alerts staff to take action (sometimes immediate) it is not always possible for staff to address issues instantly (even though the system may prompt them to do so).

Another issue was that of staff sometimes resorting to traditional ways of handling issues. For example, using Product A, documents can be posted onto the project Web site and individuals who are on the issue list are notified of the action that they need to take regarding that particular document. However, one of the problems that end-users have encountered is that, instead of posting replies on the project Web site, some users are resorting to old practices of sending e-mail notifications. This unnecessarily complicates matters and duplicates the process. According to Company 1, end-user companies need to take measures to make it mandatory for staff to communicate via that tool to avoid conflicts.

In summary it can be said that end-users do not consider legal and security issues associated with Web-based tools such as Project A, as major barriers to implementing Product A. The current lack of standards for interoperability and version control problems are classified as medium level barriers by the organisations. However, as seen from the responses, ASPs and end-user companies are taking steps to rectify the situation. Most end-user companies identified issues related to management buy-in and cultural issues as the major barriers to the ubiquitous use of this technology within the construction industry. While cost was not seen as a major issue amongst end-user companies, it was identified as a possible deterrent for adoption amongst SMEs.

4. SUMMARY AND CONCLUSIONS

This paper has shown with the help of case studies, the effects of project extranet applications on the business processes of end-user construction-sector companies. End-user companies have incurred benefits in terms of improved project performance by removing redundant processes. Technologies such as project extranets facilitate the construction process and increase the probability that the project will meet its target cost and time schedule. In this respect, project extranets contribute towards improving project performance.

The application of the technology adoption cycle for project extranets in construction indicates that the technology is still within the early adoption phase in the industry. Findings show that management buy-in is vital for implementation of project

extranets within construction organisations. The companies interviewed are amongst the early adopters of this technology and have used it to improve business benefits and gain competitive advantage. For project extranets to be widely adopted it is essential to get buy-in from the early majority. It is possible to encourage the early majority to adopt such tools when they see 'visionaries' and 'market leaders' such as those within this case study, benefiting from the tool and leading the way to its wider adoption.

Adoption of any technology brings about change and is therefore likely to be met with resistance. The case studies indicate that cultural issues are one of the major barriers to implementing project extranets within construction. ASPs should be aware that the construction industry is a 'traditionalist' industry in its own right and does not welcome change easily. The change must be introduced gradually. The tool should be developed by staff who have a full understanding of the construction process and its complexities. It should be easy to implement and use. Software tools that 'do too much' or are complex to use, are not easily adopted by the industry. Therefore, ASPs and software vendors must be careful not to develop technology-led solutions that force end-user organisations to drastically change their methods of working. They need to fully understand that the technology tool they develop is merely a facilitator of the process and not the process itself. Currently, collaboration tools such as the one used within this case study, work well, because of their minimal impact on individual businesses. Current industry practice for adoption of e-commerce tools requires software vendors to change or modify their solutions to meet individual company needs. Such practice may work in the short term, but has certain limitations in that the end-users are not necessarily making full use of the technology and hence not deriving full benefits from it. Instead of regarding e-commerce as an extension of IT and fitting it into the existing business processes, construction companies need to recognise that it is a radically different approach to conducting business and therefore should explore new processes and opportunities, which may only be possible because of e-commerce. E-commerce should not be viewed as a 'passing phase'. The early adopters warn that e-commerce is here to stay and it will not be long before it becomes an industry-wide norm.

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APPENDIX E PAPER 5 (UNDER REVIEW)

Ruikar, K., Anumba, C.J., and Carrillo, P.M., (under review). 'VERDICT – an E-readiness Assessment Application for Construction Companies.' Submitted to *Automation in Construction*.

VERDICT – AN E-READINESS ASSESSMENT APPLICATION FOR CONSTRUCTION COMPANIES

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ABSTRACT

In the recent years, the use of e-commerce tools in construction has been on the increase. The benefits of using these tools on construction projects have been well documented in research and industry publications. Studies have shown that the construction industry recognises the potential for the use of e-commerce. It is the industry view that this technology is 'here to stay'. However, the use of these tools is still not ubiquitous within the industry and the uptake of e-commerce technology in the UK construction industry has been relatively slow.

Implementation of any new technology such as e-commerce for achieving business targets requires major change in an organisation, its current practices, systems, processes and workflows. Taking this into account, construction companies who are currently using, and those who have yet to use, e-commerce tools need to take measures to successfully adopt and use this technology. It is important for companies that seek to adopt e-commerce tools to analyse their businesses to ensure a productive and beneficial implementation of these tools i.e. assess their 'e-readiness' for adopting e-commerce tools.

This paper describes the development and implementation of VERDICT, an e-readiness assessment prototype application for construction sector companies. VERDICT assesses the e-readiness of construction companies in terms of their management, people, processes and technology, and presents the readiness results in both textual and graphical formats. It also provides companies with the potential to compare their e-readiness against that of the 'best-of-breed'.

KEYWORDS

Readiness Assessment, E-readiness, Construction, E-commerce

1. INTRODUCTION

With the growing importance of the Internet, companies across several industries (including construction) are increasingly leveraging the Internet to achieve competitive advantage (Cheng et al., 2003). Internet-based tools such as project extranets are being used to manage construction projects. Such tools can be used to monitor, control, manipulate and store project information and to make it available to all participants of the construction supply chain (Alshawi and Ingirige, 2002). Examples of Internet-based tools include a computer-mediated tendering system for services or contracts, purchasing of materials via the Internet by a contractor, project extranets for project management and specifying products online by a manufacturer (ITCBP Intelligence, 2002). All these tools can be categorised under the single banner of e-commerce tools for construction as they facilitate trading, exchange of data and information, and automation of the business processes and workflows (Kalakota and Whinston, 1997).

Research studies (Ruikar et al., 2001; Anumba and Ruikar, 2002) and recent industry and research publications (Stephenson and Turner, 2003; Laudon and Laudon, 2000) have documented the possible benefits and business opportunities for companies using e-commerce tools such as project extranets. In spite of these documented benefits, the UK construction industry has been relatively slow in the uptake of these tools in their day-to-day workings (ITCBP Intelligence, 2003). A survey of the UK construction industry, undertaken by the Construction Products Association (CPA, 2000), predicted that by 2005, 50% of the industry's business activities would be undertaken using e-commerce. However, another survey carried out a year later by the same organisation indicated a considerable reduction in these projected figures to 22% (which is less than half of what was initially predicted), indicative of a much slower uptake than anticipated. The construction industry stepping back from the initial 'dot-com fever' was seen as the main reason of this change (CPA, 2001). Additionally, some other factors that have also contributed to this slow uptake are:

- Since e-commerce technology is relatively new there is limited availability of information or feedback on the technology's performance on previous construction projects;
- As with most technologies, it can be difficult to gauge the quantitative return on investment (ROI) from using new technologies such as e-commerce; and
- The teething problems and changes in working culture and practices which are required initially, with the adoption of any new technology, very often deters new users.

Although the uptake of e-commerce in the UK construction industry has been relatively slow (Construction Industry Times, 2002; Stewart and Mohamed, 2003), it can be seen that the industry has now realised the enormous potential for the use of e-commerce in the construction sector. The UK construction sector is trying to maximise the use of this new and innovative technology through several industry and government-backed initiatives [e.g. M4I (Movement for Innovation), CBPP (Construction Best Practice Programme), CPA (Construction Products Association), Construct-IT, etc.] that promote research into the use of new technologies, such as e-commerce, in construction. It is now the industry view that, e-commerce is here to stay and it will not be long before it becomes an industry norm (Ruikar et al., 2004).

Implementation of any new technology such as e-commerce for achieving business targets requires major change in an organisation, its current practices,

systems, processes and workflows (ITCBP Intelligence, 2003). The right strategies and implementation plans have to be developed, communicated and implemented. Since this is not easy, issues such as getting 'buy in', defining a strategy, selecting a system, developing a training programme, defining operating procedures, modifying organisational structures, reviewing use, and extending use. need to be thoroughly researched (ITCBP Intelligence, 2003). Taking this into account, construction companies who are currently using, and those who have yet to use, e-commerce tools need to take measures to successfully adopt and use this technology. It is important for companies that seek to adopt e-commerce tools to analyse their businesses to ensure a productive and beneficial implementation of these tools i.e.:

- They need to evaluate the impact of using e-commerce tools on their day-to-day business processes; and
- Assess their 'e-readiness' for adopting e-commerce tools.

These two aspects form the main focus of the research project for which this paper was written. This paper focuses on the development of an e-readiness assessment tool (VERDICT) for construction organisations. The next section defines e-readiness and describes the adopted methodology. This is followed by a review of readiness assessment models and detailed description of the development and implementation of the VERDICT tool. An example is used to illustrate the operation and features of the system and aspects of system evaluation are also presented.

