Loughborough University
Institutional Repository

ICT-enabled collaborative working methodologies in construction

This item was submitted to Loughborough University's Institutional Repository by the/an author.

Additional Information:

- Submitted in partial fulfilment of the requirements for the award of Doctor of Engineering at Loughborough University.

Metadata Record: [https://dspace.lboro.ac.uk/2134/798](https://dspace.lboro.ac.uk/2134/798)

Publisher: © Steven Yeomans

Please cite the published version.
This item was submitted to Loughborough’s Institutional Repository by the author and is made available under the following Creative Commons Licence conditions.

For the full text of this licence, please go to:  
http://creativecommons.org/licenses/by-nc-nd/2.5/
ICT-enabled Collaborative Working Methodologies in Construction

Steven Yeomans
ACKNOWLEDGEMENTS

This research project could not have been completed without the help of many including the writing of others, who are acknowledged within the reference section. I would particularly like to thank the following four people who unselfishly gave their time to provide me with support, advice and tuition whilst completing my research over the past four years:

Prof. N. M. Bouchlaghem – Academic Supervisor at Loughborough University.
Dr. A. El-Hamalawi – Academic Supervisor at Loughborough University.
Dr. Andrew Cripps – Industrial Supervisor at Buro Happold.
Mark Phillip – Industrial Supervisor at Buro Happold.

I would like to thank the following for their assistance, expert opinions or advice:

Dr Adrian Hanny – Associate at Mott MacDonald
Andrew Powell – Former industrial supervisor
Ben Haldin – Director of Fulcro
Don Ward – Chief Executive of Be
Claire Gielink – Extranet Administrator at Mott MacDonald
Jon Hardy – Engineering Systems Manager at Buro Happold
Paul Waskett – Avanti Programme Manager
Paul Wilkinson – Head of corporate communication at BIW
Steve Race – Director of D’Arcy Race
4Projects Team – Various members of the organisation
Autodesk Buzzsaw Team – Various members of the organisations

I would like to thank all of those who afforded me interviews, responded to the questionnaire surveys, participated in the trials and provided additional information. Finally, I would like to thank my partner of nearly ten years, Natalie Hansen for her unremitting support and patience; we can at last become married.

_The wise man said just walk this way, to the dawn of the light. The wind will blow into your face as the years pass you by. Hear this voice from deep inside, it’s the call of your heart. Close your eyes and you will find passage out of the dark - Here I Am, Here I Am_ (Scorpions 1991).
ABSTRACT

Since the turn of the new millennium the UK construction industry has witnessed the naissance of a new paradigm known as ICT-enabled collaborative working. Advocates of this new approach believe that the adoption of ICTs will lead to better project information exchange, communications, integrated processes and therefore more efficient collaborative working. It is expected that ICT-enabled collaborative working will not only overcome the industry’s many inherent problems, such as its adversarial and fragmented nature, but that it will also facilitate benefits for all involved. This supposition is based upon the recognition that its exploitation has proven successful at transforming other industries.

The EngD thesis pertains to a four-year study on two methodologies currently applied under the concept of ICT-enabled collaborative working, ‘Collaborative Prototyping’ (CP) and the use of ‘Construction Project Extranets’ (CPE). The research project utilised literature reviews, case studies, project observations, active involvement, surveys, interviews and workshops to develop expertise and knowledge within the subject area. It shows that a large disparity exists between the use of a shared 3D model and the use of CPEs to promote collaborative working. Conversely, whilst CPEs have become the de facto ICT-enabled approach to seeking improvements in project efficiency (due to their potential to enhance communications, integration and collaboration) they are not being utilised effectively. This was attributed to the use of inadequate procedures that fail to provide proper consideration of all the necessary issues to ensure successful implementation, application and management of the CPE. As a result, project teams are failing to ascertain the full potential benefits offered by such collaboration tools. The research demonstrates that to overcome this, project teams require the development of an industry best-fit framework that defines proficient procedures. It highlights the main factors for inclusion within a protocol. Furthermore, it provides a simple form to promote greater awareness of the key factors that impinge on the successful application of CPE. The thesis concludes by outlining a number of recommendations for consideration by the industry, along with requirements for future work.

KEYWORDS

TABLE OF CONTENTS

ABSTRACT ........................................................................................................................................... IX

TABLE OF CONTENTS .......................................................................................................................... XI

LIST OF FIGURES ................................................................................................................................ XV

GLOSSARY OF ABBREVIATIONS ....................................................................................................... XIX

1. INTRODUCTION TO THE RESEARCH PROJECT ........................................................................ 21
   1.1 INTRODUCTION .......................................................................................................................... 21
   1.2 CONTEXT OF THE RESEARCH .................................................................................................... 21
   1.3 JUSTIFICATION FOR THE RESEARCH ....................................................................................... 22
   1.4 NOVELTY OF THE RESEARCH ................................................................................................... 24
   1.5 AIMS AND OBJECTIVES ............................................................................................................ 24
   1.6 THESIS STRUCTURE ................................................................................................................. 24
   1.7 SUMMARY .................................................................................................................................. 26

2. REVIEW OF LITERATURE .............................................................................................................. 27
   2.1 INTRODUCTION .......................................................................................................................... 27
   2.2 THE NEED TO IMPROVE THROUGH ICT ENABLED COLLABORATION ..................................... 27
   2.3 DEFINING COLLABORATION ...................................................................................................... 28
   2.4 THE COMPLEXITIES OF COLLABORATION IN CONSTRUCTION .................................................. 28
   2.5 MODES AND CONDITIONS FOR COLLABORATION ................................................................. 29
   2.6 THE NEED FOR ICTS TO ENABLE COLLABORATION ............................................................... 31
   2.7 ICT-ENABLED COLLABORATIVE WORKING ............................................................................ 32
   2.8 ICT-ENABLED COLLABORATIVE WORKING: TOOLS OF THE TRADE ......................................... 34
   2.9 INTEGRATION AND INTEROPERABILITY .................................................................................... 34
   2.10 COLLABORATIVE PROTOTYPING ............................................................................................. 36
   2.11 CONSTRUCTION PROJECT EXTRANETS FOR COLLABORATION .......................................... 38
   2.12 SUMMARY .................................................................................................................................. 41

3. RESEARCH METHODOLOGY ......................................................................................................... 43
   3.1 INTRODUCTION .......................................................................................................................... 43
   3.2 AVAILABLE RESEARCH METHODS ............................................................................................ 43
   3.3 RESEARCH METHODOLOGY CONSIDERATIONS ..................................................................... 45
   3.4 ADOPTED METHODOLOGIES, TOOLS AND JUSTIFICATION FOR THEIR USE .......................... 46
   3.5 SUMMARY .................................................................................................................................. 49

4. RESEARCH UNDERTAKEN ............................................................................................................. 51
   4.1 INTRODUCTION .......................................................................................................................... 51
5. FINDINGS AND IMPLICATIONS ................................................................................................... 75

5.1 INTRODUCTION ...................................................................................................................... 75

5.2 THE CURRENT APPLICATION OF COLLABORATIVE PROTOTYPING – AIM ONE .................. 75
  5.2.1 Collaborative Working - Current Practices ............................................................................ 75
  5.2.2 Collaborative Working – Advantages and Disadvantages ...................................................... 76
  5.2.3 Collaborative Working – Considerations .................................................................................. 77
  5.2.4 Collaborative Working – Need to Quantifying the Benefits .................................................. 78
  5.2.5 Collaborative Working - New Developments ............................................................................ 78
  5.2.6 3D Working Practices ............................................................................................................. 78
  5.2.7 The Application of Collaborative Prototyping ........................................................................ 80

5.3 THE APPLICATION OF CONSTRUCTION PROJECT EXTRANETS – AIM TWO ....................... 80
  5.3.1 Protocols – Initial Findings ..................................................................................................... 84
  5.3.2 Training ..................................................................................................................................... 85
  5.3.3 Communication and Collaboration .......................................................................................... 86
  5.3.4 Working with Multiple CPEs ................................................................................................... 87

5.4 PROPOSED IMPROVEMENT TO FACILITATE EFFICIENT ICT-ENABLED COLLABORATIVE WORKING VIA CPES – AIM THREE ........................................................................................................... 87
  5.4.1 Current Application of CPE Protocols ...................................................................................... 87
  5.4.2 The Main Requirements for CPE Procedures – A Best-Fit Framework .................................. 88
  5.4.3 Industry Reaction to the Findings and Proposal .................................................................... 90

5.5 EARLY STAGES OF CPE PROCEDURES BEST-FIT FRAMEWORK ............................................ 92
5.6 CONCLUSION TO THE RESEARCH PROJECT ................................................................. 92
  5.6.1 Collaborative Prototyping – Aim One ........................................................................ 93
  5.6.2 Construction Project Extranets – Aim Two .............................................................. 93
  5.6.3 Proposed Improvement – Aim Three ......................................................................... 93
5.7 IMPLICATIONS AND IMPACT OF THE RESEARCH ......................................................... 94
5.8 CRITICAL EVALUATION OF THE RESEARCH .............................................................. 94
5.9 RECOMMENDATIONS AND FURTHER WORK .......................................................... 94
  5.9.1 Further Research ..................................................................................................... 95

6. REFERENCES .......................................................................................................................... 97

7. BIBLIOGRAPHY .................................................................................................................... 103

APPENDICES ................................................................................................................................. 107

  APPENDIX ONE: PAPER ONE .......................................................................................... 109
  APPENDIX TWO: PAPER TWO ......................................................................................... 129
  APPENDIX THREE: PAPER THREE .................................................................................. 143
  APPENDIX FOUR: COLLABORATIVE PROTOTYPING INTERVIEW QUESTIONS ................. 159
  APPENDIX FIVE: COLLABORATIVE PROTOTYPING ELECTRONIC QUESTIONNAIRE SURVEY .......... 163
  APPENDIX SIX: COLLABORATIVE EXTRANET WORKING ONLINE ELECTRONIC QUESTIONNAIRE SURVEY ................................................................................................................. 169
  APPENDIX SEVEN: COLLABORATIVE EXTRANET WORKING PROTOCOL QUESTIONNAIRE SURVEY ...... 183
  APPENDIX EIGHT: CONSTRUCTION PROJECT EXTRANET INITIAL IMPLEMENTATION SURVEY FORM..... 193
LIST OF FIGURES

FIGURE 1.1 BREAKDOWN OF EngD AIMS AND OBJECTIVES ................................................................. 25
FIGURE 2.1 THE IMPORTANCE OF STRATEGIC PLANNING AND THE COMPLEXITIES OF COLLABORATION IN SUPPLY CHAIN MANAGEMENT (ADAPTED FROM AUSTIN ET AL 2001) ......................................................... 29
FIGURE 2.2 FOUR MODES OF COLLABORATION (ADAPTED FROM ANUMBA ET AL, 2002) ....................... 30
FIGURE 2.3 THE POTENTIAL OF COLLABORATIVE DESIGN TO REDUCE ERROR AND WASTE (ADAPTED FROM AUSTIN 2002) .................................................................................................................................................. 32
FIGURE 2.4 CATEGORISATION OF CONSTRUCTION PROJECT (ADAPTED FROM BERCERIK 2004A) ........... 39
FIGURE 2.5 EXAMPLE OF MODERN (WITH CPE) VERSUS TRADITIONAL (WITHOUT CPE) PROJECT COMMUNICATIONS (SARCOPHAGUS 2005) ................................................................................................................................. 40
FIGURE 3.1 APPLIED SURVEY RESEARCH METHODOLOGY AND TRIANGULATION FOR COLLABORATIVE PROTOTYPING (Aim 1) ............................................................................................................................................... 48
FIGURE 3.2 APPLIED CASE RESEARCH METHODOLOGY AND TRIANGULATION FOR CONSTRUCTION PROJECT EXTRANETS (AIMS 2 AND 3) .................................................................................................................................. 48
FIGURE 4.1 MAP OF THE RESEARCH DEVELOPMENT PROCESS ............................................................... 53
FIGURE 4.2 EVIDENCE OF RESEARCH ANALYSIS FOR RESEARCH AIM ONE ........................................... 56
FIGURE 4.3 EXAMPLE OF UNCOORDINATED CEW PROCESSES AND CLASHES IN PROCEDURES ............ 59
FIGURE 4.4 3D MODEL OF RELATED ........................................................................................................ 62
FIGURE 4.5 EXAMPLE OF MARK-UP ........................................................................................................ 62
FIGURE 4.6 INFORMATION PROCESS .................................................................................................... 62
FIGURE 4.7 PROJECT INFORMATION DATABASE RECORD ........................................................................... 63
FIGURE 4.8 EXTRANET INFORMATION DATABASE RECORD SHEET ............................................................ 64
FIGURE 4.9 EVIDENCE OF RESEARCH ANALYSIS FOR RESEARCH AIM TWO .......................................... 67
FIGURE 4.10 LEVELS OF CPE OPERATION AND THEIR RESPECTIVE PROTOCOL CONSIDERATIONS ...... 70
FIGURE 4.11 SCREEN SHOT OF AUTHOR’S WEBSITE ON ICT-ENABLED COLLABORATIVE WORKING ...... 72
FIGURE 5.1 MODES OF COLLABORATION TECHNIQUES AND THEIR USE BY RESPONDING ORGANISATIONS ............................................................................................................................................... 76
FIGURE 5.2 MODES OF COLLABORATION TECHNIQUES AND THEIR EFFECTIVENESS (RATED ONLY BY THOSE WHO HAD USED THE TECHNIQUE) .................................................................................................. 76
FIGURE 5.3 RESPONDENTS VIEWS OF THE CPE EFFECT ON PROJECT RELATIONSHIPS ......................... 83
FIGURE 5.4 RESPONDENTS VIEWS ON THE CPE EFFECTS ON PRODUCTIVITY .......................................... 83
FIGURE 5.5 RESPONDENTS VIEWS ON THEIR WILLINGNESS TO WORK ON A CPE AGAIN ......................... 83
FIGURE 5.6 AMOUNT OF TRAINING RECEIVED BY EMPLOYEES ON THE CPE ........................................ 85
FIGURE 5.7 TYPE OF TRAINING RECEIVED ON THE CPE SYSTEM .......................................................... 85
FIGURE 5.8 EMPLOYEES REASON FOR NOT RECEIVING TRAINING ....................................................... 86
FIGURE 5.9 THE VARIOUS PROTOCOL TYPES AND DEVELOPMENT TEAMS ................................................ 89
FIGURE 5.10 THE REALITIES OF WORKING WITH OR WITHOUT CURRENT PROTOCOLS AND THE DESIRED APPROACH .................................................................................................................................................. 89
FIGURE 5.11 HOW PRACTICAL IS THE CPE INITIAL IMPLEMENTATION FORM? ........................................ 92
ICT-enabled Collaborative Working
LIST OF TABLES