2. METHODOLOGY FOR E-READINESS

E-readiness can mean different things to different people, in different contexts, and for different purposes. Thus it is important to define e-readiness in the context of this paper. E-readiness is defined here as 'the ability of an organisation, department or workgroup to successfully adopt, use and benefit from information and communication technologies (ICTs) such as e-commerce'. It is important for companies that seek to adopt e-commerce tools to undertake an analysis of their businesses to ensure a productive and beneficial implementation of these tools (i.e. they need to evaluate their 'e-readiness'). The approach adopted in the development of an e-readiness assessment tool for construction organisations is presented in this section.

The triangulation methodology is adopted for the development of the e-readiness model that assesses the readiness of construction organisations for e-commerce technologies. A triangulation method involves the use of both qualitative and quantitative approaches. Using this method, theories can be developed qualitatively and tested quantitatively (Khalfan, 2001). Triangulation increases the validity and reliability of the data, since the strengths of one approach can compensate for the weaknesses of another (Sunyit, 2004).

A systematic two-stage approach was adopted for assessing e-readiness. The first stage involved the development of an assessment model for gauging the e-readiness of construction organisations for using e-commerce applications. Using a qualitative approach, a review of existing literature on the subject matter (i.e. readiness assessment models and tools) was carried out. The best suited models in the context of this research study were then adapted to develop a model that assesses the e-readiness of construction organisations. The existing processes, working methods, procedures and practices in construction organisations were also analysed using qualitative methods such as one-to-one discussions, case studies and interviews. The outcome of this led to the development of a set of questions that assess the overall e-readiness of construction organisations for adopting and implementing e-commerce

technologies. Further, a quantitative approach was adopted to analyse end-user responses (by calculating cumulative and average scores) and presenting the findings graphically.

The second stage involved development and evaluation of a prototype application. The development of the application was an iterative process based on the Rapid Application Development (RAD) methodology of software development. RAD is a concept that facilitates the faster development of application software (Webopedia, 2004). RAD is performed iteratively through several stages as illustrated in Figure 1.

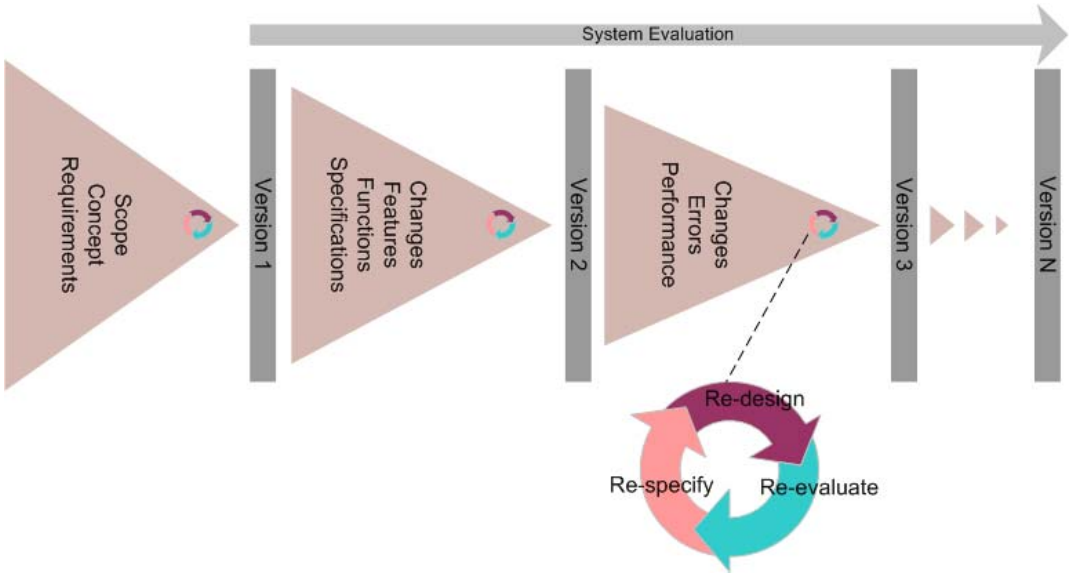


Figure 1. Rapid Application Development using Iterative Prototyping (Adapted from Maner, 1997)

The e-readiness tool was evaluated using a number of methods including self-evaluation and peer reviews during the development phase and then through industry validation of the final prototype software. Details of the evaluation are described in Section 6.4 of this paper.

3. REVIEW OF READINESS ASSESSMENT MODELS

An increasing number of readiness assessment tools have been developed over the last few years. On the surface, each tool gauges how ready a society or economy is to benefit from information technology and e-commerce. However, according to Peters (2001) the range of tools use widely varying approaches for readiness assessment, including different methods for measurement. Each assessment tool or model has a different underlying goal and definition of e-readiness. While some gauge the readiness of countries and economies to adopt Internet-technologies on a global platform, others are more focussed on assessing the readiness of specific industry sectors to adopt Internet technologies.

Several readiness assessment models were reviewed as a part of this study, including those that were not construction-specific. Harvard University's tool called the 'Networked Readiness Index' assesses a country's capacity to make use of its ICT resources. It defines e-readiness as the degree to which a community is prepared to participate in the networked world including its potential to participate in the networked world in the future (Kirkman, et al., 2004). On the other hand, APEC's (Asia Pacific

Economic Co-operation) E-Commerce Readiness Initiative focuses on government policies for e-commerce (Bui, et al., 2002; Information Technology and Broadcasting Bureau, 2000; and Peters, 2001). Mosaic's readiness assessment tool aims to measure and analyse the worldwide growth of the Internet (The Mosaic Group, 1998).

While these tools focus on assessing readiness of countries, governments and policies for adopting Internet technologies, some others e.g. SCALES (Supply Chain Assessment and Lean Evaluation System) assess the readiness to adopt different concepts or approaches for engineering (e.g. readiness assessment tools for concurrent engineering). SCALES was developed for a specific industry sector, - the manufacturing industry (K3 Business Technology Group, 2004). It was designed to assess a company's (especially SMEs) readiness for adopting Lean Manufacturing techniques. RACE, on the other hand, is a Readiness Assessment tool for Concurrent Engineering (CE) and is widely used in the software engineering, automotive and electronic industries (CERC, 1998).

Two other readiness models that are of particular relevance to this study are the BEACON model (Khalfan, 2001) and the IQ Net Readiness Scorecard (Cisco Systems, 2004).

1. The BEACON model: BEACON (**B**enchmarking and R**e**adiness **A**ssessment for Concurrent Engineering in **Con**struction) assesses the readiness of construction companies to improve their project delivery processes through the implementation of concurrent engineering (Khalfan, 2001). It consists of four elements, which are Process, People, Project and Technology. A commercial software tool has been developed to automate the process of CE readiness assessment for construction organisations. The software takes the user through a series of questions and generates a diagram called the BEACON model diagram that graphically illustrates the assessment results.
2. iQ Net Readiness Scorecard: This was developed by CISCO and is a Web-based application that assesses an organisation's ability to migrate to an Internet Business model. It is based on the book Net Ready by Amir Hartman and John Sifonis (2000), which gauges the readiness of IT service providers. The application comprises of a series of statements that fall into four categories - Leadership, Governance, Technologies and Organisational Competencies. Similar to the BEACON model, companies are required to respond to the statements and on completion, they are presented with an IQ Net Readiness Profile.

The model that is described in this paper combines aspects of these two models and builds on them. The proposed model adopts a similar methodology where the end-users are presented with a set of statements and an assessment of their e-readiness is based on their responses. On completion, the respondents are presented with a report which includes textual and graphical data. Where the proposed model differs from the two described above is that, while the BEACON model focuses on CE and the iQ Net Readiness Scorecard addresses the readiness of technology companies (e.g. software companies, vendors and ASPs) to develop applications and profit from what is termed the "e-conomy", the proposed model assesses the e-readiness of construction organisations to adopt e-commerce technologies. The readiness assessment tool that is based on the proposed model is called VERDICT (an acronym for Verify End-user e-Readiness using a Diagnostic Tool).

4. VERDICT

4.1 BACKGROUND

VERDICT is an Internet-based prototype application that assesses the overall e-readiness of end-user companies and profiles the companies in this regard, based on their responses. The name, 'VERDICT' reflects the overall aim and purpose of the application. VERDICT is developed to aid construction sector end-users to gauge their e-readiness for using e-commerce technologies such as Web-based collaboration tools. It can be used to assess the e-readiness of construction companies, department(s) within a company, or even individual work groups within a department.

4.2 THE VERDICT MODEL

Several research publications (Basu and Deshpande, 2004; Goolsby, 2001; IBM, 1999; and Kern, et al., 1998) and articles (Fuji Xerox, 2003; Larkin, 2003; and Emmett, 2002) indicate that people, processes and technology are the three key aspects that need to be considered for successful implementation of technologies. Emmett (2002) states that together these three elements create business value. However, he further states that "the people, processes, and technology need a leader", just as "an orchestra needs a conductor". Emmett, draws a parallel with the performance of an orchestra and states,

" in an orchestra….You've got musicians (people), musical scores (process), and musical instruments (technology). But without a conductor, they're more likely to produce noise than music. Even if everyone in the string section plays the right notes at a relatively similar tempo, creating a symphony requires more than following the sheet music." Therefore "…..An orchestra needs a conductor"

The same analogy can be applied to the adoption and implementation of new and innovative technologies within construction companies. The "conductor" in this case is the management. To successfully implement and use any new technology it requires management buy-in and belief in order to plan and drive policies and strategies. The research findings from an industry-wide survey (Ruikar, et al., 2002) and case studies (Ruikar, et al., 2004a; Ruikar, et al., 2004b), complement this view. The case study findings have identified management buy-in and leadership as a critical factor affecting the adoption of technology within construction organisations. The adoption of any new and innovative technology (e.g. e-commerce) within an organisation/department/work-group requires total commitment from the management (or group leader). It is important for the management to buy into the technology so that they can lead the business into successfully implementing and adopting the technology, i.e. the management needs to be e-ready. Thus a fourth category, "management" is necessary. Taking this into account, the Verdict Model has been so structured that for an organisation to be e-ready it must have:

- *Management* that believes in the technology and takes strategic measures to drive its adoption, implementation and usage in order to derive business benefits from the technology;
- *Processes* that enable and support the successful adoption of the technology;
- *People* who have adequate skills, understanding of, and belief in, the technology; and finally

- *Technology* tools and infrastructure necessary to support the business functions (e.g. processes and people).

All four categories are considered important for an organisation to be e-ready. A company cannot be e-ready if it satisfies the requirements of just one category and not the others. For example, even if the management, processes and people are e-ready, the fact that the technology infrastructure is inadequate will affect the overall e-readiness of the organisation. This example indicates that the company will need to address its technology issues in order to be e-ready. Drawing from the orchestra analogy, *"a memorable symphony performance doesn't happen when the players just assemble with their instruments and scores."* and, *"the orchestra with the most violinists isn't necessarily going to sound the best."* Similarly, all four categories - management, processes, people and technology - need to work hand-in hand and symbiotically (see Figure 2).

Figure 2. Four Key Elements for an E-ready Organisation

Many organisations fail to realise that if they install a system without first achieving universal buy-in and changing business processes, they will have a software installation, not an implementation of a comprehensive solution to business problems. According to Larkin (2003), if an organisation merely completes an installation by automating inefficient processes, it will not realise a long-term positive impact. A successful company-wide rollout includes more than simply buying and installing software. It requires the management to align people, processes, and technology to implement a solution that meets business needs. The result is the ability to capitalize on the full potential of the technology investment. Thus, the implementation of new technology needs to be carefully managed and orchestrated. Companies should recognise that in order to successfully implement and benefit from new technologies such as e-commerce, it is essential that the people (who are the ultimate users of the technology) and the process are given due consideration. The technology within the company also needs to be assessed in order to ensure that the company has the necessary infrastructure (ICT infrastructure) to use existing and new or emerging technologies successfully. Further, the company needs clear leadership and direction that is provided by the management in order to successfully implement the technology. These four categories are described in detail below.

MANAGEMENT

Management is an important factor that leads and governs the adoption, implementation and use of technology within organisations through the careful orchestration of business strategies in order to derive definite business benefits. This can be achieved by defining specific business strategies for technology adoption and by ensuring that adequate resources are available in terms of funds, time and man-power.

The case studies that were conducted as part of this study have also highlighted management buy-in as an important aspect that can influence the successful implementation and adoption of technology/technologies within a construction organisation (Ruikar, et al., 2004). Senior managers can authorise investigations into all aspects of current activities to identify areas where improvements can be achieved by changing to new e-commerce–based systems. However, management should endorse the technology only after investigating the technology for its overall capability and scope. It should examine whether the technology has been successfully used in construction or other industries before, including the reviews (favourable or otherwise). In the absence of such reviews it is worthwhile identifying and investigating the possible risks and taking adequate measures for minimising the risks and maximising the rewards. The adoption of technology will bring about change, and management needs to carefully consider different aspects of how this change will be brought about and managed. These aspects are highlighted in Figure 3.

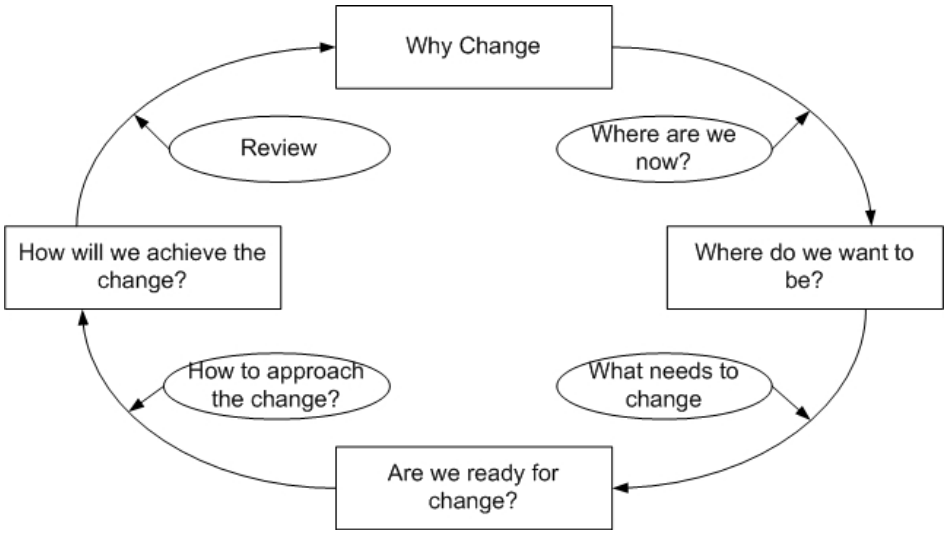


Figure 3. Aspects of Change Management (Adapted from TUV Management and IT Consultancy, 2004)

If the management takes into account these aspects of change management, it is more likely than not that the business will be favourably geared towards (or ready for) adopting and implementing e-commerce technology. However, it is important that the senior management does not loose sight of its ultimate vision and aim in using the technology (e.g. to derive business benefits). To quote Paul Nitze, a famous American diplomat and strategist, “One of the most dangerous forms of human error is forgetting what one is trying to achieve” (Hill, 2004). In business terms this can have dire consequences.

PROCESS

Process means a practice, a series of actions, done for a specific purpose (Craig, 2004). It also includes the working rules, ethics, procedures, within and between organisations. It is important to consider the process factor as the adoption of new technology will directly affect an organisation's processes and vice-versa. Therefore, companies will need to ensure that the new technology either complements their existing processes or that the existing processes are flexible enough to accommodate the technology. In order to maximise the benefits from technology adoption (e.g. increased transparency, reduced response time and improved integration of activities across the supply chain), organisations need to examine and map their existing processes. This will help in identifying the bottlenecks and devising measures to remove such bottlenecks or process inefficiencies. The process-related change that technology can bring about is four-fold (Laudon and Laudon, 2002):

- Process Automation, which is the most common form of change where organisations use computers to speed up the performance and efficiency of existing tasks and functions.
- Rationalisation of Procedures, which involves the streamlining of standard operating procedures, eliminating obvious bottlenecks, so that automation makes operating procedures more efficient.
- Business Process Reengineering, which is a powerful form of organisational change in which business processes are analysed, simplified and redesigned.
- Paradigm Shift, which involves rethinking the nature of the business and the nature of the organisation itself.

According to Laudon and Laudon (2002), process change of any nature carries its own rewards and risks. Process automation and rationalisation of procedures are relatively slow-moving and slow-changing business strategies that present modest returns, involving lower risks. The much faster and more comprehensive change is brought about by process reengineering and paradigm shifts carry higher rewards and risks.

PEOPLE

The people factor accounts for the social and cultural aspects related to the people within an organisation. It takes into account the attitudes, outlook, and feelings of staff within an organisation towards change brought about by technology adoption. People make organisations and are important to its success. No matter how carefully the management has geared the business to successfully adopt new technology, it is less likely to succeed to its full potential, if the people are not ready. The people, who are the ultimate users of the technology, need to have the appropriate skills and competencies, functional expertise, the right attitudes, a positive mindset, and the culture to adapt and adopt.

The people factor is important and can affect an organisation's overall e-readiness, because the introduction of any new technology (or change) will affect the workforce within that organisation. It is therefore necessary to assess the organisational culture and the readiness of company staff (people) in accepting new and innovative technologies such as e-commerce. It is also important to ascertain whether the organisational structure provides an appropriate environment for e-commerce adoption

and use. According to Ostroff (1999), the horizontal organisation is well suited for the information age. Such horizontal structures allow for greater flexibility in dealing with today's competitive and rapidly changing business environment. Through the use of e-commerce tools, projects can be managed in an open environment with more transparency between different members of the team. For an organisation in which such an open culture already exists, there is less likely to be a 'culture shock' and therefore the change is less likely to be met with any resistance. However, for those organisations in which there traditionally exists a culture of secrecy and privacy, the people factor may be more of an issue that needs to be addressed.