TABLE 2.1 Four philosophies on the conditions for effective collaboration .................................31
TABLE 2.2 Collective summary of the barriers, drivers, requirements and benefits of ICT-enabled collaborative working ..................................................................................................................33
TABLE 3.1 Summary of the overall research project aims, objectives and applied methodologies ................................................................................................................................47
TABLE 4.1 Details of the four projects used in case studies ..........................................................58
TABLE 4.2 Respondents views on the importance of including various procedures within a best-fit framework of procedures .................................................................................................................68
TABLE 4.3 CPE Initial Implementation Form - questionnaire survey questions ..........................71
## Glossary of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td>Two Dimensional</td>
</tr>
<tr>
<td>3D</td>
<td>Three Dimensional</td>
</tr>
<tr>
<td>4D</td>
<td>3D plus Fourth Dimensional of time</td>
</tr>
<tr>
<td>aecXML</td>
<td>Architectural, Engineering, and Construction eXtensible Markup Language</td>
</tr>
<tr>
<td>AEC</td>
<td>Architectural, Engineering and Construction</td>
</tr>
<tr>
<td>App</td>
<td>Appendix</td>
</tr>
<tr>
<td>ASP</td>
<td>Application Service Provider</td>
</tr>
<tr>
<td>BIM</td>
<td>Building Information Model</td>
</tr>
<tr>
<td>BDB</td>
<td>Building Down Barriers</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>CE</td>
<td>Concurrent Engineering</td>
</tr>
<tr>
<td>CEW</td>
<td>Collaborative Extranet Working</td>
</tr>
<tr>
<td>CP</td>
<td>Collaborative Prototyping</td>
</tr>
<tr>
<td>CPE</td>
<td>Construction Project Extranet</td>
</tr>
<tr>
<td>CPN</td>
<td>Construction Productivity Network</td>
</tr>
<tr>
<td>CRISP</td>
<td>Construction Research and Innovation Strategy Panel</td>
</tr>
<tr>
<td>CITB</td>
<td>Construction Industry Training Board</td>
</tr>
<tr>
<td>DETR</td>
<td>Department of Environment and the Regions</td>
</tr>
<tr>
<td>DTI</td>
<td>Department of Trade and Industry</td>
</tr>
<tr>
<td>EA</td>
<td>Extranet Administrator</td>
</tr>
<tr>
<td>EDM</td>
<td>Electronic Data Management</td>
</tr>
<tr>
<td>EngD</td>
<td>Engineering Doctorate</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FM</td>
<td>Facilities Management</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
</tr>
<tr>
<td>ICTeCW</td>
<td>ICT-enabled Collaborative Working</td>
</tr>
<tr>
<td>IFCs</td>
<td>Industry Foundation Classes</td>
</tr>
<tr>
<td>IGES</td>
<td>Initial Graphics Exchange Specification</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organisations</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>M&amp;E</td>
<td>Mechanical and Electrical</td>
</tr>
<tr>
<td>NEC</td>
<td>The Engineering and Construction Contract</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>nD</td>
<td>4D plus nth number of design dimensions in a holistic model</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>OASIS</td>
<td>Organisation for the Advancement of Structured Information Standards</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operation and Maintenance</td>
</tr>
<tr>
<td>OO</td>
<td>Object Orientated</td>
</tr>
<tr>
<td>PBL</td>
<td>Project-Based Learning</td>
</tr>
<tr>
<td>PC</td>
<td>Prime Contractor</td>
</tr>
<tr>
<td>PCC2000</td>
<td>Standard form of Contract for Project Partnering</td>
</tr>
<tr>
<td>PDES</td>
<td>Product Data Exchange Specification</td>
</tr>
<tr>
<td>PIECC</td>
<td>Planning and Implementation of Effective Collaboration in Construction</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
</tr>
<tr>
<td>RDI</td>
<td>Research, Development and Innovation</td>
</tr>
<tr>
<td>RE</td>
<td>Research Engineer</td>
</tr>
<tr>
<td>RFI's</td>
<td>Request For Information</td>
</tr>
<tr>
<td>RTD</td>
<td>Research Technology Development</td>
</tr>
<tr>
<td>SBM</td>
<td>Single Build Model</td>
</tr>
<tr>
<td>SCM</td>
<td>Supply Chain Management</td>
</tr>
<tr>
<td>STEP</td>
<td>STandard for Exchange of Product data</td>
</tr>
<tr>
<td>TQM</td>
<td>Total Quality Management</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>VC</td>
<td>Virtual Collaboration</td>
</tr>
<tr>
<td>VE</td>
<td>Virtual Enterprise</td>
</tr>
<tr>
<td>VP</td>
<td>Virtual Prototyping</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>XML</td>
<td>eXtensible Markup Language</td>
</tr>
</tbody>
</table>
1. INTRODUCTION TO THE RESEARCH PROJECT

1.1 Introduction

This chapter provides an introduction to a thesis on the subject of ICT-enabled Collaborative Working, conducted as partial fulfilment for the award of Doctor of Engineering at Loughborough University. It sets out the context of study both within the construction industry and Buro Happold (industrial sponsor), and offers justification for the research. In addition, it highlights the novelty of the research work and outlines the main aims and objectives of the project, before describing the remaining structure of the thesis.

1.2 Context of the Research

The last decade has witnessed the extensive examination and documentation of the construction industry's inherent problems (including Latham 1994; Egan 1998; NA0 2001 & Egan 2002), with issues such as its fragmented and adversarial nature, poor knowledge management and a lack of integrated and transparent processes coming to the fore. Such reports have also periodically criticised construction for being too slow to adopt both new technologies and methods of working, and encouraged the industry to adopt new innovative approaches (Moore & Abadi 2005).

In response, a number of organisations, IT companies, industry experts and research establishments (since the mid 1990s) examined how best to utilise IT within the construction process to bring about business benefits. Early efforts permitted the automation of individual business activities, via a flux in disparate software applications. However, this had an adverse reaction and created islands of automation; as the software packages were developed by different vendors, all with their own particular data formats (Sun & Aouad 2000).

By the end of the nineties, advances in technology meant the scope of technology-driven innovation had widened to encompassing broader issues that included the business process. Innovators were reinventing their organisations and integrating ICT based business processes to add value (Brewer 2004) and improve quality, competitiveness and profitability, along with client value and satisfaction. This was because the use of ICTs to share information across business processes, from marketing and procurement to design and site management, was seen as permitting more collaborative working, which would benefit everyone in the construction team (DTI 2001). It is also perceived as the prime tool for driving revolution within construction, as it has already worked in the aerospace, shipbuilding, automotive and process industries (Saxon 2003).

From the turn of the new millennium, such philosophy witnessed the naissance of a new paradigm within construction known as ‘ICT-enabled collaborative working’; of which Collaborative Prototyping (CP) and Construction Project Extranets (CPEs) are two of the principle mechanisms for delivery. 3D CAD modelling and collaborative working are seen as the main tools for reshaping the way the industry thinks and works (DTI 2001) as there are enormous benefits to be gained, in terms of eliminating waste and rework, from using modern CAD technology to prototype buildings (Egan 1998).
Although 3D modelling is seen as the way forward, its use has significant barriers to overcome before widespread application is feasible; whereas web-based collaboration tools offer a readily available solution to multi party collaboration and communications to ensure efficient information capture, sharing and analysis (CPN 2004a).

The primary requirement for this research transpired from a desire by Buro Happold to investigate the merits of ICT-enabled collaborative working (specifically the application of CP and CPEs to facilitate collaborative working) and to identify an improved process for the successful delivery of projects within the context of the engineering consultancy. The company’s aspiration to conduct research in the subject originated from the need to revise their business operations, react to industry recommendations (to enable company processes and activities via technology) and their involvement with a major industry initiative called Teamwork (2000).

Buro Happold was founded in 1976 by the late Sir Edmund Happold and several of his former colleagues from Arup. The primary focus of the business concentrated on the design of structures. Over the next 25 years, the company continued to expand until by the end of 2004, the practice employed over 850 employees throughout 14 offices around the world. Today, Buro Happold consist of three ‘core’ disciplines (Building Services, Structures and Infrastructure, Transport and Environment) and fifteen specialist services (including disability design, façade and fire engineering, sustainability services and computational simulation analysis). To maintain and enhance the company’s capabilities, Buro Happold place significant investment into RDI activities and a wide range of educational research. In 2003, the company reorganised the way it delivered its services into multidisciplinary groups to provide both a ‘one stop shop’ and an integrated approach to all their project work. The company’s aim is to become the world’s best integrated, multidisciplinary engineering and strategic consultancy for the built environment. The sponsoring of a Research Engineer (RE) to undertake an Engineering Doctorate (EngD) on ICT enabled Collaborative Working within the company was viewed as one of many steps to be taken towards achieving this desired status.

**1.3 Justification for the Research**

At the time of commencing the EngD in 2001, a review of the available literature found current research had focused on investigating the appropriateness of numerous individually applied technologies (and subsequent hypothesis) to support collaborative environments at various stages of the construction process (e.g. various CAD systems, 3D modelling, prototyping, Virtual Reality, the Internet, emerging ICT tools and Extranets etc). Through this work, many of the contiguous issues surrounding collaboration and the use of such tools were identified and discussed (e.g. communication, human interaction, teamworking, integration, information exchange, interoperability and standards development). There were also a large number of research initiatives starting in this year (funded by European Research Programmes), which covered a wide range of subjects from examining the integration of IT into the design process, to overcoming interoperability issues through to the application of 3D-object orientated modelling to facilitate collaborative working1. Despite the amount of

---

1 A web site accessed in December 2001 listed 218 research projects on these issues but is no longer available.
research being conducted at this time, a high percentage of the work concentrated on the technological perspectives of collaboration with less attention being applied to the process and humanistic elements of collaborative working. There was also limited emphasis on applying technology to promote a collaborative solution that incorporated the whole project life cycle from conception to demolition; as prescribed to by the CP concept. It was apparent that there was also a lack of knowledge on this subject of CP and its use within the industry. It is important to note that at this time, ICT-enabled collaborative working was not an established paradigm.

The literature review on the application of project extranets to facilitate collaboration and attainment of business benefits revealed several key sources of information, all of which contained recommendations for additional research to be conducted. A series of reports by the Construction Productivity Network (CPN 2001 & 2004a, b, c) recounted the experiences of various individual project teams and their use of project extranets. Through these accounts, key issues and good practice were highlighted to inform other would-be users of the factors that required consideration for more efficient use of CPEs. Principle recommendations conferred the need for better consideration of collaboration issues (with more emphasis placed on process and people), the need to apply greater strategic management; and more importantly, the need to develop and use detailed procedures to facilitate better set-up, implementation and management of the system. Conversely, they did not provide an explanation of how to achieve these desired objectives, but called for further work in these areas.

Supplementary evidence on the need for additional research in this field is also provided by Alshawi and Ingirige (2002) who wrote the efficiency of current processes must be carefully addressed and re-engineered to take advantage of advances in technology. Furthermore, Nitithamyong & Skibniewski (2004) stated that all of the studies conducted thus far have been based on either individual case studies using interview techniques, or anecdotal evidence provided by success stories reported in the press. There has been no empirical research on a large scale conducted on this topic. The author found no evidence of investigations into examining the impact of working with multiple CPEs within a single organisation; as available literature had always referred to the need for adopting or working with CPEs within a single project/system scenario.

Taking into account all of the above, the need for this research can be justified through the need to:
1. Assist Buro Happold in adopting industry recommendations for integrated working based upon processes that are supported by ICTs (Egan 1998, 2002);
2. Improve inter-office and cross-disciplinary working throughout the practice;
3. Satisfy Buro Happold requirements to gain additional knowledge on the subject of CP along with understanding and seeking to improve the way the company works with multiple CPE systems;
4. Provide an up-to-date review of the application of CP within the construction industry;
5. Enable the sponsoring company to take a decision on whether to pursue additional work in CP;
6. Contribute to, and expand upon the existing body of knowledge in the subjects of collaborative working, CP and CPEs (especially due to new work on understanding the implications of working with multiple systems);
7. Facilitate an incremental enhancement to the extranet project integration process, therefore contributing to improving the construction industry’s use of such systems and its overall performance;
8. Contribute to the collection and dissemination of best practice information under the subject domain of ICT-enabled collaborative working.

1.4 Novelty of the Research

The novelty of the research is demonstrated through acquisition and dissemination of new knowledge on the emerging concepts of ICT-enabled collaborative working and Collaborative Prototyping; the previously uninvestigated implications of working with multiple CPEs; and the development of a new method for ensuring more efficient implementation and use of project extranets. This argument was substantiated by examining the definition of the term ‘novelty’, which is described thus: novelty is something having the quality of being new and interesting (Collins 1995) or an unfamiliar (Oxford 2005), unusual or innovative (Dictionary.com 2005). Something innovative includes the featuring of new methods (Oxford 2005).

1.5 Aims and Objectives

A core element of the EngD degree is the solution of one or more significant and challenging engineering problems with an industrial context (CICE, 2005). Within Buro Happold two significant challenges were found. The first challenge was to determine if the adoption of collaborative prototyping was a viable option to improving collaborative working. The second challenge was to improve the organisation’s current approach to working with construction project extranets to facilitate collaborative working. Both of these issues were associated with the subject domain of ICT-enabled collaborative working. Therefore, the overall or primary aim of the entire research project was to investigate and identify improvements for ICT-enabled collaborative working within the context of an engineering consultancy (Buro Happold). To achieve the primary aim, three secondary aims were set with four objectives attributed to each, as shown in Fig. 1.1.

1.6 Thesis Structure

The following describes the remaining structure of the EngD thesis:
- Chapter Two imparts the findings of the literature review on the subject of ICT-enabled collaborative working to acknowledge existing research work and the thought of others within the field.
- Chapter Three presents a précis of research methodologies before outlining the method and tools applied to the research project, along with justification for their use.
- Chapter Four provides an overview on the history of the EngD project and describes the research carried out over the course of the programme; through recounting the various activities applied in achieving individual objectives and the overall research aim.
- Chapter Five discusses the key findings of the research and their implications for the sponsoring company. It also provides a critical evaluation of the research and identifies a number of recommendations for the industry and further work.
The Appendices contains three peer-reviewed publications, completed as part of the EngD requirements, and additional supporting material as evidence of research undertaken including questionnaires and a copy of a form developed to promote efficient implementation of project extranets.

**Figure 1.1** Breakdown of EngD Aims and Objectives
1.7 Summary

This chapter has presented the reader with an introduction to the thesis on ICT-enabled collaborative working methodologies, which was conducted as partial fulfilment for the award of Doctor of Engineering. It explained the context of study, in relation to both the sponsoring company and the wider construction industry, and provided justification for the research. Finally, an explanation on the novelty of the work and the project’s main aims and objectives were proffered, along with an outline on the remaining sections of the thesis.
2. REVIEW OF LITERATURE

2.1 Introduction

This chapter imparts the findings of a literature review carried out to acknowledge existing research, work and thoughts of experts and practitioners within the subject field. It begins by briefly examining major government reviews, to establish how the combination of collaborative working and Information and Communication Technologies have been seen to have the potential for facilitating necessary improvements in the construction industry’s performance. It then examines the subject of collaboration (complexities, modes and conditions) before providing a précis of ICT-enabled collaborative working (including the drivers, barriers, benefits and requirements); to establish how Collaborative Prototyping (CP) and Construction Project Extranets (CPEs) are currently utilised as two methods to facilitate ICT collaborative working. The issue of interoperability is discussed due to its recognised impact in the subject domain, before both the CP and CPE methodologies are explored in further detail.

2.2 The Need to Improve through ICT enabled Collaboration

Over the past decade, several reports (including Latham 1994; Levene 1995; Egan 1998; DTI 2001; NAO 2001 & Egan 2002) have called on the construction industry to change the way it works and significantly improve performance. They have also periodically criticised construction for being too slow to adopt both new technologies and methods of working, and encourage the industry to adopt new innovative approaches (Moore & Abadi 2005). It is argued that the majority of these new methods are based upon various applications of collaboration and the encouragement to develop and utilise tools and techniques that facilitate teamworking, especially Information and Communication Technologies (ICTs). To substantiate this reasoning, a brief outline of the key recommendations from the various reports is provided:

1. In Constructing the Team, Sir Michael Latham (1994) commented on the adversarial nature of the industry and outlined the need to adopt Joint Ventures (JV), Partnering and integrated teams to help alleviate this situation.

2. The Defence Estates (DE), Ministry of defence (MoD) and the Department of Environment, Transport and the Regions (DETR) set up ‘Building Down Barriers’ (BDB) to develop an innovative collaborative based approach to procurement (BDB, 2005), which resulted in the release of the handbook of supply chain management (Holti et al, 2000).

3. In Rethinking Construction, Sir John Egan (1998) acknowledged that the industry was highly fragmented and to surmount this, it must adopt proven techniques from other industries such as integrated teams, framework agreements, long-term relationships, Supply Chain Management (SCM) and teamworking. He also noted the potential for adopting CAD technology to prototype buildings and therefore enable redesign to occur in the workplace rather than on site (saving a vast amount of waste and rework); although the industry was warned to address its culture and process problems first before using technology to support them.

4. The Modernising Construction (NAO, 2001) report concluded that the UK had fallen behind other countries in the use of IT in construction, and cited other...
industries use of ICT to transform their sectors; such as aerospace, financial services and food retailing.

5. The Foresight report (DTI 2001) conveyed the need for UK construction to respond to a changing Britain and the revolution in computers and information technologies. It recommended the use of advanced technology-driven thinking through web enabled processes and stated that the use of ICT to share information across business processes, from marketing and procurement to design and site management, would allow more collaborative working and benefit everyone in the construction team.

6. In Accelerating Change, Egan (2002) called for the adoption of project insurance, equal share of risk and reward, along with placing further emphasis on the need for more integrated working; setting a target of 50% of all projects by value, by 2007.

Now that it has been demonstrated that collaborative working (particularly when enabled by ICTs) has been recognised as the way forward for the construction industry to overcome its inherent problems (including an adversarial culture and fragmented procurement process), it remains to examine them in further detail.

2.3 Defining Collaboration

An authoritative discussion and listing of the various definitions for the term collaboration was found on the PIECC (2005a) web site, although two definitions not included but considered particularly relevant by the author were as follows. Collaboration is:

- …the agreement among specialists to share their abilities in a particular process, to achieve the larger objectives of the project as a whole, as defined by a client, a community, or a society at large (Hobbs 1996).
- …working together in a seamless team for common objectives that deliver benefit to all (be 2004).

Muir & Rance (1995) define ‘collaborative practices’ as the development and encouragement of a greater amount of collaborative practice, stressing the importance of team work and partnership at all stages of the development process and embracing all its aspects throughout the built environment. However, conventional collaborative practices in construction do not always display these principles as demonstrated in the findings of the remaining sections (and the previously mentioned government reports).

2.4 The Complexities of Collaboration in Construction

Collaboration has been the subject of study in virtually every field: sociology, psychology, politics, science, technology, law, medicine and engineering; yet, collaboration in the AEC sector is considered different to other fields (Kalay 2001). This is because construction relies on collaborative working between a wide range of disparate professionals working together for a relatively short period to design and deliver a project; much of it is based upon a traditional sequential approach using face-to-face meetings; and many of the participants often work independently, taking decisions alone that inevitably affect others (Anumba et al 1997a, 2001 & 2002). Furthermore, various individual stakeholders collaborating on a project also have
differing organisational objectives; rarely have a common project aim; and have also received diverse educational upbringings that use different terminologies (unlike a group of medics collaborating to aid a patient). Whilst this ad hoc approach has entrenched the practice of collaborative working, it has also reinforced traditional disciplines to the extent that, on many projects, an adversarial environment prevails and the fundamental ethos of collaboration is not fully evident (Anumba et al 2000). The situation is also further exacerbated by the use of collaborative practices alongside traditional approaches and adversarial contractual arrangements; as substantiated by Kalay (1999) who found professional practices whom had recognised the need for collaboration, generally adopted one of two methods to facilitate it. These were:

- **Hierarchically-partitioned** – based on a contractual form, where one team member (often the architect) takes leadership of the group (consultants and sub-contractors); considered as an efficient process but less than optimal for collaboration.

- **Temporary-partitioned** – where responsibilities follow the typical ‘over the wall’ practice, shifting from one professional group to another; again considered detrimental due to the implication of ownership and quality.

The sequential or ‘over the wall’ approach to project development has resulted in numerous problems for the construction industry (Anumba et al 1997b), including poor integration, coordination, communications and collaboration leading to fragmentation and untimely poor value for the client. As the ‘over the wall’ syndrome has been well documented (Anumba et al 2002), it is not necessary to provide further details here.

Based upon the above findings, it is feasible to argue that whilst the fragmented nature of the industry makes collaborative ventures more important, it also makes it simultaneously harder to realise (CRISP 2000a). Simply bringing a team of people together does not necessarily ensure that they will function effectively as team. Lack of organisation, misunderstanding, poor communication and inadequate participation can all lead to problems (CPN 2004d). Collaboration in construction is therefore an extremely complex process that requires a high level of strategic planning (Fig. 2.1); especially within SCM (Austin et al 2001).

![Figure 2.1](image)

**Figure 2.1** The importance of strategic planning and the complexities of collaboration in Supply Chain Management (adapted from Austin et al 2001)

### 2.5 Modes and Conditions for Collaboration

According to Anumba et al (2002) there are four modes of collaboration depending on the nature of separation and pattern of communication, between the participants on a
project (Fig 2.2). Hossain & Wigand (2004) highlight two further classifications which relate to the use of ICTs. These are:

1. ICT enabled with ‘face-to-face’ communication – where any number of ICT tools are used that do not involve Virtual Reality (VR).
2. ICT enabled where little or no ‘face-to-face’ communication is used – referred to as Virtual Collaboration (VC), base upon VR and Virtual Organisations (Hossain & Wigand 2003).

<table>
<thead>
<tr>
<th>Same Time</th>
<th>Different Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Face-to-Face Collaboration</strong></td>
<td>e.g. in meeting rooms where participants engage in face-to-face discussions</td>
</tr>
<tr>
<td><strong>Asynchronous Collaboration</strong></td>
<td>e.g. where communication is conducted via some form of notice/bulletin board</td>
</tr>
<tr>
<td><strong>Synchronous Distributed Collaboration</strong></td>
<td>e.g. real-time communication using any of a vast array of current ICTs i.e. telephone, video conferencing, electronic group discussion etc.</td>
</tr>
<tr>
<td><strong>Asynchronous Distributed Collaboration</strong></td>
<td>e.g. communication via the post such as letters, fax machines, telephone messages / voice mail, pagers, email etc.</td>
</tr>
</tbody>
</table>

**Figure 2.2** Four modes of collaboration (adapted from Anumba et al, 2002)

It is also worth noting that the boundary between teamwork and collaboration is not yet well defined, although teamwork can make or break a collaborative project (Lang et al 2002). The key conditions for achieving effective collaboration vary according to the source read, as four non-ICT specific and one ICT specific philosophies were found to exist. The first four have been placed into Table 2.1 to provide easy comparison, as they do not relate to the use of ICT per se. Even though it appears at first, as if the four sources had identified entirely different considerations in the majority of cases, the RE contests that a number of them are pertaining to the same meaning, but through different syntax. For example, ‘shared-understanding’, ‘alignment of purpose’, and ‘shared meaning’ can be seen to describe the importance of developing universal appreciation and agreement on the objectives for achieving the purpose of the collaborative effort.

With regards to ICT collaboration, Hossain & Wigand (2004) write that previous studies into computer-mediated communication and computer-supported cooperative working suggest higher utilisation of ICT for supporting collaborative work is largely dependent on the business strategy. Geisler and Rogers (2000) documented six basic characteristics to ICT enabled collaboration (sharing, proposing, discussing, ratifying, updating and disseminating) and the need to satisfy the following criteria to ascertain effective collaboration through ICTs:

- Interlink public and private workspaces,
- Provide participants with lines of communication to the other project members,
- Provide participants with lines of control,
- Provide participants with the full array of professional tools.
Table 2.1 Four philosophies on the conditions for effective collaboration

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Shared-understanding</td>
<td>• Alignment of purpose</td>
<td>• Shared meaning</td>
<td>• Vision</td>
</tr>
<tr>
<td>• Conflict resolution</td>
<td>• Ability to perform</td>
<td>• Cognitive synchronisation</td>
<td>• Engagement</td>
</tr>
<tr>
<td>• Tolerance and accommodation</td>
<td>• Attitude of trust and respect</td>
<td>• Shared memories</td>
<td>• Trust</td>
</tr>
<tr>
<td>• Communication</td>
<td>• Acuity to communication</td>
<td>• Communication</td>
<td>• Communication</td>
</tr>
<tr>
<td>• Willing to listen</td>
<td>• Attention to processes</td>
<td>• Planning</td>
<td>• Processes</td>
</tr>
<tr>
<td>• Technologies</td>
<td>• Ability to learn and change</td>
<td>• Management of tasks</td>
<td>• Technologies</td>
</tr>
<tr>
<td>• Commitment and ownership of results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Freedom of choice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Training and mentoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Standards</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regardless of the mode or approach, it is argued that effective collaboration necessitates successful and efficient sharing of knowledge, negotiation, coordination and management of activities (Lang et al 2002). It should also be founded on good communication, as it is the means by which intents, goals and actions of each of the participants are made known to others (Kalay 2001). Consequently, organisations need to formulate a well defined communication strategy to ensure delivery of the appropriate information, to the correct recipient and in real-time; to facilitate truly effective collaborative working. Collaboration should also commence at project conception; as key design decisions in the early stages would have a far-reaching effect on detailed design and construction and hence, the overall project cost (Anumba & Newnham 2000). If implemented and managed correctly at this early stage, the potential exists to reduce error and rework by up to 50% when compared to traditional methods (Austin 2002), as shown in Fig. 2.3, p. 32.