TECHNOLOGY

The final category to consider is technology. The technology factor covers all aspects related to IT (Information Technology) and communications technologies (e.g. Internet technology), which include both the hardware and software usage and its availability within a company, department or workgroup. Also important are the aspects related to the performance of the technology – thus, even if the technology infrastructure is adequate and available, it is of no consequence, if it cannot efficiently perform the required functions. For example, an end-user company may have a computer linked to the Internet, but still cannot send large files (e.g. CAD drawings) because the system is not equipped to handle such tasks. The problem in this case is not just confined to that individual company. This is mainly because, technologies such as e-commerce allow project teams to communicate and exchange data in a collaborative environment. Thus, even if one company in the chain is ill-equipped, it has adverse effects on the entire chain. 'A chain is only as strong as its weakest link.' Thus this is an important technology issue that needs to be considered in assessing e-readiness.

Technology is capable of coordinating different activities within and across organisations and also across industries (Laudon and Laudon, 2002). With the help of technology, companies can reduce transaction and document processing costs and time (Ruikar et al., 2004a). Processes can be made more efficient and streamlined by removing the obvious bottlenecks. However, all these benefits cannot be realised if an adequate technology infrastructure is not in place and available to the people in an organisation, who are the ultimate end-users. Organisations that aim to use e-commerce tools should at least be equipped with the basic infrastructure necessary to operate such tools.

Furthermore, it is important to establish if companies are familiar with the use of specialist software applications such as Electronic Document Management (EDM) and Groupware. Such software applications enable the exchange of knowledge, sharing and editing of documents, revision of reports or publications, within or between workgroups. The case studies undertaken indicated that companies that were familiar with the use of these software tools found it easier to migrate to the next level i.e. Web-based collaboration tools (Ruikar et al., 2004b).

4.3 VERDICT IMPLEMENTATION

The VERDICT application consists of a series of judgement statements which fall into the four categories discussed in the previous section. The end-users may either agree or disagree with these statements, to varying degrees. Verdict relies on the judgement of the respondent (i.e. end-user) as to whether or not he/she agrees with the statement/s in the context of their organisation, department or group. The respondent(s) should ensure that their responses are consistent with their assumptions

e.g. if the responses are in the context of the department (and not the organisation), then that assumption must be consistently reflected throughout. The extent to which the respondent agrees or disagrees with the statement is graded on a scale of 1 to 5, where 1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strongly Agree. A 'don't know' option is also included (where don't know = 0 score). The questions/statements are so orchestrated that a response of strongly agree will generate the highest score of 5 points. An average score is calculated for each category. The higher the average score the more likely it is that the end-user company is 'e-ready'. Respondents are required to answer all questions for a meaningful outcome. Once all the questions are completed the end-users are presented with a final verdict with respect to their e-readiness in the form of reports, which include textual and graphical data. Further details of these reports is included in Sections 6.1, 6.2 and 6.4 of this paper.

5. VERDICT - SYSTEM ARCHITECTURE AND OPERATION

5.1 SYSTEM ARCHITECTURE

Verdict is built around a three-tier architecture model, which comprises the following (see Figure 4):

- The client tier;
- The middle tier; and
- The database tier.

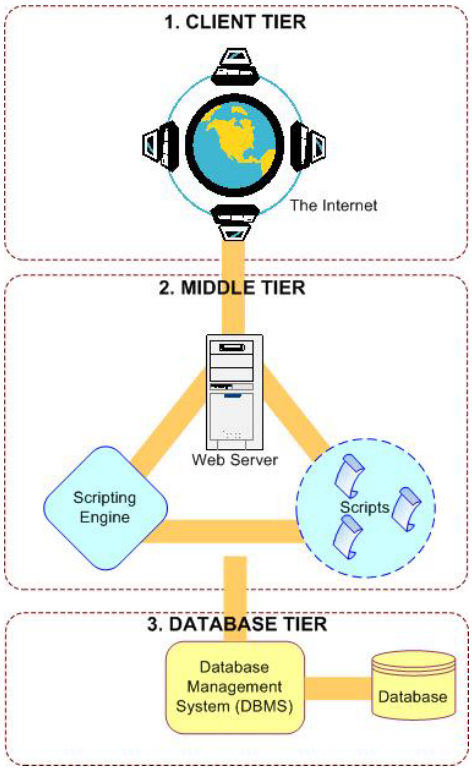


Figure 4. Three-tier Architecture of Verdict (adapted from Williams and Lane, 2002)

At the top level of the model is the *client tier*, which includes the Web browser software (e.g. MS Internet Explorer) that interacts with the Verdict application. In

between the top and bottom tiers is the *middle tier*, which communicates data to and from the client and database tiers. The middle tier is more complex and contains most of the application logic. The Web server, the scripting engine and the scripts reside in this tier. The base tier of the Verdict application is the *database tier*, which is made up of a database management system (DBMS) that manages the data that is created, added, modified, deleted and/or requested by the end-user/s.

VERDICT has been developed using PHP (Hypertext Preprocessor) as the scripting language. PHP is an open source[4], server-side, HTML-embedded (Hyper Text Mark-up Language) scripting language used to create dynamic Web pages. It is compatible with many types of databases (Webopedia, 2004). The front-end of the VERDICT prototype is designed using Macromedia Dreamweaver and Fireworks (for graphics). The application mainly consists of a series of Web-based questionnaire-forms that can be accessed by the end-user/s using standard Web browsers such as MS Internet Explorer and Netscape. Any information that is added to these forms (i.e. end-user responses) is stored in the MySQL database (situated in the *database tier*). MySQL is an open source RDBMS[5] (Relational Database Management System) that can run on UNIX, Windows and Mac operating systems. It has become a popular alternative to proprietary database systems because of its economy, speed and reliability (Webopedia, 2004). The VERDICT system resides on a server with which the end-user communicates. This forms the core of the *middle tier*.

5.2 OPERATION

Any requests made by the end-users are communicated via the Web server. This action invokes the PHP script code embedded in the Web page to request and retrieve the data from the MySQL database. This data, returned by the MySQL database, is then processed by the PHP script. The processed data is then presented to the end-user on a Web page. A high level view of this process, which includes the operations and the system architecture of the VERDICT application are illustrated in Figure 5.

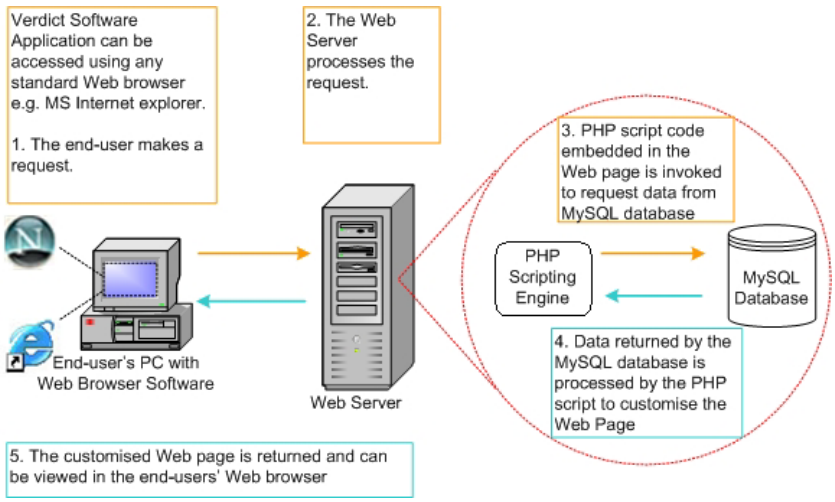


Figure 5. Operations of VERDICT (Adapted from Keitz, 2002)

[4] Open source refers to a program in which the source code is available to the general public for use and/or modification from its original design free of charge (Webopedia, 2004).

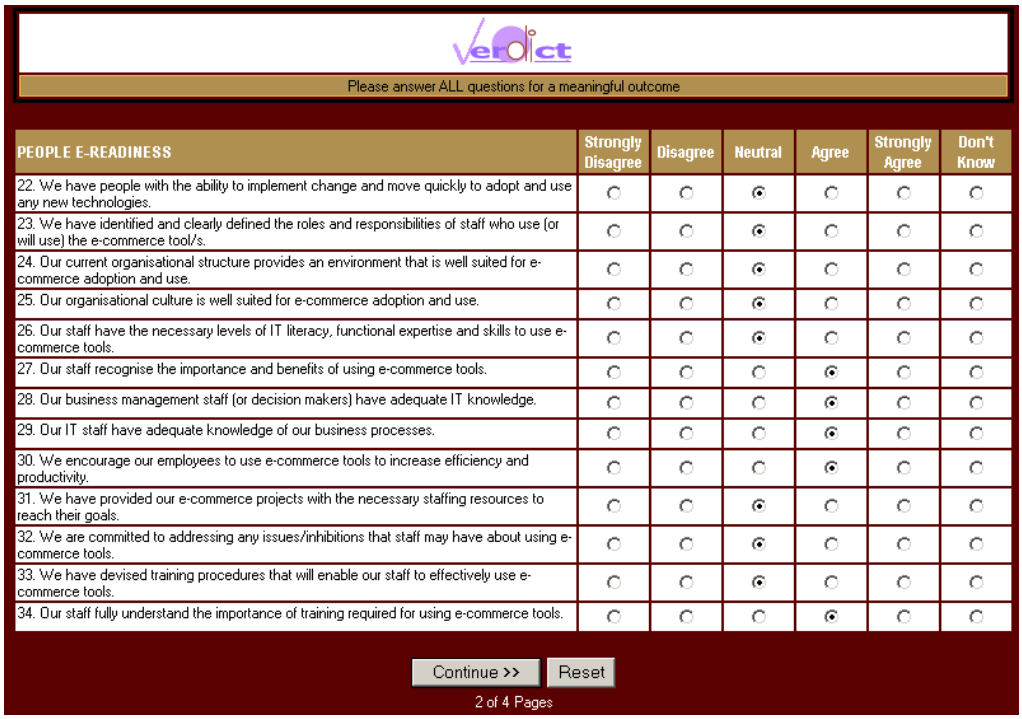
[5] RDBMS is a type of database management system (DBMS) that stores data in the form of related tables. Relational databases are powerful because they require few assumptions about how data is related or how it will be extracted from the database. As a result, the same database can be viewed in many different ways (Webopedia, 2004).