2.6 The Need for ICTs to Enable Collaboration

Despite the benefits of traditional collaborative working (non ICT based), the approach relies heavily on manual paper-based procedures, which are difficult to manage, have poor coordination and offer low-grade communication; leading to misunderstanding, errors, waste and client dissatisfaction (Kalay 2001 & Zaneldin et al 2001). It is therefore essential that enabling ICTs are used for effective collaborative working between the parties in a construction project (Anumba & Newnham 2000) as they are the future instruments for supporting leading edge, innovative and powerful solutions that target the main issues faced by today’s construction sector (ROADCON 2003a). As ICT-enabled Collaborative Working (ICTeCW) incorporates such a vast array of issues, initiatives and research activities it would be impractical to try and address all of them hereto. Instead, as the subject of the thesis pertains to the use of Collaborative Prototyping and Construction Project Extranets as two principle methodologies for
delivering effective ICTeCW, it was felt necessary only to provide a synopsis on ICTeCW, before concentrating further discussion on these two specific elements.

Figure 2.3 The potential of collaborative design to reduce error and waste (adapted from Austin 2002)

2.7 ICT-enabled Collaborative Working

The literature review failed to uncover a definitive definition for the term ICTeCW. As the term implies the use of ICTs to support collaborative working, and collaboration was discussed and defined in the previous section, the next stage was to examine and define what is meant by the idiom ICTs. Although a myriad of definitions exist, those considered most relevant were as follows. ICT can be defined as:

- …enabling technologies for electronic information management and sharing between potentially remote locations especially used in support of virtual enterprise (Avanti 2005a).
- … ICTs include telecommunications technologies, such as telephony, cable, satellite and radio, as well as digital technologies, such as computers, information networks and software (Harvard 2005).
- …the fusion of computers and telecommunications and/or a means of obtaining education, information, and working creatively with others irrespective of geographical barriers (Mobbs 2002).

Through reviewing the various definitions (including those for collaborative working) it is possible to maintain that the rudiments of ICT-enabled collaborative working are:

...the use of enabling technologies to facilitate efficient and seamless information management and collaboration amongst multiple parties, regardless of location, to enable their shared abilities to achieve the larger objectives of the project and deliver benefit for all.
Table 2.2 Collective summary of the barriers, drivers, requirements and benefits of ICT-enabled collaborative working

<table>
<thead>
<tr>
<th>BARRIERS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial constraints</td>
<td>Resistance to change</td>
<td>Fear of failure</td>
<td>Human behaviour</td>
</tr>
<tr>
<td>Lack of strategic planning</td>
<td>Fear of failure</td>
<td>Different cultures</td>
<td>Lack of trust</td>
</tr>
<tr>
<td>Lack of commitment time/energy/resource</td>
<td>Different cultures</td>
<td>Time Zones</td>
<td>Multiple standards</td>
</tr>
<tr>
<td>Late implementation</td>
<td>Diverse company values</td>
<td>Diverse company procedures</td>
<td>Poor standards</td>
</tr>
<tr>
<td>Traditional contacts</td>
<td>Diverse company procedures</td>
<td>Lack of understanding</td>
<td>Poor interoperability</td>
</tr>
<tr>
<td>Fragmented process, professions &amp; disciplines</td>
<td>Lack of experience</td>
<td>Lack of education</td>
<td>Information overload</td>
</tr>
<tr>
<td>Data protection</td>
<td>Lack of training</td>
<td>Lack of ability</td>
<td>Vendor commercial interests</td>
</tr>
<tr>
<td>Intellectual Property Rights</td>
<td></td>
<td></td>
<td>Lack of investment</td>
</tr>
<tr>
<td>Legal admissibility</td>
<td></td>
<td></td>
<td>Poor adoption rates</td>
</tr>
<tr>
<td>Fear of change</td>
<td></td>
<td></td>
<td>Inaccessible information</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Skill shortage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rapid ICT product change</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DRIVERS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EU Directives</td>
<td>Integrated approach</td>
<td>Process improvement</td>
<td>Innovation &amp; new technology</td>
</tr>
<tr>
<td>Industry initiatives</td>
<td>Process improvement</td>
<td>Better collaboration</td>
<td>Globalisation</td>
</tr>
<tr>
<td>Industry improvement</td>
<td>Integrated systems</td>
<td></td>
<td>Knowledge Management</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Client requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>Collaborative contractual arrangements</td>
<td>Transparency</td>
<td>Best value not lowest price</td>
</tr>
<tr>
<td>Collaborative mindset</td>
<td>Transparency</td>
<td>Open negotiation</td>
<td>Performance measurement</td>
</tr>
<tr>
<td>Early involvement</td>
<td>Adaptable</td>
<td>Change Management</td>
<td>Continuous Improvement</td>
</tr>
<tr>
<td>Mutual trust &amp; respect</td>
<td>Change Management</td>
<td>Standardisation</td>
<td>ICTs</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td></td>
<td>Education</td>
</tr>
<tr>
<td>Long-term relationships</td>
<td></td>
<td></td>
<td>Training</td>
</tr>
<tr>
<td>Common processes</td>
<td></td>
<td></td>
<td>Legal clarification</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BENEFITS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attainment of industry targets</td>
<td>Increased efficiency</td>
<td>Greater predictability</td>
<td>Resource management</td>
</tr>
<tr>
<td>Increased profitability</td>
<td>Improved decision taking</td>
<td>Improved programme time</td>
<td>Improved work environment</td>
</tr>
<tr>
<td>Efficient collaboration</td>
<td>Reduced programme time</td>
<td>Shared understanding</td>
<td>Rapid information exchange</td>
</tr>
<tr>
<td>Improved communications</td>
<td>Consensus</td>
<td>Design certainty</td>
<td>Better data management</td>
</tr>
<tr>
<td>Integrated supply chain</td>
<td>Integrated working</td>
<td>Process improvement</td>
<td>Redesign on PC not site</td>
</tr>
<tr>
<td>Reduced &amp; shared risk</td>
<td>Change Management</td>
<td></td>
<td>Remote &amp; mobile working</td>
</tr>
<tr>
<td>Less conflict</td>
<td></td>
<td></td>
<td>Overcoming geographical barriers</td>
</tr>
<tr>
<td>Higher quality</td>
<td></td>
<td></td>
<td>Improved health &amp; safety</td>
</tr>
<tr>
<td>Lower costs</td>
<td></td>
<td></td>
<td>Whole life cycle analysis</td>
</tr>
<tr>
<td>Less errors, rework &amp; waste</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
benefit from its use. This may be due to the fact that 96% of clients use email to exchange project information, whilst only 13% of clients use other ICT based collaboration tools to manage projects (Barbour 2003). By collating all the key factors brought out by the literature review on the subject of ICTeCW, it was possible to define a comprehensive listing of the barriers, drivers, requirements, and benefits of ICTeCW; as shown in Table 2.2 (Latham 1994; Anumba et al 1997a; Leevers 1998; Kalay 1997; Egan 1998; Kalay 1999; CRISP 2000a & b; Barkawski et al 2001; DTI 2001; NAO 2001; Teamwork 2000, 2001 & 2002; ROADON 2003b; be 2004; X-Slang 2004; Avanti 2003 & 2005b).

2.8 ICT-enabled Collaborative Working: Tools of the Trade

By analysing the various sources of information gathered for the literature review, it was possible to determine a list of the main ICT tools used to promote collaborative working. These are: land telephones; fax machines; mobile phones; email; Electronic Document Management (EDM) systems; Intranets; the Internet; Multimedia communication systems; videoconferencing; Virtual Reality; Mixed Reality; Virtual Meeting Rooms; shared 3D models; 4D modelling; nD modelling and Web-enabled project collaboration tools (Project Extranets) (Anumba 1997b; DETR 1999; CRISP 2000a, CRISP 2000b; CPN 2001; ITCBP 2001; Teamwork 2000, 2001, & 2002; Avanti 2003; Compagnia 2003; & ITCBP 2003a).

A review of the ICT-enabled collaborative working best practices (Avanti 2003) found that present efforts to improve integration and collaboration focused exclusively on the various applications of integrated 3D models and Project Extranets. The Teamwork (2000, 2001 & 2002) experiments, which utilised 3D CAD modelling, prototyping and extranet-enabled information sharing to facilitate their approach to collaborative working, found that amongst their 18 conclusions, the issue of interoperability was the principle inhibitor of ICT-enabled collaboration; discussed in the next section before moving onto examine the areas of Collaborative Prototyping and Construction Project Extranets.

2.9 Integration and Interoperability

The first attempt to develop ‘building data model standards’ to allow the exchange of information between CAD applications were undertaken in the early 1980s in America and resulted in the development of the Initial Graphics Exchange Specification (IGES). The IGES format achieved limited success, and as a result, several other standards were developed in the early 1980s; including Product Data Exchange Specification (PDES). Eventually in 1983, they were all brought together under the International Standard Organisation (ISO), and the Standard for Exchange of Product data (STEP) was conceived. STEP sought to define not only standard data models to facilitate information exchange but also standard methodology for data modelling and data exchange. The STEP standard is set out in ISO 10303 Part 1 and is defined as:

“...an international standard for the computer-sensible representation and exchange of product data. The objective is to provide a mechanism capable of describing product data throughout the lifecycle of a product, independent of any particular system. The nature of this description makes it suitable not only for file exchange, but also as a basis for implementing and sharing product database and archiving” (Amar et al, 2000).
Over the past two decades, researchers and industry experts have constantly tried to develop various types of software applications to aid the diverse disciplines in construction to carry out their work more effectively. Unfortunately, this led to islands of automation, which had to be overcome to provide a seamless link between all of the various applications used by the separate disciplines. However, given the large number of applications used throughout the build life cycle, it is impractical to set up one-to-one mapping between all of them. A more efficient solution would be to use a neutral data format as a medium for data exchange (Sun and Aouad 2000).

Despite the large amount of research and work in this field, there is still no single integrated solution that meets the needs of the construction industry. This has caused much frustration throughout construction industries worldwide, and has contributed to the uprising of separate bodies whose main aim is to overcome the challenge of interoperability. These include the CAD Society, Organisation for the Advancement of Structured Information Standards (OASIS), National Institute of Standards and Technology (NIST) and the International Alliance of Interoperability (IAI). At the A/E/C Systems ‘95 show (in Atlanta, Georgia), the IAI demonstrated that interoperability was not just a dream; but could be made into reality (IAI, 2001). Their vision is to enable software interoperability in the AEC/FM industry and provide a universal basis for process improvement and information sharing in the construction and facilities management industries (IAI, 2001). Similarly, the STEP approach by the IAI, utilises Object Oriented (OO) methods to define each individual object such as a door or window; and provides an information processing paradigm for efficient development and management of complicated software systems (Karim & Adeli 1999). Once an object has been defined, it is known as a 'class'. These ‘classes’ are collected together and used to build the model, also known as 'Industry Foundation Classes' (IFCs). Harrod (2001) states the IFC system is a data representation standard for defining architectural and constructional CAD graphic data as 3D real-world objects. IFCs are available to software vendors to create applications that are built to an IFC specification which will allow IFC compliant software to share data in an electronic format and thus permit interoperability. However, to try to define all of the objects in construction is a monumental task and one that has already taken several years and millions of dollars to get thus far.

Since the unprecedented rise of the Internet, another major development has risen within construction; the Architectural, Engineering, and Construction eXtensible Markup Language (aecXML). Firstly developed by Bentley, it was passed to the IAI for further development. aecXML was built upon the earlier developed XML, which is a web based standard for talking about things, not modelling them (Harrod, 2001). Day (2001) notes that it is clear to see that the past couple of years has seen a growing divide between the new Internet aims of CAD developers and the initial charter and objective of the IFC object interoperability. When aecXML was released in 1999, over 100 parties (software companies, research institutions, standards bodies, AEC firms and other interested parties) responded to its application within a week (Harrod, 2001); many saw it as a means of obtaining a more rapid solution to the exchange of data between CAD systems. Teamwork (2001) summed up the need for better interoperability by writing; information should be capable of being moved from system to system without translation, data loss or change in semantics.
2.10 Collaborative Prototyping

It has been established that Collaborative Prototyping is one of many tools that fit under the umbrella of the ICT-enabled collaborative working paradigm. Furthermore, evidence has been provided to show that it is one of the two most commonly applied methodologies most commonly used in an attempt to ascertain more effective collaboration (Avanti 2003); due to the implicit understanding that it offers the ability to alleviate many of the inherent problems of more traditional construction processes. It now remains to demonstrate an appreciation of the main elements of 3D Computer Aided Design (CAD) practices, particularly for Collaborative Prototyping. However, it must be appreciated that the application of ‘modelling’ to construction incorporates such a wide range of potential applications, covering the full life cycle of a built asset (CRISP 2000b) that it would be impracticable to discuss all of the issues in detail, within the context of this work.

CAD tools have become the standard method for producing building documentation over the past twenty years. As a consequence, the need to transfer CAD-information between the different participants in a construction project in digital form has become of vital importance (Björk et al 1997). There has been a great amount of research carried out into the areas of integration and 3D / VR tools to aid in the construction of a project model and facilitate collaboration (including, Bouchlaghem et al 1996; Rosenman & Gero 1997; Nam & Wright 1998; Bouchlaghem & White 2000 and Sun & Aouad 2000). Presently, CAD packages contain large libraries of parametric building parts, such as doors, and windows, and structural components, which are used to organise building assembly and material information. This library of components contains 2D and 3D representations of the building parts that can be substituted in different viewpoints (Whyte et al, 1999). Therefore, a user can design in 2D and then automatically generate a 3D model, or design in 3D, and extract plans and sections. It is also possible to ‘pan’ and ‘zoom’ around drawings in order to gain a better understanding of how the model fits together and identify clashes (known as clash detection) or problems, whilst visualisation techniques such as rendering and animations help to provide context and shadows that give the model a ‘photo realistic’ finish. This allows the viewer(s) to ascertain an enhanced perception of what the actual product would look like in real-life. Virtual reality models are interactive 3D models that can be experienced in real-time. The term virtual reality is similar to and sometimes used synonymously with visual simulation, digital mock-up, virtual prototyping, walk / flythrough, and 4D CAD (Whyte et al 1999).

A great deal of confusion has been created by the number of different concepts that involved the use of 3D building models, virtual buildings, virtual prototyping etc., all of which had advanced from initial research conducted in the 1970s (Evans 2004 & Goldberg 2004). Two other very similar concepts to CP were identified as:

- Virtual Prototyping – where the vision was to develop and integrate a set of advanced information services and technologies in order to support the concurrent, distributed, and collaborative design and engineering needs of manufacturing organisations (Jasnoch 1996).
- Single Build Model (SBM) – similar to the Automotive and Aerospace industries, where the desire was to prototype a building in its entirety before any ground had been broken (Day, 2001). Croser (2001) stated many software developers saw it as the construction industry's equivalent of penicillin; curing the process of ills.
However, Day (2001) wrote that the SBM concept could not provide a common environment for collaboration; as it could only work if there was a common application.

Conversely, CP involves all of the project stakeholders coming together to work collaboratively to develop a fully integrated 3D model/prototype of a product before it is built. The model is then used to test, integrate and co-ordinate (through collaborative working) the production of the product. The concept of ‘Collaborative Prototyping’ provides a process that challenges existing cultural attitudes and working processes and advocates a change in the way conventional projects are managed, in order to achieve a more competitive industry. The benefits of CP (Egan 1998; Teamwork 2000 & 2001 and DTI 2001) were found to be:

- The rapid exchange of information between design disciplines;
- Efficient integration of design and drafting tools;
- Potential for joint ownership of design solution (although this could be a major problem);
- Potential for extending the scope of information exchange to the supply chain;
- Facilitates a greater degree of interest and dialogue between design disciplines;
- Facilitates the wider exchange of information with contractors and other members of the supply chain;
- Reduction in project time and costs;
- Improvements in quality;
- Improved Health and Safety;
- Reduced waste;
- Ability to facilitate total model analysis.

However, it would seem that whilst the industry is starting to see many solutions to these translation and exchange problems, especially the transfer of intelligence, there are still many technical issues to resolve and cultural and business factors to consider (Dean 2000), including:

- The problem of interpreting geometry between different systems;
- The translation of models intelligently (the information stored with them);
- The refusal of developers to publish their native file formats, with many developers encrypting their files, so other developers cannot even read the format in which they store data, never mind translate it;
- The constant question of project information ownership.

Day (2001) states many of us have been sold the dream of virtual buildings and the inherent benefits that can be attained by 'upgrading today'. However, from what I have seen so far, the CAD developers are still a long way off delivering on their promises... the model-centric promise of true collaborative architectural design is also some way off. Teamwork (2001) shares these sentiments by writing, successful CP requires a comprehensive suite of tools for all disciplines to use, contribute and share information…, the industry’s Holy Grail of collaborative working from a shared central model still appears to be some way ahead of where we are now.
2.11 Construction Project Extranets for Collaboration

Section 2.8, established Construction Project Extranets (CPEs) as one of the two most commonly applied ICT tools under the ICT-enabled collaborative working paradigm. The term Construction Project Extranet (CPE) refers to Internet sites that offer communication platforms, project management functionalities and hosted collaboration spaces for the Architectural Engineering and Construction (AEC) industry (Becerik 2004a). The application of CPEs was also found to form the nucleus of several concepts, and therefore known by the following various designations:

- Project-specific web sites (Thorpe & Mead 2001);
- Project web sites (Augenbro et al 2002);
- Project collaborative extranets (Hamilton 2002a);
- Web-enabled Project Management (Alshawi & Inginrige 2003);
- Project collaboration tools (Unger 2003);
- Web-enabled Project Management Systems (Nitithamyong & Skibniewski 2004);
- Web-based Project Information Management systems (Stewart & Mohamed 2004);

The author contests that all of the above pertain to the same tool (a CPE) and hence, to ensure continuity of understanding, only the term CPE will be used throughout the remainder of the literature review. Also used is the idiom Collaborative Extranet Working (CEW) to articulate the methodology of applying CPEs to facilitate online project collaboration. By extracting the main line of reasoning from the reviewed literature, it is possible to maintain that the fundamentals of CEW are the application of web-enabled technologies and appropriate project management techniques to facilitate online collaboration through better communication and workflow management, and thus ensure efficient information exchange to successfully deliver a project.

Hamilton (2002a) explains that a CPE can take a number of different forms. It can simply be used to transfer files between parties as and when required, as a web site where files can be lodged and retrieved, or a fully hosted service. In the majority of instances, the system used is rented from an Application Service Provider (ASP) who then supplies the project with secure and controlled access to the extranet. The project team then uses the system to transmit and store project information (via a centralised repository) as well as communicate and collaborate, all by way of the Internet and web browser (Nitithamyong & Skibniewski 2004). Most clients and project teams opt for a rentable system, as it is available ‘off the shelf’, easy to set up in a day and costs relatively little, when compared to the option of developing your own system; which requires a great deal of expertise, time, resources and money.

A limited number of studies have been completed on examining the vast array of CPEs, the main tools available under each system and the implications as to their use on a project (Breetzke & Hawkins 2002 & 2003; Alshawi & Inginrige 2002; Hamilton 2002a & b and Nitithamyong & Skibniewski 2004). The results show that there are a number of common tools amongst the CPE systems (too many to list here) although variations have led to the systems being classified under three categories: team communication and document management tools; workflow and process automation tools; and process and project management tools (Becerik 2004a); as shown in Fig. 2.4. The reviews have also had to concentrate on only a small percentage of the obtainable systems (22 at
most), due to the insurmountable task of reviewing all 270 systems available within the industry; of which only 82 are specifically aimed at the AEC sector (Becerik 2004b). Breetzke & Hawkins (2003) reflect on the number of different systems as perhaps one of the main barriers to their greater adoption.

![Table]

<table>
<thead>
<tr>
<th>Team communication &amp; document management tools:</th>
<th>Work flow &amp; process automation tools:</th>
<th>Process and project management tools:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supporting various modes of communication, acting as a repository for storing project information and allowing timely sharing and exchange of information and documents</td>
<td>Supporting various business models for managing flow of information, managing and monitoring progress of tasks which enables attention to durations</td>
<td>Supporting process and project monitoring and management, providing better management of the projects resources</td>
</tr>
</tbody>
</table>

Examples: Buzzsaw standard, Citadon CW, ProjectTalk

Examples: e-Builder, Constructware, Bricsnet, 4Projects, Asite

Examples: Primavera Systems, BIW, Meridian Project Systems

![Figure 2.4](image)

Since the turn of the millennium the notion of using a CPE to facilitate information exchange and collaboration has increasingly come to the fore, and from a standing start of just three or four years ago, methods of online project collaboration have started to revolutionise the way in which construction projects are managed (Broyd, 2003). The IT Construction Forum (2004) affirmed CPE adoption was growing rapidly due to nearly half of all respondents stating they had use project extranets to collaborate online (43% of the 373 responding firms). McCrea (2005) suggests that around 45% of construction projects over £5m are now using CPEs and there are more and more clients, contractors and government clients endorsing them as a tool for improving efficiency. This is because new developments in web-based technology have offered more opportunities for multi party collaboration along with improvements in communications and process, through the entire project lifecycle (CPN 2004b). A typical example on how the industry is sold the potential of CPEs to improve communication and collaboration by Application Service Providers (ASPs) is shown by Fig. 2.5, p. 40.

The potential benefits to working with CPEs have been comprehensively debated and (including AJ 2001; Hamilton, 2002b; Alshawi & Ingirige 2003; ITCBP 2003b; CPN 2004b; CPN 2004c; CPN 2004d; Martin 2003; Nitithamyong & Skibniewski 2004) are widely acknowledged as:

- Provision of process transparency and fewer excuses
- Greater standardisation
- Reduced paperwork, task repetition and distribution costs
- Increased speed in information delivery
- Faster access to information
- Reduced review times and faster resolution of enquiries
- More efficient project integration and communications
- Less document storage space required
- Improved efficiency and consideration of data capture
- Standardised reporting
- Reduces error, rework and waste
- 24/7 access anywhere in the world (where internet access is available)
- Better document viewing compatibility

Figure 2.5 Example of modern (with CPE) verses traditional (without CPE) project communications (Sarcophagus 2005)

Conversely, the literature review also revealed a significant number of potential latent ‘pitfalls’ that required evasion (CPN 2001; Thorpe & Mead 2001; Hamilton 2002a; Breetzke & Hawkins 2003 and CPN 2004a, b & c). However, these were not expanded upon in any great detail, but rather cautionary warnings on what to ‘look out’ for or consider including:

- Clients choosing to use a system after they have appointed the consultants and contractors. Clients must be encouraged up-front to determine the collaboration system that is to be used.
- The difficulties associated with quantifying cost of system to benefits accrued, when trying to gain ‘buy in’ from clients and project teams.
- Collaborative maturity amongst various parties, with some being more open to such a method of working and trust that others.
- Everyone has their own issues which are not always considered and managed; there is a requirement to be ‘fully inclusive’ in collaboration within the team.
- Lack of preparation and consideration before implementing a system, which makes successful applications difficult to plan and manage.
- Lack of procedures on what to do with information upon project completion (especially legal requirements, ownership of data, what happens when a dispute arises).
• A lack of clarity on the legal issues that must be addressed include: data protection; legal admissibility; agreements with technology suppliers; ownership and access to data and Intellectual Property Rights (Hassan et al 2004).

• Problems created by ISO 9001: 2000 (primary requirement to ‘satisfy the client’) and Professional Indemnity (which states the need to retain paper copies) when individual organisations also have their own internal procedures and standards to meet.

• Lack of software interoperability particularly between different types of systems, where it is not possible to transfer or use previous data.

• Poor provision of time allowed learning new systems and methods to overcome resistance to change.

• Failure to consider how the extranet will integrate with internal company systems.

• Density of other communication methods such as meetings, emails, telephones, mobile phone and fax machine.

• The vast numbers of people placing information onto the system at any one time, and moderating the usefulness of the information.

The majority of the above problems are not due to the technology, and consequently can be negated through attention to detail in the creation of procedures (CPN 2001). This is because people collaborate, not systems; it’s 80% people and process, and only 20% technology (CPN 2004c). As a result, project teams are advised to establish and agree procedures as early as possible; to assist workers in achieving efficient use of the CPE as well as to ensure effective implementation and management of the system. The requirement for a best-fit framework of procedures (protocol) was also found in CPN (2004c), which writes: there is no standard yet, it is too early in the development cycle. With different extranets, different sectors, supply chains, functionality etc, it is not yet possible to define a generic protocol. They tend to be client or project specific, and need to be decided for each project. In future the first document found will be the protocol document!

Finally, it was also found that all of the studies conducted thus far on have been based on either individual case studies using interview techniques or anecdotal evidence provided by success stories reported in the press. There has been no empirical research on a large scale conducted on this topic (Nitithamyong & Skibniewski, 2004). Furthermore, past research has continually focused on the need for adopting such systems within in a single project/system scenario. There has been no investigation into the impact of collaborative working with multiple CPEs within a single organisation.

2.12 Summary

The literature review demonstrated that in order to overcome the problems inherent within construction, industry reviews have recommended (amongst others) the adoption of collaborative working enabled by ICTs. It found that collaboration in construction is a complex practice although, when implemented correctly it has the potential to bring about significant improvements. Conversely, whilst non ICT enabled collaboration was deemed to be more efficient than traditional procurement processes, ICT-enabled collaborative working was considered to be more effective than both; although a major inhibitor to greater uptake is the issue of interoperability. Also established was the fact
that Collaborative Prototyping and Construction Project Extranets are two of the principle tools currently utilised to facilitating ICTeCW. Finally, it has been shown that the requirement exists for a best-fit framework to be developed in order to assist project teams in implementing and managing CPEs more effectively; and therefore contributing to the wider successful application of ICT-enabled collaborative working throughout the industry.
3. RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this chapter is to provide a précis of the various methodologies available for undertaking research, highlight the selected and applied methods within this particular case and provide justification for their use along with the tools utilised.