End-user companies only require a computer and an Internet connection to access and operate the tool. The performance of the tool will depend on the speed of the Internet connection and the version-type of the operating systems. For example, end-user companies with broadband connections will be able to access the site and process information faster than those with dial-up connections. End-users can access VERDICT online using the Web-address: http://civil-unrest.lboro.ac.uk/cvkr

The next section describes the actual working of the VERDICT software using an end-user case study.

6. END-USER CASE STUDY

The VERDICT questionnaire is required to be completed by appropriate company staff e.g. senior staff with adequate knowledge of the key aspects of the organisation – people, process, technology and management. The background information page of this application requires user input in the areas of company information and employee information. The example selected for this case study is that of a large construction management organisation with over 500 employees. This end-user company is identified as Company A in this paper. On completion of the required fields in the background information page, the user begins the e-readiness questionnaire which is distributed over four pages (one page for each category.) A typical page is shown in Figure 6.


Please answer ALL questions for a meaningful outcome

PEOPLE E-READINESS	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
22. We have people with the ability to implement change and move quickly to adopt and use any new technologies.	○	○	◉	○	○	○
23. We have identified and clearly defined the roles and responsibilities of staff who use (or will use) the e-commerce tool/s.	○	○	◉	○	○	○
24. Our current organisational structure provides an environment that is well suited for e-commerce adoption and use.	○	○	◉	○	○	○
25. Our organisational culture is well suited for e-commerce adoption and use.	○	○	◉	○	○	○
26. Our staff have the necessary levels of IT literacy, functional expertise and skills to use e-commerce tools.	○	○	◉	○	○	○
27. Our staff recognise the importance and benefits of using e-commerce tools.	○	○	○	◉	○	○
28. Our business management staff (or decision makers) have adequate IT knowledge.	○	○	○	◉	○	○
29. Our IT staff have adequate knowledge of our business processes.	○	○	○	◉	○	○
30. We encourage our employees to use e-commerce tools to increase efficiency and productivity.	○	○	○	◉	○	○
31. We have provided our e-commerce projects with the necessary staffing resources to reach their goals.	○	○	◉	○	○	○
32. We are committed to addressing any issues/inhibitions that staff may have about using e-commerce tools.	○	○	◉	○	○	○
33. We have devised training procedures that will enable our staff to effectively use e-commerce tools.	○	○	◉	○	○	○
34. Our staff fully understand the importance of training required for using e-commerce tools.	○	○	○	◉	○	○

Continue >> Reset

2 of 4 Pages

Figure 6. Typical Questionnaire Page

On successful completion of the questionnaire, users are presented with a report that summarises their overall e-readiness. This report is divided into the following three sections:

1. Table summarising average scores in each category (with 'traffic light' colour coding to indicate e-readiness);

2. Radar diagram of overall scores in comparison to the 'best-of-breed' in the construction sector; and
3. Summary of all responses highlighting areas that need attention.

6.1 TABLE SUMMARISING AVERAGE SCORES IN EACH CATEGORY

This section summarises the responses in each category i.e. Management, People, Process, and Technology and records the average score obtained in each category (see Figure 7).

Category Name	Average Score	Traffic Light Indicator
Management	3.33	
People	3.62	
Process	3.83	
Technology	4.46	

Figure 7. Typical Table Summarising Average Scores in each Category with Traffic Light Indicators

The minimum score that can be obtained for each category equals ‘zero’ where the respondents ‘don’t know’ the answers to any of the questions, and are therefore not ‘e-ready’. The scores are averaged and, depending on the average score, the respondents are presented with ‘traffic light‘ colour coding i.e. red, green and amber, to visually indicate their e-readiness in each category, where:

- Red indicates that these aspects need urgent attention;
- Amber highlights those aspects that need attention to ensure e-readiness; and
- Green indicates that the end-user organisation has adequate capability and maturity in these aspects and therefore is e-ready (in those aspects).

As indicated from Figure 7, Company A is e-ready in the areas of people, process and technology. This is represented by the green lights, but the amber light in the area of management indicates that the company has only addressed some of the issues that are required to achieve e-readiness, but still needs to address other issues to ensure e-readiness. This can be done by focussing on those points in the summary report, where the scores are 3.5 or less.

6.2 RADAR DIAGRAM

Average scores obtained in each category are plotted on a radar diagram. A radar diagram includes ‘spokes’ which represent dimensions or criteria, scores on which are joined up (Chambers, 2002). This gives the respondents a visual representation of their overall e-readiness (shown in blue) in comparison to the best-of-breed in construction (shown in red). The radar diagram for Company A is illustrated in Figure 8.

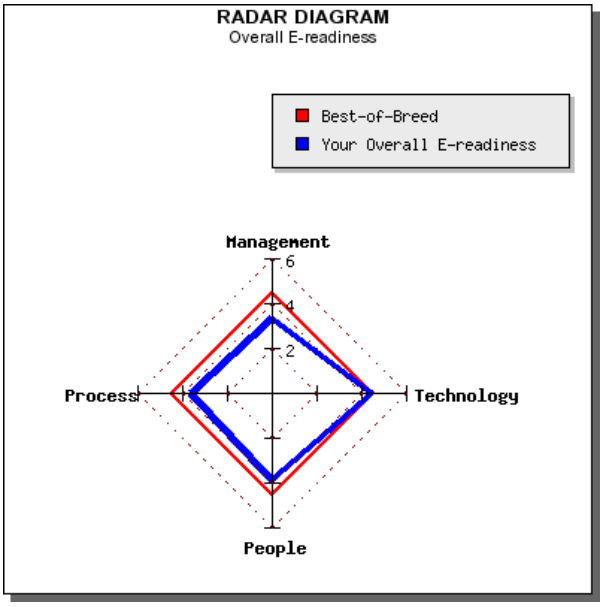


Figure 8. Radar Diagram Illustrating Overall E-readiness of Respondent's Company as Compared to Best-of-Breed

6.3 SUMMARY REPORT OF ALL RESPONSES

A summary of responses to all questions/statements is also included in the final e-readiness report. This includes a list of all the statements included in each category and the corresponding score of each response. This section also highlights specific points within each category that need attention to achieve e-readiness. This allows companies to focus on, and improve on, those specific aspects within each category, even if they may have achieved e-readiness in that category.

6.4 EVALUATION

Evaluation was based on the functionality of the prototype application, its user-friendliness, and its relevance to its target audience i.e. construction companies. The reviewers (i.e. evaluators) were given a standard evaluation questionnaire covering these areas. Reviewers were encouraged to include any additional suggestions for further enhancing the application.

The VERDICT prototype was evaluated using a number of methods including self-evaluation and peer reviews during the development phase and then through industry validation of the final prototype application.

- Self evaluation: The tool was continually tested for any errors or bugs, which were corrected simultaneously with the development of the prototype.
- Peer reviews: A carefully selected panel of researchers and academics conducted the peer review process.
- Industry reviews: A random sample of relevant industry practitioners evaluated the prototype application.

The industrial evaluation was conducted by managerial staff of leading UK construction organisations, which included consultants, contractors and project managers. A total of ten construction companies were approached for evaluating the

application. At present five construction companies have stated their willingness to evaluate this prototype. These companies fall in a range of construction disciplines including, contractors, engineers and quantity surveyors. Four of these five have already used the prototype to establish their e-readiness. Table 1 shows the average scores of each of the companies in the categories of management, people, processes and technology.

Table 1. Category-wise comparison of e-readiness average scores for end-user companies

Category Name	Average Scores			
	Management	**People**	**Process**	**Technology**
Company 1	3.48	3.46	3.83	3.54
Company 2	3.48	3.62	3.50	3.85
Company 3	3.33	3.62	3.83	4.46
Company 4	3.52	3.54	3.58	4.69
Average	**3.45**	**3.56**	**3.77**	**4.14**

From the table it is seen that:

- Management in all the companies is the least e-ready with the lowest scores compared to other three categories;
- All the companies are e-ready in process and technology categories;
- On an average, technology has scored the maximum points (i.e. have a score >3.5) showing that the companies have a high level of e-readiness in this aspect.
- All the companies have 'green-lights' in at least three categories and an amber in the one remaining category.