3.2 Available Research Methods

Research can be defined as a careful search or inquiry; endeavour to discover new or collate old facts etc. by scientific study of a subject; a course of critical investigation. (Naoum 1998). There are a wide variety of research methodologies available to the researcher, all of which are categorised in a variety of ways (Siegle 2005); although frequently, classification of work is difficult, not only due to the use of ‘fuzzy’ definitions but, more importantly, because work occurs within a continuum (Fellows & Liu 2005). According to Dainty (2002) there are three distinct approaches to research methodology:

- **Positivist (scientific)** – where research looks to discover laws and generalisations that explain reality and allow for prediction; explaining events or phenomena through knowable facts, real causes that have a law-like regularity (Woods & Trexler 2001) and measurement.

- **Interpretative (phenomenological)** – where the focus of research is based upon understanding and interpreting occurrences and social structures to provide a meaning to a phenomenon (Woods & Trexler 2001).

- **Critical** – the questioning of truths about subjectivity, experience, and the way the world is combined with recognition of the cultural, political and historical factors which shape experience (PSYCH 2005).

In addition to the above research perspectives, there are a number of principle research styles including ‘Action’, ‘Ethnographic’, ‘Surveys’, ‘Case Studies’, ‘Experimental’, ‘Correlational’, ‘Causal-Comparative’ and ‘Historical’ (Fellows & Liu 2005, Siegle 2005). Also used to acknowledge and differentiate between different research styles are the terms ‘qualitative’, ‘quantitative’ and ‘triangulation’. The most suitable forms (for this type of research project) were examined in more detail to enable further understanding of the techniques available, and to facilitate taking a decision on the most appropriate research strategy to facilitate completion of the overall research project.

**Action research** – is seen as a process in which a group of people come together more or less regularly to help each other learn from their experience (Dick 1997). Or, where the researcher actively participates in the process under study, in order to identify, promote and evaluate problems and potential solutions (Fellows & Liu 2005). Reason (2001) identifies the following characteristics as part of action research:

- To contribute to the ‘body of knowledge’ through ‘practical knowing’, involvement in the process;
- Research is conducted through collaboration with others involved in the process;
• Research is founded around participation in the process (unlike most other forms of academic research, where it is conducted from a distance);
• It aims to develop a theory which is not simply abstract and descriptive, but is a guide to inquiry and action in present time.

Ethnographic research – is the study of a group or culture by a researcher, founded upon their personal interaction and experiences (through fieldwork) with those being investigated, and typically employs three kinds of data collection: interviews, observations and documents, which results in a narrative description (Genzuk 2003).

Case Studies – can be defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used (Yin, 1984). According to Soy (1996) case study research excels at allowing an understanding of complex issues and can extend experience or add strength to what is already known through previous research. However, this approach can be time consuming and care must be taken not to draw generalised conclusions from limited cases to ensure academic rigor. Conversely, it can lead to new and creative insights, and have high approval amongst practitioners. Through triangulation with multiple means of data collection, the validity can be increased further (Voss et al 2002).

Experimental research – is an attempt by the researcher to maintain control over all factors that may affect the results of an experiment. In doing this, the researcher attempts to determine or predict what may occur (Key 1997). This type of research is best suited to ‘bounded’ problems or issues in which variables involved are know, or at least hypothesised with some confidence (Fellows & Liu 2005).

Survey research – is seen as one of the most important areas of measurement in applied social research. A ‘survey’ can be anything from a short paper-and-pencil feedback form to an intensive one-to-one in-depth interview (Trochim 2002). The principle benefit of this research method is its ability to collect information efficiently from a large number of distributed respondents. The main weaknesses are reliance on respondents to be honest and accurate in their responses, and the inability of survey research to deal with complex social phenomena (Baker 2003).

Quantitative research – can be defined as the numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations reflect (Kaplan 2004); i.e. it uses the collection of statistics, based on real data, observations or questionnaires, to test a hypothesis or theory. It is therefore considered to be ‘objective’ in nature.

Qualitative research – in direct contrast to quantitative research, qualitative research is based upon the non-numerical examination and interpretation of observations for the purpose of discovering underlying meanings and patterns of relationships (Strauss & Corbin 1998). It attempts to obtain an in-depth understanding of the meanings and ‘definitions of the situation’ presented by informants, rather than the production of a quantitative ‘measurement’ of their characteristics or behaviour (Wainwright 1997). It is therefore considered to be ‘subjective’ in nature. There is also a wealth of literature available on this subject, along with comparing and contrasting the two distinct research
methodologies. From these in-depth and complex discussions, a third practice has been identified and emerged; that of ‘triangulation’.

*Triangulation* – can be defined as the application and combination of several research methodologies in the study of the same phenomenon, used to obtain confirmation of findings through convergence of different perspectives (Jakob 2001) taken from both quantitative and qualitative methodologies. There are conflicting reports on the different number/types of triangulation, but the general consensus (including Mathison 1988, Begley 1996 & Guion 2002) appears to indicate that five variants exist. These are:

1. Data – triangulation of different sources of data across time, space or persons.
2. Investigator – triangulation of work amongst several researchers.
4. Theory – triangulation of two or more contrasting theoretical positions.
5. Analysis – triangulation via use of more than one analysis technique.

### 3.3 Research Methodology Considerations

Leming (1996) infers that deciding on a methodology should not be dictated by one’s ‘favourite’ methodology. Rather, the decision should be influenced by the nature of the research hypotheses, the body of existing knowledge, expertise in a given methodology and the resources available to the researcher. When considering the given research problems and the initial hypotheses in relation to the above issues, the following were distinguished as key factors in taking a decision on the most appropriate methodologies.

- The nature of the research problem was classed as ‘open’ and complex; as the problem was not easily identifiable, which required a dynamic and fluid approach at the early stages of the project.
- The existing body of knowledge on the subject of Collaborative Prototyping (Aim 1) was not easily recognised and classified due to an overlapping and blurring of several comparable approaches to the use of 3D modelling and prototyping.
- The body of existing knowledge surrounding the use of Construction Project Extranets (Aim 2) was far more comprehensive, although limited to the use of a single system in individual project scenarios.
- Resources available to the RE included access to:
  - The university’s academic supervisors, comprehensive library and electronic journals.
  - The sponsoring company’s worldwide offices, employees, projects and industrial links.
  - Two major industry initiatives in collaborative working; Teamwork and the Avanti programme.
  - Three practitioners within the subject area who worked for the sponsoring company.
  - An internal company Construction Project Extranet system (Autodesk Buzzsaw).
- Constraints included attending the university on a regular basis to complete an MSc course, completing a number of papers for the EngD programme and having a limited amount of time and budget.
Finally, it was necessary not only to arrive at conclusions that satisfied the requirements of the EngD programme but which were also applicable both within the sponsoring company and an industrial context. To achieve this, validation by industry practitioners was seen as a crucial requirement of the research method.

3.4 Adopted Methodologies, Tools and Justification for their use

Based on consideration of the afore mentioned factors, the decision was taken to apply a different research methodology for each of two research problems (see Table 3.1 for summary of the overall research project aims, objectives, and applied methodologies and tools).

A survey research methodology with methodological triangulation (Fig. 3.1, p. 48) was applied to the first problem (Aim 1). Justification for this decision was based upon the need to implement a strategy which would facilitate a prompt appreciation of the current application of collaborative prototyping within the industry, to enable a decision on whether or not to proceed with further research in the subject area.

A literature review was carried out to facilitate comprehension of existing theories and work by others; to form a coherent argument for further research and to demonstrate a fundamental understanding of the concept ‘Collaborative Prototyping’. The data obtained from the literature review was then utilised to conduct semi-structured interviews with industry champions, in order to research the current principles of collaborative working and 3D modelling, whilst also capturing emerging thoughts and ideas. An electronic descriptive questionnaire survey was used to collect factual (as well as statistical and measurable) evidence on the day-to-day application of collaborative working and collaborative prototyping within the construction industry. Finally, through triangulation of the results from both the interviews and the survey, it was possible to determine and advise the sponsoring company on the current application of Collaborative Prototyping within the Architectural, Engineering and Construction (AEC) industry (Paper 1, pp. 109 - 127).

A case research methodology approach with methodological triangulation (Fig. 3.2, p. 48) was applied to the second research problem (Aims 2 & 3), as the RE was required to investigate the emerging and increasingly complex use for multiple CPEs to facilitate collaborative working; as well as provide a strategy for improving the current process. Justification for the decision was based upon an understanding presented by Voss et al (2002) that case research allows:

- Early exploitation and investigation where the variables are still unknown and the phenomenon is not clearly understood;
- A phenomenon to be studied at close range within its natural environment;
- The questions of why, what and how to be answered with a relatively full comprehension of the nature and complexity of the phenomenon.
**Table 3.1** Summary of the overall research project aims, objectives and applied methodologies

**PRIMARY AIM:**
Investigate and identify improvements for ICT-enabled Collaborative Working within the context of an engineering consultancy (Buro Happold)

<table>
<thead>
<tr>
<th>AIMS</th>
<th>OBJECTIVES</th>
<th>METHODOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Investigate the application of Collaborative Prototyping</td>
<td>1. Review state-of-the-art in collaborative prototyping</td>
<td>Conduct literature based review</td>
</tr>
<tr>
<td></td>
<td>2. Establish current developments in collaborative working and 3D prototyping</td>
<td>Semi-structured interviews</td>
</tr>
<tr>
<td></td>
<td>3. Determine current application of collaborative prototyping within the industry</td>
<td>Questionnaire survey</td>
</tr>
<tr>
<td></td>
<td>4. Results analysis and dissemination</td>
<td>Triangulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Journal paper</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal presentations</td>
</tr>
<tr>
<td>2. Investigate the application of Construction Project Extranets</td>
<td>5. Review industry application of Construction Project Extranets</td>
<td>Conduct literature-based review</td>
</tr>
<tr>
<td></td>
<td>6. Establish the organisations approach to working with Construction Project Extranets</td>
<td>Field case studies</td>
</tr>
<tr>
<td></td>
<td>7. Determine the implications of working with multiple CPEs and protocols</td>
<td>Project Survey and observations</td>
</tr>
<tr>
<td></td>
<td>8. Results analysis and dissemination</td>
<td>Internal Electronic survey Questionnaire</td>
</tr>
<tr>
<td>3. Identify improvements to facilitate efficient ICT enabled collaboration</td>
<td>9. Review the current application of protocols within construction projects</td>
<td>Field case studies</td>
</tr>
<tr>
<td></td>
<td>10. Establish the main requirements for a proficient protocol</td>
<td>Project protocol comparison study</td>
</tr>
<tr>
<td></td>
<td>11. Determine reaction to proposed best-fit framework</td>
<td>Open ended interviews</td>
</tr>
<tr>
<td></td>
<td>12. Results analysis and dissemination</td>
<td>Electronic survey Questionnaire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Triangulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conference paper</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal presentations</td>
</tr>
</tbody>
</table>
A literature review was completed to acknowledge the work of others and determine current issues surrounding the use of CPEs and procedures to facilitate CEW; whilst also substantiating the need for further work. An in-depth study of 48 projects, using 22 different CPEs between them, was completed over a two-year period. The findings of the latter were based upon a project survey, observations and participation in various stages of CPE and protocol implementation and management. An online descriptive questionnaire survey of the sponsor’s employees was undertaken to capture factual (as well as statistical and measurable) evidence on the realities of day-to-day extranet working.

The RE also undertook a series of semi-structured email questionnaires, telephone interviews and meetings with senior managers within their organisation to establish how the company currently approached working with multiple CPEs. Finally, the triangulated results were placed into an electronic survey to validate the research.
conclusions and test proposals for an improved process. To aid the acquisition of subject knowledge, the RE also:

- Observed and participated in an Avanti, ICT-enabled Collaborative Working, satellite project;
- Managed the implementation and daily application of a CPE system (Buzzsaw Standard) with their sponsor’s organisation to promote internal CEW;
- Attended the UK industry conferences Project Extranets IV & V (PE 2003, 2004);
- Observed several extranet vendor presentations on various projects;
- Completed user training on four different CPE systems (4Projects, Asite, Buzzsaw and BIW) and administrator training on 4Projects and Buzzsaw;
- Participated in the Planning and Implementation of Effective Collaboration within Construction (PIECC) initiative.

The above activities were an invaluable means of attaining firsthand experience and knowledge in collaborative working, Collaborative Extranet Working and procedures development.

### 3.5 Summary

This chapter has outlined and briefly reviewed the main types of methodologies available to a researcher, within the context of the subject area. It also provides justification for the application of two methods to address the given problems. The first of these is the ‘survey research’ approach (Fig. 3.1) and the second, being a ‘case research’ approach (Fig. 3.2), with both being validated by triangulation. Finally, Table 3.1 provides a summary of the overall research project aims, objectives, applied methodologies and tools used. The next chapter provides a review of the research undertaken in relation to the chosen methodologies.
4. RESEARCH UNDERTAKEN

4.1 Introduction

This chapter describes the research carried out over the course of the Engineering Doctorate programme, through recounting the various activities applied in achieving individual objectives and the overall research aim.

4.2 Preliminary Studies

In the first few months of the four year programme (see Fig. 4.1, p. 53), the RE undertook a sustained period of investigation, learning and participation in a number of internal project activities; whilst also completing an MSc in Construction Innovation and Management. The aim of this initial period was to permit the RE time to:

- Adjust to a new working environment;
- Develop an appreciation of the sponsoring company’s culture, work ethics and modes of operation;
- Gain an insight into the project duties of engineers, as the RE came from a construction management background;
- Learn about the company’s involvement with the Teamwork (2000 & 2001) experiments and their internal trials conducted as a consequence;
- Build relationships with a number of key personnel, who had a keen interest in the subject and/or had participated in early trials;
- Develop an appreciation and understanding of 3D prototyping and ICT-enabled collaborative working;
- Interpret the importance and direction of the research within the context of the organisation to formulate a research direction, hypothesis and methodology.

As a consequence, much of the RE’s time was attributed to attending various meetings, the university library and modules, as well as becoming involved with internal CP experiments. The culmination of the data gathered at the preliminary stage led to the understanding that:

1. The construction industry was underperforming, wasteful and needed to drastically improve the way it delivered its services and products (as discussed in the literature review).
2. Recommendations on how to improve the procurement process focused on the adoption of teamworking, Partnering, SCM and integration; all which should be enabled by integrated IT systems and emerging ICTs.
3. Due to the above, key industry initiatives, a number of large construction organisations and research establishments had started to examine the issues of integrated systems and ICTs within the construction process; to bring about process improvement and benefits.
4. The desire to develop and use a fully integrated 3D model, to facilitate the entire project process, had increasing momentum amongst many practitioners. Such an approach was deemed to have the potential to improve project collaboration (particularly in the design stage which is highly fragmented and iterative), whilst a
prototype would enable reductions in errors, abortive work and waste (through use of clash detection). However, interoperability was a major barrier to the use of this method; as it was not possible to integrate the majority of software packages due to their various and differing syntax.

5. Web enabled collaboration tools, specifically CPEs, had also become acknowledged as permitting enhancements throughout the entire project process; due to their perceived ability to facilitate improved information exchange, communication, workflow, document management, integration, and collaboration.

6. Both of the above tools/methods were vital components of a new expanding paradigm, ICT enable Collaborative Working.

7. The sponsoring company required research in the field of ICT-enabled collaborative working; with a concentrated focus on the abilities of Collaborative Prototyping (CP) and CPEs to facilitate collaborative working. Furthermore, that they desired a more efficient approach to ICT-enabled collaborative working using either of the approaches.

To aid knowledge acquisition and promote development of expertise within the field, the RE undertook a number of assignments, which included:

- Selecting and completing a number of MSc modules that provided access to tools and techniques applied within ICT-enabled collaborative working (identified by the literature review). These included Management of Information Systems; Organisational Behaviour; Design Management; Value Management & Value Engineering; Lean Construction and E-commerce. This aided understanding of how to:
  - Set up, conduct and facilitate workshops;
  - Undertake and map processes in order to discover inefficiencies and waste in the current process, then by working with those involved in the process, identify an improved approach to obtain better value;
  - Use other tools and techniques to facilitate better collaboration i.e. brainstorming; toolbox talks; decision matrix; PlanWeaver; process protocols; and Total Quality Management (TQM) principles.
- Attended one-day seminars on Design Chains, PlanWeaver, and the CITB’s Learning by Doing, ‘leading a team’. The incentive was to capture and disseminate information on initiatives that could support ICTeCW, as well as prepare the author for leading collaborative teams.
- Visited a leading company within the weapons industry to help understand how the processes of teamwork, integrated project teams, supply chain management and open-book accounting are used to best facilitate a Collaborative Prototyping approach to project work. The company was chosen based upon their location, size (similar to the sponsoring company) and field (design engineers). They had just completed a large organisational changed over from non-integrated 2D design to 3D collaborative working with their suppliers. The visit comprised of a tour, examination of software and a three-hour question session with key personnel.
- Participated with, and observed in many discussion groups and projects within Buro Happold (at the request of senior directors) in areas such as Collaborative Prototyping Group, 3D Software trials, the Document Management Group, Engineering IT Group, and the Organisational Development Group.
- Developed and managed a web site on ICT-enabled collaborative working to aid dissemination of captured knowledge and understanding on the subject throughout the wider audience within the practice, as discussed in section 4.6 and shown in Fig. 4.11 (p. 72).

![Diagram of research development process]

**Figure 4.1** Map of the research development process

### 4.3 Collaborative Prototyping – Aim One

The following section details the work undertaken to achieve aim one and objectives one to four.

#### 4.3.1 Collaborative Prototyping Literature Review – Objective One

The next planned stage of the research strategy was the completion of a comprehensive literature review on the subject of CP. The main objective was to ascertain an up-to-date
and extensive understanding of the concept to enable interview and survey questionnaire development; necessary to determine the level of CP use within the industry. Based upon presentation of the results, the engineering consultancy would then take a decision on whether or not they required the author to implement a CP solution over the remaining time of the course. The literature review was achieved through:

- A comprehensive search of the Learning Resource Centre at Loughborough University, including all industry journals, research papers, industry magazines, and newspapers, which provided over 200 items on the subjects of collaboration and prototyping (although within varying industrial contexts). Monthly visits were also made throughout to capture new developments. The information gathered at this stage also led to other sources of information via references contained within.

- Subscribing to free industry magazines, both paper and electronic base i.e. the AEC magazine, CADUser, cadalyst, cadserver, CADinfo.NET etc.

- An Internet search that led to the discovery of a number of research papers, projects, and wide range of web sites (listed under web sites in the references section). Useful sites were ‘bookmarked’ and subsequently revisited on a periodic basis.

- Obtaining crucial information from key personnel both within the company and through their network of contacts within the industry.

- Participating in knowledge capture and summation meetings held after Teamwork2001; as well as obtaining a copy of the previous report for Teamwork2000.

The completed review also assisted in the capture of existing theories and current research, whilst allowing the development of a coherent argument for further research within the subject domain (section 1.2). Reasons were established why the construction industry had started to look towards ICTs to overcome inherent process inefficiencies, and how collaborative working and 3D prototyping had been earmarked as two principle methods for attainment of business benefits (Paper 1: section 1, p. 112). The literature review also highlighted the fact that a CP solution would need to consider the issues of collaboration, 3D modelling, integration and interoperability; all of which were discussed in further detail due to their implications within the subject field.

### 4.3.2 Current Developments and Application – Objectives Two and Three

To accomplish objectives two and three of establishing current developments in collaborative working and 3D prototyping, and determining the current application of CP within the industry, the author utilised the afore-gained knowledge and experience to construct a series of semi-structured interview questions (App. 4) and an electronic questionnaire survey (App.5). It was felt necessary to undertake both qualitative and quantitative research to provide as in-depth a perspective of Collaborative Prototyping as practicably possible (within the given constraints of time and limited resources). Interviewing industry champions with many years of experience on the subjects of collaboration and 3D modelling would allow the author to further learn about both the fundamental issues and the not-so-well-known emerging initiatives, practices and personal views (the logic to this approach is described in Paper 1: section 3.1, p. 113).

The use of a questionnaire survey was included to provide additional quantitative data to the qualitative data captured in the interview stage. By triangulating the results for
these methods, it was possible to learn about and provide statistical information on the application of CP. The research sample for the electronic questionnaire was based on non-random selected sampling. A list of companies, names and contact details were obtained from the ‘be’ web site (members’ details pages) and cross-referenced with the IAI web site (list of members’ details). It is important to note that the author approached Be and gained permission to contact its members before sending out the questionnaire. The research sample was chosen upon the basis of an available name, email details, and where companies had shown interest in both collaboration and ICT (determined in this case by a company’s name being present on both web sites). The author felt that this would provide the best chance of obtaining useful data on the application of collaborative working and 3D modelling/prototyping. Further information on the development of the questionnaire is available in App.1, Paper 1: section 3.2 (p.113), whilst analysis of the research sample is located in sections 4.1 and 4.2 (pp. 114 - 115).

4.3.3 Results Analysis and Dissemination – Objective Four

The next stage of the research strategy involved the RE producing a full transcription of the taped interview results (Fig. 4.2) and completing a comprehensive breakdown of the survey questionnaire results. The survey data was presented in the form of bar charts, radar charts and tables and applied the Pearson test (as described by Naoum 1998) to determine possible relationships. The author then undertook triangulation of the statistical and qualitative results, based on the approach described by Fellows & Liu (2002), identifying ‘bridges’ to validate the results and make them mutually more informative; whilst maintaining the distinct contributions and integrity of each independent approach. Therefore, the main findings of the first paper are discussed singularly under section 5, Interview findings (pp. 115-121) and section 6, Questionnaire Findings (pp. 121 - 124), before the ‘bridges’ are presented as the overall conclusions and recommendations in sections 7 and 8 (pp. 124 - 126). The justification for adopting this approached was explained in chapter three.

Finally, the conclusions of the research, including analysis of the engineering consultancy’s approach to CP were presented to the industrial supervisors and other interested parties. A formal decision was taken shortly afterwards, which required the RE to focus on the other given research problems. The justification for this was based on the findings that technology alone was not the solution, but rather an enabler of change for bringing about greater efficiency. The development of a Collaborative Prototyping solution required research and work in other areas than that of 3D modelling (such as processes, people and a significant internal cultural change). Buro Happold had originally anticipated that the only work required would be on use of 3D software. Consideration of the above issues, the loss of the three key supporters of the internal CP initiative, and the company going through a period of consolidation, meant they were not in a position to continue with the programme. Moreover, there was growing need to examine the application of CPEs, due to their increased application on projects. 3D modelling is the way forward, but is a larger barrier to overcome at present, in comparison to that of the potential benefits offered by using CPEs (CPN 2004c).
ICT-enabled Collaborative Working

Q1.7 What experiences have you had of working collaboratively using 3D modelling?

Interview 1 – We have tried to use 3D modelling on a couple of occasions, one of them was on project shelter Osbourne Clark in Bristol. It was not really collaborative working, it was the 3D modelling element with the other members of the team who did not have the ability to do 3D modelling at that stage. Apart from projects we are now trying to get going, I do not think we have really done any others. The Teamwork stuff was not real it was all exercises. The BAA work has used collaborative working with 3D modelling and that is, I think, quite well progressed.

Interview 2 – I have worked on many large projects, all in excess of £50 million, and managed a large team of 3D co-ordinators on a £128 million pharmaceutical laboratory. We worked on a single data source, single document control system and placed all building components (except pipe work below 32 mm in diameter, electrical small power, and low-level partitions) into the model. All laboratory equipment was also placed into the 3D world to ensure that the M&E connections were corrected.

Completed transcription of data collected by interviews

SECTION 2: YOUR COLLABORATIVE WORKING EXPERIENCE

Table A3-6 Collaborative working techniques used by companies (Q2.1)

<table>
<thead>
<tr>
<th>Collaborative working techniques</th>
<th>Yes Frequency</th>
<th>No Frequency</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>24</td>
<td>38</td>
<td>62</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td>34</td>
<td>38</td>
<td>72</td>
</tr>
<tr>
<td>Integrated Project Teams</td>
<td>30</td>
<td>38</td>
<td>68</td>
</tr>
<tr>
<td>Framework Agreements</td>
<td>20</td>
<td>38</td>
<td>58</td>
</tr>
<tr>
<td>Project Team Insurance</td>
<td>6</td>
<td>38</td>
<td>44</td>
</tr>
<tr>
<td>Project Entrants</td>
<td>20</td>
<td>38</td>
<td>58</td>
</tr>
<tr>
<td>Single Build Model</td>
<td>5</td>
<td>38</td>
<td>43</td>
</tr>
<tr>
<td>Collaborative Prototyping</td>
<td>10</td>
<td>38</td>
<td>48</td>
</tr>
</tbody>
</table>

Table A3-6 a) Collaborative working techniques used by companies that undertake Collaborative Prototyping

<table>
<thead>
<tr>
<th>Collaborative working techniques</th>
<th>Yes Frequency</th>
<th>No Frequency</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Integrated Project Teams</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Framework Agreements</td>
<td>7</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Project Team Insurance</td>
<td>1</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Project Entrants</td>
<td>8</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Single Build Model</td>
<td>2</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Collaborative Prototyping</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

Collaborative working techniques used by respondents (see p. 93 for results)

Figure 4.2 Evidence of research analysis for research aim one
4.4 Construction Project Extranets and Collaborative Extranet Working – Aim Two

The following section provides an examination of the work completed to achieve aim two and objectives five to six.

4.4.1 Literature Review – Objective Five

Whilst working on the first industrial problem, the author had also come into contact with projects employing Construction Project Extranets (CPEs) to facilitate project information exchange, integration and collaborative working. As a result, the RE had already started to gain an appreciation of the issues project team members were encountering when trying to conduct traditional paper-based work procedures, through a new electronic media and working process. It was evident, that while most of those using CPE systems understood the reasons why they were required to do so, the majority were not happy using them; although it was not immediately evident why this phenomenon existed. Based upon the need to further investigate the problem and acquire background knowledge on CPEs, a literature review was completed using the same methodology as described in 4.3.1. In addition, available literature on each of the various web-enabled collaboration tools was examined (by visiting each of the individual systems web sites). A number of key findings are also discussed in Paper 2: section 1 (p.131), along with a definition (p.132) of Collaborative Extranet Working (CEW).

4.4.2 Organisational Approach and Working with Multiple CPEs – Objectives Six and Seven

The first stage of completing investigations into the internal approach to working with CPEs (objective six) and determining the implications of working with multiple CPEs (objective seven) involved the author sending a practice-wide email to all project participants. The email outlined details of the study, and the opportunity for teams to utilise a free resource to examine and help identify possible improvements in their CEW approach; in return for the chance to observe the project and question key personnel. During the research period, four projects were determined suitable (Table 4.1, p. 58) based upon their compatibility with the research project duration.