The initial feedback has been positive and these organisations have welcomed the use of such an assessment tool in construction. One of the reviewers suggested that more needs to be done to help organisations in addressing aspects for which they are not e-ready, however, this is beyond the scope of this project but can certainly be addressed in the future. Other suggestions mainly focused on 'fine-tuning' the application to enhance its user-friendliness and appeal. Such suggestions have been taken on board and the current version of this prototype application reflects this.

7. CONCLUSIONS AND FUTURE WORK

This paper has discussed the outcome of a study that resulted in the development of an e-readiness assessment prototype for the construction sector - VERDICT. The paper presented the e-readiness model for assessing the readiness of construction organisations for using e-commerce tools. The model is based on the premise that for any company to be e-ready, its management, people, process and technology have to be e-ready in order to derive maximum business benefits. The development and operation of the prototype application have also been presented using end-user case studies. The following conclusions can be drawn from the implementation and evaluation process of this tool:

- VERDICT can be used as a self-assessment tool by organisations to gauge

their e-readiness (for e-commerce) in terms of their management, people, process and technology.

- The tool can also help in highlighting areas that need to be addressed to achieve e-readiness.
- Initial evaluation within the industry has shown that VERDICT can be successfully used for evaluating e-readiness of construction organisations.
- Evaluation results show that the case study companies are weakest in management e-readiness and strongest in technology e-readiness (Table 1).
- Industry evaluators have welcomed the concept of e-readiness and acknowledged the need for an e-readiness assessment tool, such as VERDICT, to encourage wider adoption of e-commerce technologies.
- By surveying a large sample of construction sector end-users, the best-of-breed can be established. This can be achieved by following the example of Cisco Systems (2004), who have based their sample on Fortune 1000 executives. A similar approach can be adopted in construction.

The results of this work will be further used to develop appropriate strategies for achieving e-readiness in construction organisations. Besides the positive responses to the evaluation process, some of the reviewers made suggestions that could further enhance the application. Given that this is a prototype application, such improvements will be implemented in future versions of the prototype. Some of the areas that can be improved in the future are:

- Providing guidance to those end-user companies that are not e-ready in order to achieve e-readiness. This can be done by setting short-term achievable targets that lead to e-readiness.
- The relative importance of the criteria for e-readiness of organisations may vary according to the nature of the end-user organisation and its discipline. What is a priority for one may not be for another. It will be useful to identify key questions in each category for which the end-users *have to* achieve high scores to be e-ready. Alternatively, provision can be made for the end-users to assign relative weights to the four categories and/or to the individual questions.

These and other improvements can be incorporated in future versions of the prototype.

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APPENDIX F SUPPORT MATERIAL

This appendix includes the following support material:

1. Survey Questionnaire;
2. End-user Interview Questionnaires (For Products A and B);
3. VERDICT E-readiness Assessment Model: Questions; and
4. VERDICT Prototype: Evaluation Questionnaire.

Faculty of Engineering, Department of Civil and Building Engineering

SURVEY ON INFORMATION TECHNOLOGY AND E-COMMERCE IN CONSTRUCTION

This survey is a part of a research programme at Loughborough University to establish the current state of IT and E-commerce within the UK construction sector. Structured questions have been formulated to achieve this goal. Your response to this questionnaire is highly valued and will be treated with the strictest confidence. It will be used for academic purposes only. Thank you.

*1. BACKGROUND INFORMATION (*Please provide full contact details if you wish receive a copy of the survey results)*

1.1 Company Name* ……URL…….

Address:……Tel…..……..

……Fax……

……..……E-mail……..

Number of Employees……..…..Annual Turnover (UK £)…….

Name of Respondent……..Position…….

% Investment in IT *(Current*)……...Future % of IT Budge *(Forecast*)…….

1.2 Please indicate which category/categories best describe your organisation. *(Please tick wherever appropriate)*

Client		One-off		Developer		Government Agency		Other	
Architect		Planning		Landscape		Design		Other	
Engineer		Civil		Services		Structural		Other	
Contractor		Civil		Building		Both		Other	
Manufacturer		Components		Materials		Both		Other	
Supplier		Components		Materials		Both		Other	

1.3 What types of construction works does your company undertake? *(Please specify in percentages)*

BuildingWork	%	Civil Works	%	Refurbishment	%	Other *(specify)*	

2. GENERAL INFORMATION ON COMPUTERS

2.1 What types of computer(s) does your company use? *(Please **select** appropriate option/s)*

PC's	Mac's	Unix Workstations	Other *(specify)*

2.2 Which of the following Operating Systems does your company use? *(Pl. **select** appropriate option/s)*

Windows 98	Windows 2000	Windows NT	UNIX	MacOS	Other *(specify)*

2.3 Which of the following programs does your company have? *(Pl. **select** appropriate option/s)*

E-mail		**Project Planning**		**Databases**		**EDM Software**		**Groupware Software**	
MS Mail		MS Project		MS Access		PAFEC EDM		Lotus Notes	
Pegasus		Time Line		Lotus Approach					
Outlook		Primavera		dBase				NovellGroupwise	
Other *specify*									

2.4 Does your Company use CAD? (*If you have answered **NO**, go to Section **3**)* Yes [__] No [__]

2.5 What type of CAD software does your company use?

AutoCAD	AutoCAD LT	MicroStation	ArchiCAD	Other *(specify)*

2.6 What percentage of Design Drawings are done using CAD Packages?……...%

3. USE OF INFORMATION TECHNOLOGY TOOLS

3.1 Establish in percentages the extent to which the following activities/documents are computerised. *(Please **tick** appropriate option/s)*

Activity	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**
Design Drawings					
Specifications					
Tendering					
Scheduling					
Technical Calculations					
Bill of Quantities					
Purchase Orders/ Invoices					
Other *(specify)*					

3.2 State how often the following information is exchanged electronically. *(Please **tick** appropriate option/s)*

Type of Information	**Never**	**Rarely**	**Unsure**	**Occasionally**	**Always**
Design Drawings					
Specifications					
Tendering					
Scheduling					
Technical Calculations					
Bill of Quantities					
Purchase Orders/ Invoices					
Meeting Minutes					
Administration Documents					

3.3 What % of your staff use computers at work?
0-20% [__] 21-40%[__] 41-60%[__] 61-80%[__] 81-100%[__]

4. COMMUNICATIONS NETWORK

4.1 Which of the following does your company use? *(Tick all that apply)*

Intranet	
Project Intranet (with links to other organisations)	
Multiple Local Area Networks (LAN)	
Wide Area Network (WAN)	

4.2 Please indicate the type of network connection *(please tick appropriate option/s)*

Internet	ISDN	Modem	Permanent	Other

4.3 Please state the % of staff members with access to the following communication media.

	On Site %	**In the Office** %
Mobile Phones		
Personal e-mail		
Internet		
Pager		

4.4 Please state how documents are exchanged **internally** within the company. *(Grade on a scale of 1 to 5, where 1 = highly unlikely & 5 = highly probable)*

	1 *highly unlikely*	**2**	**3** *neutral*	**4**	**5** *highly probable*
By E-mail					
By Fax					
FTP					
By Hand					
Other *(specify)*					

4.5 Please state how documents are exchanged with other **stakeholders** during a construction project. *(Grade on a scale of 1 to 5, where 1 = highly unlikely& 5 = highly probable)*

	1 *highly unlikely*	**2**	**3** *neutral*	**4**	**5** *highly probable*
By E-mail					
By Fax					
FTP					
By Post					
By Hand					
Web Portals					
Other *(specify)*					

5. ROLE OF IT WITHIN THE COMPANY

5.1 Please specify whether your company has
a) An IT Manager Yes [__] No [__]
b) An IT Department Yes [__] No [__]
c) A defined IT policy Yes [__] No [__]

5.2 What is your staff's attitude towards implementing IT? *(Grade on a scale of 1 to 5, where 1 = highly negative & 5 = highly positive)*

1*highly –ve*	**2**	**3** *neutral*	**4**	**5** *highly +ve*

5.3 Please state which of the following factors will motivate you to make fresh IT investments? *(Grade on a scale of 1 to 5, where 1 = highly unlikely & 5 = most likely)*

	1 *highly unlikely*	**2**	**3** *neutral*	**4**	**5** *most likely*
Demands from clients					
Demands from staff/employees					
To stay ahead of competitors					
To increase administrative work efficiency					
Need to be in the front line of technical innovation					
Other *(specify)*					

5.4 Do you agree that IT has changed the design/construction process by: *(please tick wherever appropriate)*

	1 *disagree*	**2**	**3** *neutral*	**4**	**5** *agree*
Improving document quality					
Reducing number of documentation errors					
Reducing construction errors					
Increasing the speed of work					
Improving interdisciplinary communication					
Streamlining current business processes					
Other *(specify)*					

5.5 Has the introduction of IT lowered or increased productivity in the following areas?

	Lowered	**Unchanged**	**Increased**	**Unsure**
Company administration				
Project management				
Project co-ordination				
Design management				
Site management				
Interdisciplinary communication				
Other *(specify)*				

5.6 Rate according to priority, in which of the following areas you are *most likely* to invest within the next two years.

	Low Priority	**Medium**	**High Priority**	**Unsure**
CAD (Computer Aided Drafting)				
Document management				
Design				
Project management				
Web collaboration portals				
Virtual Reality				
Other *(specify)*				

5.7 To what extent do you agree that higher use of IT results in *(Grade on a scale of 1 to 5, 1 =strongly disagree & 5= strongly agree)*

	1 *strongly disagree*	**2**	**3** *neutral*	**4**	**5** *strongly agree*
Better financial control					
Better interdisciplinary communications					
Better quality of work					
Faster work					
Easier management of data					
Less paper work					
More streamlined the business process					
Higher possibility of sharing common information					
Comments					

5.8 Please rank in order of 1 to 11, which of the following you think are the barriers to IT implementation? *(Where 1=main barrier)*

Initial investment costs are too high	
Software and hardware upgrades	
Staff training is expensive and time consuming	
Information overload	
Security issues	
Standards/coordination problems	
Lack of commitment from management	
Decision maker's lack interest	
Cultural change (issues)	
Low profit margins	
Other *(specify)*	

6. E-COMMERCE

6.1 Which of the following do you use the Internet for? *(Please Grade on a scale of 1 to 5, where 1 = never and 5 = always)*

	1 *never*	**2**	**3***neutral*	**4**	**5** *always*
E-mail					
Company promotion through company website					
Marketing /Advertising					
Making online purchases					
Generating direct sales					
Providing customer service/support					
Handling complaints					
Visiting other construction related sites					
Obtaining information					
Online database services					
Purchase Orders					
Billing and Invoicing					
Data transfer and exchange					
Compare prices/services of different suppliers					
Online tendering					
Collaborating with project partners					
Other					

6.2 Please rank in order of 1 to 12, which of the following you see as the barriers to E-commerce in construction?*(Where 1= main barrier)*

Security Issues	
Invasion of privacy	
Authenticity (of source)	
Confidentiality issues	
Lack of Standards	
Cultural Issues	
Initial investment cost	
Unsolicited e-mail	
Lack of personal contact	
Viruses	
Cost of Training staff	
Speed/Performance	
Other	

6.3 To what extent have you benefited from the following, since using the Internet for E-commerce? *(Please tick wherever appropriate)*

	Not at all	**Neutral**	**Most certainly**
Raising/improving company profile			
Increased sales / enquiries			
Extending customer base			
Improving customer relationships			
Improving supplier relationships			
Speeding up transactions			
Reduced costs of transactions, marketing etc			
Better Internal processes/ communications			
Staying informed of products/services/market			
Flexibility/convenience			
Other *(please specify)*			

6.4 Which of the following factors will encourage you to use the Internet for E-commerce? *(Please Grade on a scale of 1 to 5, where 1 = highly unlikely and 5 = most likely)*

	1 *highly unlikely*	**2**	**3** *neutral*	**4**	**5** *most likely*
Better security					
Improved training facilities					
Defined Internet laws					
No necessity to upgrade computer hardware					
No necessity to upgrade computer software					
Other *(specify)*					

6.5 To what extent are you familiar with Electronic Data Interchange (EDI)? *(Please specify)*……

6.6 Do you use EDI? *(If yes, please specify in what context)* …..……..

6.7 To what extent are you familiar with eXtensible Markup Language (XML)? *(Please specify)* ……

6.8 Do you use XML? *(If yes, please specify in what context)*…….

7. IT AND E-COMMERCE FUTURE

7.1 What do you think is the future of IT and E-commerce in construction? ……..

……

Thank you for your co-operation and time. Kindly return the completed questionnaire in the pre-stamped envelope to: Ms Kirti Ruikar, Centre for Innovative Construction Engineering (CICE), Loughborough University, Loughborough, Leics, LE11 3TU

Loughborough University

Faculty of Engineering, Department of Civil and Building Engineering

IMPACT OF E-COMMERCE APPLICATIONS ON BUSINESS PROCESSES OF END-USER CONSTRUCTION COMPANIES

This questionnaire is a part of a research programme at Loughborough University aimed at establishing the impact of specific e-commerce applications on the business processes and supply chains of end-user companies. It also aims to investigate how effectively these applications integrate into the business processes of these end-user companies. Structured questions have been used to assess this goal. Your response to this questionnaire is highly valued and will be treated with the strictest of confidence. It will be used for academic purposes only.

1. COMPANY BACKGROUND INFORMATION

Company Name:…… Web Site:……
Address:…….. E-mail:……
…….. Tel:……

1.1 How many employees does your company have?

0-4	5-19	20-99	100-499	>500

1.2 Which of the following construction disciplines does your company belong to?

Architecture	Engineering	Q.S.	Contractor	Other *(specify)*

1.3 Describe the main services offered by your company to the construction sector.

2. PROCESS RELATED INFORMATION

2.1 At what phase in a construction project will you get involved?

Planning	Design	Construction

2.2 In most construction projects you get involved in who appoints the supplier?

Contractor	Sub-contractor	Client	Architect	Project Manager	Other

2.3 What was your traditional project process from inception to completion before using Product A?

2.4 How did your traditional process change with the adoption of Product A?

2.5 Could Product A be used directly or did your company change its method of working?

2.6 Has the use of Product A been client-driven or was it a company strategy ?

2.7 Since when are you using Product A? How long did it take to implement Product A?

2.8 Do you require specialist staff for operating Product A or who within your organisation uses Product A ?(Project Managers etc) ?

2.9 How has the use of Product A benefited each of the following stages of your construction process? Please Explain

Inception	
Feasibility Studies	
Schematic Design	

Detailed Design	
Production information	
Bill of Quantities	
Tendering	
Procurement	
Project Planning	
Construction	
Facilities Management	

2.10 Which of the following reflect your company's reasons to engage in online Project Management using Product A? Explain why and how?

	Yes	**No**	**Explanation**
Increase end-customer satisfaction			
Improve profits &reduce operating costs			
Gain strategic market position			
Reduce lead-time & improve productivity			
Client/Market driven			
Other *(specify)*			

2.11a Which of the following do you see as the benefits of using Product A for your company's business needs? Explain why/why not? Is there any supporting evidence? In-house evaluation?

a. Improving integration of activities across your Supply Chain (SC)
b. Establishing more frequent contact with your SC members
c. Reducing response time across your supply chain
d. Eliminates manual re-keying, hence lesser time wasted and transcription errors
e. Creating a greater level of trust among SC members due to increased transparency
f. Increased client involvement and client's understanding of the construction process
g. Integration with company's back-end systems
h. On-time delivery directly to customer's points of use
i. Single document interface for all trading and construction partners
j. No need to change company's core systems
k. Low set up cost
l. Improved customer service, how?
m. Knowledge database and preservation of corporate memory
n. Avoid disputes
o. Paperless-environment

2.11b From above selection, please state the TOP THREE benefits of using Product A and any OTHERS not mentioned above.

1……2……..……...……..……3……

2.12 How easy is it to access the specific documents from the document/data audit trail?

2.13 Who owns the data after the project is completed, the ASP or your company?

2.14 Do you see any of the following as being drawbacks of using Product A? Why or Why not?

a. Security concerns
b. Invasion of privacy (the big-brother effect)
c. Authentication
d. Lack of Confidentiality
e. Unsolicited e-mail
f. Viruses
g. Lack of well-defined industry standards (one end-user may use several extranets)
h. Version control problems
i. Recurring costs
j. ROI & Initial investment cost

k. Lack of personal contact
l. Cultural Issues
m. Other

2.15 Wish list (what features would you like added to Product A)? Or what would be an ideal e-business solution?

3. MISCELLANEOUS

3.1 Do you use any other e-commerce tools besides Product A? If yes, which tools and why?

3.2 Do you still use your old traditional methods of storing/viewing/exchanging documents? Explain.

3.3 Has it been difficult to convince project partners to shift from their traditional tried and tested methods to the relatively new methods of collaboration and document exchange? (i.e. cultural resistance?)

Loughborough University

Faculty of Engineering, Department of Civil and Building Engineering

IMPACT OF E-COMMERCE APPLICATIONS ON BUSINESS PROCESSES OF END-USER CONSTRUCTION COMPANIES

This questionnaire is a part of a research programme at Loughborough University aimed at establishing the impact of specific e-commerce applications on the business processes and supply chains of end-user companies. It also aims to investigate how effectively these applications integrate into the business processes of these end-user companies. Structured questions have been used to assess this goal. Your response to this questionnaire is highly valued and will be treated with the strictest of confidence. It will be used for academic purposes only.

1. COMPANY BACKGROUND INFORMATION

Company Name:…… Web Site:……
Address:…….. E-mail:……
…….. Tel:……

1.1 How many employees does your company have?

0-4	5-19	20-99	100-499	>500

1.2 Which of the following construction disciplines does your company belong to?

Architecture	Engineering	Q.S.	Contractor	Other *(specify)*

1.3 Describe the main services offered by your company to the construction sector.

2. PROCESS RELATED INFORMATION

2.1 At what phase in a construction project will you get involved?

Planning	Design	Construction

2.2 In most construction projects you get involved in who appoints the supplier?

Contractor	Sub-contractor	Client	Architect	Project Manager	Other

2.3 What was your traditional trading process before implementing Product B?

2.4 How did your traditional process change with the adoption of Product B?

2.5 Could Product B be used directly or did your company change its method of working?

2.6 Why did you start using Product B (drivers)?

2.7 How long did it take to implement Product B?

2.8 Do you require specialist staff for operating Product B or who within your organisation uses Product B?

2.9 Which of the following activities are performed using Product B?

	Yes	**No**	**Remarks**
Send and Receive Emails			
Buy/sell goods online			
Place orders online			
Receive orders online			

Acknowledge receipt of order online			
Online order tracking facility			
Make electronic payments (online)			
Provide online customer service			

2.10 Which of the following reflect your company's reasons to engage in Supply Chain Management using Product B? Explain why and how?

	Yes	**No**	**Explanation**
Increase end-customer satisfaction			
Improve profits &reduce operating costs			
Gain strategic market position			
Reduce lead-time & improve productivity			
Client/Market driven			

2.11a Which of the following do you see as the benefits of using Product B? If yes, why? If not, why not? Is there any supporting evidence? In-house evaluation?

a. Improving integration of activities across your SC
b. Establishing more frequent contact with SC members
c. Reducing response time across the supply chain
d. Eliminates manual re-keying and transcription errors, how?
e. Creating a greater level of trust among SC members
f. Creating a compatible information system
g. Determining customers future needs
h. Use of informal/formal information sharing
i. On-time delivery directly to customer's points of use
j. Single document interface for all trading partners.
k. No need to change core systems
l. Low set up cost
m. Improved customer service
n. Visibility as to when the document is accessed by the recipient?
o. Reduces time spent on reconciliation and exception handling?
p. Paperless-environment, is that true or are copies maintained in paper and electronic format?

2.11b From above selection, please state the TOP THREE benefits of using Product B

1……..…2…….……3……

2.12 How easy is it to access the specific documents from the document/data audit trail?

2.13 Are there any drawbacks in using Product B and why?

a. Security concerns
b. Difficulty in managing SC inventories
c. Lack of well-defined industry standards (one supplier may use several extranets)
d. Version control problems
e. Recurring costs
f. ROI

2.14 Wish list (what features would you like added to Product B)? Or what would be an ideal e-business solution?

3. MISCELLANEOUS

3.1 Do you use any other tools besides Product B? If yes, why?

3.2 Do you still use your old trading methods, if yes, why?

3.3 Out of a total of 100%, what proportion of trading transactions are carried out using the following methods?

By phone	%
By fax	%
By e-mail	%
By post	%
Using Product B	%
Total	**100 %**

3.4 Has it been difficult to convince trading partners to shift from using traditional tried and tested methods to the relatively new methods of trading? (i.e. cultural resistance?)

VERDICT PROTOTYPE: EVALUATION QUESTIONNAIRE

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1. Is VERDICT easy to use?					
Q2. Is VERDICT easy to understand?					
Q3. Is the format easy to navigate?					
Q4. Is it error free?					

	Please Comment:
Q5. Which parts of the application impressed you most? Why?	
Q6. Which parts of the application fell short of your expectations? Why?	
Q7. In your view, what are the benefits of using VERDICT?	
Q8. What is your opinion about the questions in each category? Do any need to be rephrased? If yes, which question/s? Please state rephrased version.	
Q9. Do any new questions need to be added? If yes, please specify.	Yes / No
Q10. In your view, how can VERDICT be improved?	
Q11. Would you use (or recommend using) the application in the future? Explain Why/Why not?	Yes / No
Additional comments:	

VERDICT E-READINESS ASSESSMENT MODEL: QUESTIONS

SD= Strongly Disagree D=Disagree N=Neutral A=Agree SA= Strongly Agree DK=Don't Know

1. MANAGEMENT E-READINESS

	SD	D	N	A	SA	DK
1. We recognise the benefits of using e-commerce tools.						
2. Our senior management is aware of the potential rewards and risks of using e-commerce tools.						
3. We have a well defined strategy for adopting e-commerce tools.						
4. We have developed strategies to migrate users of existing services to Internet-based applications.						
5. We have a defined strategy to align e-commerce tools with our existing business processes.						
6. We have a long-term strategy to ensure continuous project and process improvement using e-commerce tools.						
7. Our e-commerce strategy is well communicated at all levels within the organisation (for a shared 'vision' across the company).						
8. All levels of management in our organisation have an e-business mindset.						
9. Our senior management is actively involved in developing and implementing our company's e-business strategy.						
10. We like to be at the forefront of technology adoption.						
11. We have adopted e-commerce tools to improve our overall business and project performance.						
12. We have adopted e-commerce to gain a competitive advantage.						
13. Our current use of e-commerce tools compares favourably to that of our competitors.						
14. Our approach to e-commerce adoption is flexible enough to accommodate new and emerging technologies.						
15. We are committed to allocating adequate resources in terms of time, staff and budget, required to implement and use e-commerce tools.						
16. Our total spending on using e-commerce tools is high as compared to other IT spending (PCs, infrastructure).						
17. We are committed to training staff to make optimal use of, and benefit fully from, e-commerce tools.						

18. We have established well defined parameters (e.g. KPIs) for measuring the impact of e-commerce tools.						
19. We have a well defined process for the selection of e-commerce tools.						
20. Our business has learnt from the successes and failures of other e-commerce-led projects/initiatives.						
21. We have effective procedures in place to share (in-house) the successes and failures of using e-commerce tools.						

2. PEOPLE E-READINESS

	SD	D	N	A	SA	DK
22. We have people with the ability to implement change and move quickly to adopt and use any new technologies.						
23. We have identified and clearly defined the roles and responsibilities of staff who use (or will use) the e-commerce tool/s.						
24. Our current organisational structure provides an environment that is well suited for e-commerce adoption and use.						
25. Our organisational culture is well suited for e-commerce adoption and use.						
26. Our staff have the necessary levels of IT literacy, functional expertise and skills to use e-commerce tools.						
27. Our staff recognise the importance and benefits of using e-commerce tools.						
28. Our business management staff (or decision makers) have adequate IT knowledge.						
29. Our IT staff have adequate knowledge of our business processes.						
30. We encourage our employees to use e-commerce tools to increase efficiency and productivity.						
31. We have provided our e-commerce projects with the necessary staffing resources to reach their goals.						
32. We are committed to addressing any issues/inhibitions that staff may have about using e-commerce tools.						
33. We have devised training procedures that will enable our staff to effectively use e-commerce tools.						
34. Our staff fully understand the importance of training required for using e-commerce tools.						

3. PROCESS E-READINESS

	SD	D	N	A	SA	DK
35. We have analysed our current business processes.						

36. We have identified the bottlenecks and inefficiencies in our current business processes.						
37. Our existing processes are flexible enough to accommodate e-commerce tools.						
38. We have designed new Web-enabled processes.						
39. We usually work with the same companies within the supply chain.						
40. We use email for exchanging all our drawings and documents, both internally and externally, with members of the supply chain.						
41. We have adopted e-commerce tools to overcome current process inefficiencies (e.g. removal of redundant processes).						
42. We have adopted e-commerce tools to automate our existing processes.						
43. We make changes to current processes (where necessary) to facilitate the adoption of e-commerce tools.						
44. Our use of e-commerce tools will facilitate faster and more cost-effective business processes.						
45. Our use of e-commerce tools will improve integration of activities across the supply chain.						
46. We have used Web-based tools to support different construction processes (e.g. procurement, project management, facilities management, etc).						

4. TECHNOLOGY E-READINESS

	SD	D	N	A	SA	DK
47. We have a well defined IT policy.						
48. We have adequate IT support (in-house or external).						
49. Our current ICT (Information and Communication Technologies) infrastructure is adequate for supporting the functions of e-commerce tools.						
50. Our current ICT infrastructure is adequate for supporting our staff and current business processes.						
51. Our current ICT systems are flexible to accommodate rapid change and scalability.						
52. We regularly upgrade our ICT systems to meet changing business/market needs.						
53. We will update/upgrade our ICT infrastructure (wherever necessary) to avoid integration and interoperability problems with other supply chain members.						
54. Our current ICT infrastructure enables trouble-free exchange, viewing, or downloading of large document files (e.g. CAD drawings) both internally and externally.						
55. We have a well maintained company intranet for storing and sharing data.						

56. Our technical staff have access to hardware and software as required.						
57. We regularly use groupware (e.g. Lotus Notes).						
58. We regularly use EDM (e.g. Electronic Document Management) systems.						
59. We regularly use the Internet to find/retrieve information.						

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