4.4.2.1 Case Studies

On project one, the RE started by attending and observing a number of meetings conducted by the project management team, on examining the implications of implementing a CPE system on the project during stage D of the RIBA (2004) Plan of Works. The Prime Contractor (PC) had just bought into a single extranet solution to service all of their projects, and had decided to use it midway through the most information-intensive stage of the project. There were a number of repercussions to this action, including:

- There were over 2000 existing documents and drawings that had to be placed onto the system at speed, to enable new work to take place on the system;
- Additional resources had to be drafted to cope with the laborious task of updating the system with the above information;
• The logistics of achieving system integration had not been properly considered, which led to mass confusion amongst all parties about what information should be placed where.
• The strain of trying to manage implementation of the system under these conditions led to one person resigning from the post of extranet manager and one employee being dismissed due to poor performance. This produced an inconsistent approach and loss of continuity.
• A large amount of resistance was encountered to using the system and changes in working practice due to the lack of information and consultation with project workers.
• Crucial time dedicated to training people (undertaken after the system had already been installed) was lost during the training sessions, due to the organisers having to pacify anger and uncooperative project workers; especially the PC’s employees. More time was spent explain why the decision to use the system had been made than on learning how to use it. Comments observed ranged from ‘I guess it will benefits us later on’ through to ‘I’m not using it’ to ‘if I have to use it I will leave’.

Table 4.1 Details of the four projects used in case studies

<table>
<thead>
<tr>
<th>CEW Case Study Project - Main Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Number</td>
</tr>
<tr>
<td>Country</td>
</tr>
<tr>
<td>Product type</td>
</tr>
<tr>
<td>Project value</td>
</tr>
<tr>
<td>Contract type</td>
</tr>
<tr>
<td>No. of companies involved</td>
</tr>
<tr>
<td>Sponsor offices involved</td>
</tr>
<tr>
<td>Sponsor disciplines</td>
</tr>
<tr>
<td>System used</td>
</tr>
<tr>
<td>Implemented by</td>
</tr>
<tr>
<td>System use paid for by</td>
</tr>
<tr>
<td>System implemented at RIBA stage</td>
</tr>
<tr>
<td>Initial reason for contacting author</td>
</tr>
<tr>
<td>Extranet coordination</td>
</tr>
<tr>
<td>Protocol document</td>
</tr>
</tbody>
</table>
The RE also studied the company’s internal approach to working with the CPE on this project. Activities completed included:

- Determining if additional collaborative working practices were being utilised;
- Meeting with senior project managers and system users to discuss and capture problematic issues;
- Mapping the flow of information and communication between the various offices, disciplines and the CPE to identify ‘disconnects’ and/or barriers to efficient working practices (Fig. 4.3);
- Analysing and comparing the different requirements of the CPE protocol and internal Quality Assurance procedures;
- Attend project meetings on the use of the CPE system and report back findings to team members (as well as recording them for research purposes);
- Conducting research to find the main considerations for folder, file and CAD structures when developing a CPE best-fit framework of procedures;
- Undertaking training on the 4projects system to both be able to use the Extranet and to provide a source of internal training when required.

**Figure 4.3 Example of uncoordinated CEW processes and clashes in procedures**
Project two provided the author with the chance to observe and participate in pre-system specification stages of a project. The client had recognised the need to use a web-enabled project management system to facilitate project integration and help save capital spend. The design team were charged with the responsibility of recommending an appropriate system. As the sponsoring company had taken the lead role in this task, the RE was asked to research and outline the major requirements of choosing a system. To complete this assignment the author revisited information captured in the literature review and spoke with all of his existing contacts; both internal and external. A list of issues was drawn up and forwarded to the project manager, as well as being retained for continuing research. Furthermore, the RE attended the ASP presentations and participated in the interview questioning.

In project three, the author observed the system implementation phase and participated in the subsequent procedures development stage; either via accessing the Extranet system or conducting almost daily conversations with an employee, the RE was supporting/shadowing on the project. Relationships were also developed with the main Extranet Administrators (EAs) from the ASP and PC. Also by this point in the research project, the author had also started to formulate a list of potential generic factors that required consideration when undertaking CEW and protocol development. Although there was no structure to the list as of yet, they were passed to the internal project worker to facilitate negotiation of the company’s requirements and help build the protocol document; in return for feedback on their adeptness.

There was evidence of a significantly more structured approach to setting up and installing the CPE on this project. The PC and Extranet vendor had worked together on several past projects and therefore, had acquired knowledge on how to facilitate the implementation process more effectively. The first stage involved identifying a single representative within each company to assume the role of company EA. People were chosen for various reasons e.g. their past experience and/or willingness to fulfil the role or, being allocated the role by project managers. The EAs were trained as a collective group in a single location to enable team forming and bonding. Upon returning to their respective organisations, each EA was responsible for training their colleagues, whilst collaborating amongst themselves to develop a best-fit framework of procedures. This permitted each of the participating companies ‘needs’ to be considered in the CPEP (as deemed good practice by experts within the literature review). However, the RE observed that despite each company forwarding a full list of requirements for inclusion within the protocol, many were not adopted. Reasons for this were:

- Other companies did not see them as necessary or relevant due to different cultures, trade backgrounds, working standards and requirements.
- Items such as CAD standards and file formats were too varied to allow full inclusion.
- The EAs were not trained negotiators, with many coming from junior roles (document controllers, CAD technicians or graduates). As already demonstrated, negotiation and consensus are key factors in collaboration.
- Those overseeing the protocol development process, which generally includes the CPE vendor, were able to nullify many items due to the proviso that they conflicted with, or were beyond the capabilities of the CPE system.
In addition to the above, the protocol was unable to provide proper consideration of companies joining the project later on. The CPE system did allow flexibility in folder setup, reporting styles and new user access. It was also possible to update parts of the protocol document such as new mark-up colours and slight deviations in naming conventions. However, it was not feasible to overcome potential concerns created by newly joined organisations e.g. QA procedures, network capabilities and interoperability issues. As a result, latecomers had to either work with what already existed, or find their own way round difficult obstacles. This problem would have been negated by the adoption of a true collaborative working practice based on early involvement and common processes.

Project four offered a slightly differently proposition from the other three, as the RE was given the chance to utilise acquired knowledge and experience to setup and mediate use of a CPE between three interlinked projects, blocks C, D and E (Fig. 4.4, p. 62), as part of one major development. However, the system was only used internally amongst two offices and five disciplines (in Leeds and Warsaw) as no CPE system was available on the main project. The project manager overseeing all three projects wanted to apply a more integrated and efficient approach to information exchange and collaborative working between the different groups. The aim was to use the internal Buzzsaw ‘Standard’ CPE system to manage the exchange and coordination of information amongst the offices, before releasing it from a single point of control into the main project arena. Buzzsaw standard is an abbreviated version of the professional edition, which does not contain preset folder structures, workflow models, reports or forms such as Request For Information (RFI) and Change Orders (COs).

To begin, the author visited each office in turn to conduct a presentation on the research being undertaken, the potential benefits of using CPEs, main requirements of CEW and an overview of the proposed system. Learning from the observations on past projects, the RE also held a two hour question and answer session (after each presentation) to allow employees to discuss their feelings about the proposed use of a CPE. This provided the RE with the opportunity to alleviate any concerns, whilst also allowing a valuable firsthand insight into managing the fears and resistance to change created amongst workers when faced with new technology and processes. Once the employees had been assured, the author trained them on operating the system before training one individual in each office to administrator level. Over the course of a year, the RE worked alongside the project teams to setup, implement and manage the CPE to facilitate better internal integration and collaboration. Duties incorporated system support and training, workshop facilitation, information capture and reporting (via meeting minutes and presentations), along with periodic reviews to promote continuous process improvement. Through the workshops, trials were conducted, information flows were mapped (Fig. 4.6), a simple workflow model developed and a number of individual procedures written (Fig. 4.5) for various system operations.

All data captured from the case studies was maintained within an electronic database and fed into the final result analysis provided in both the second and third papers presented at the conferences (see App. 2 and App. 3 respectively).
1. Enter user name here
2. Enter company / office name i.e. Warsaw
3. Left Click on 'Default Markup'
4. Select your allocated colour
5. Click OK

**Figure 4.4** 3D model of related projects working on the CPE (above)

**Figure 4.5** Example of mark-up procedures developed by the author for the project (right)

**Figure 4.6** Information process mapping used by author to improve workflow (below)
4.4.2.2 Information Record Database

During the case study research period, the author developed a Microsoft Access Database (Figs. 4.7 & 4.8) to facilitate the process of recording, managing and analysing data; gathered from observations and the surveys. The database was expanded several times to reflect the increasing number of issues identified throughout the course of the work. Whether visiting and observing project teams, attending meetings, conducting workshops, or having general one-to-one conversations with individual colleagues, the RE used either a daily diary or a digital record to capture crucial information, which was then uploaded to the system later that day. The criteria used to build the database, along with the questionnaire surveys were based upon information gathered from:

- All three literature reviews into ICTeCW, CP and CPEs;
- Preliminary discussions with key project managers (recognised through a round-robin discussion thread, via email) who were seeking answers to their queries about emerging problems with CPEs;
- Issues captured whilst completing the previous investigation into CP and collaborative working;
- A series of meetings with seven internal project extranet users (from Buro Happold, Bath office), to identify what types of issues system users were concerned about;
- The RE’s experience of setting-up a CPE system to facilitate internal collaboration amongst offices in the EU;
- Continual re-evaluation of data captured from new sources and projects.

![Project Information Database Record](image)

Figure 4.7 Project information database record
4.4.2.3 Electronic Employees Survey Questionnaire

The questionnaire survey form was built with Microsoft FrontPage and uploaded on to the internal server for testing with regards to accessibility and usability. Before releasing the form, the RE sought council from the personnel department to ensure no infringement of the data protection act had occurred. Next, several key personnel were invited to participate in a pilot study (adapted from Naoum 1998), which included the subsequent questions:

- How long did the form take to complete?
- Were instructions clear enough to facilitate completion?
- Did you find any questions to be unclear or ambiguous?
- Did you object to answering any of the questions?
- In your opinion, has any major issues been omitted?
- How did you find the layout of the questionnaire?
- Do you have any additional comments that you would like to make about the questionnaire?

The feedback was generally positive with no major issues outlined, other than the length of the form. The author decided not to change the length, due to already omitting several desired questions (required for additional information). It was felt that the complexity of the problem (involving systems, people and process concurrently), necessitated detailed questioning. Furthermore, sending two or three shorter forms was perceived to be a less desirable option, due to repeated impingement upon employees’ time. To overcome the hurdle of a lengthy survey, the RE used an incentive by way of vouchers. To further increase the chances of obtaining a high percentage of returns, individual emails were sent to known colleagues, before a general email was sent to remaining project workers.
To counteract a lack of knowledge on CPE usage within the company, several questions were located within an employees’ survey to aid location of a project using extranet systems (see App. 6, CEW Questionnaire, pp. 170 - 181) along with the following:

- Section one was used to determine CPE usage in relation to office, discipline and job role.
- In section two, questions were used to measure employees' experience of different CPEs, and identify those working with multiple systems (interviewed at a later stage to discuss the implications). It also provided information on if, and where, protocols were applied and what effects if any, employees perceived them to have.
- Section three was used to develop an illustration of the various systems used within the company, along with how often various tools from the systems were used, and if employees felt they hindered or improved their job activities.
- As training is important to helping overcome resistance to change, section four was used to measure the amount of training provided for the company’s workers; and the reasons why training had not being received (where applicable).
- A major issue documented within the literature review was the fact that CPEs were not being used correctly. In section five, questions 5.1 – 5.7 were used to determine how efficiently employees were using the various systems, through quantifying the amount of time wasted due to incorrect use; measured by time checking information for relevance, and the number drawings printed off. The remainder of this section focused on capturing problems experienced with the actual software programs and the ability of CPE vendor support services to overcome them. It also allowed the volume of times the internal IT department had been involved in providing support in order to determine whether a specific CPE IT support role was required.
- Section six facilitated capture of CPE users attitudes to working with such collaboration tools, which was then compared with the amount of training employees had received and the issues they complained about. This was in recognition of the effort of 40% people, 40% process and 20% technology approach, and to determine if a correct culture/ethos was being cultivated.
- Finally, the last section was used to enable respondents to provide additional information not covered by the survey.

### 4.4.2.4 Project Survey

Whilst establishing the organisation’s current approach to working with CPEs, the author felt it was also important to demonstrate the increasing amount of project work being completed on Extranets. This enabled emphasis to be placed on the importance of the work and the need for improved internal practices. The RE completed these objectives by conducting a project survey to complement the findings of the questionnaire survey. A search of the company’s intranet project portfolio was conducted to capture data on jobs using extranets systems; job numbers were identified by respondents of the employee survey. Through analysing information such as start and finish dates to project and company fees, it was possible to ascertain the growth rate of CPEs on the projects (Paper, 2: section 4, p.133). Additional information on procurement routes and contract types (Paper 2: section 4.2, p.133) were used to obtain information on whether or not clients were using CPE to achieve document management and integration or collaboration. A true collaborative approach would utilise the use of a collaborative procurement route and contract; as identified in the...
earlier literature reviews. To collect the remainder of the information required to complete the project survey, the database form was used to question the project managers about various aspects on the company’s approach to CEW. Where it was not practical to meet face-to-face (for projects in New York, Dubai, Ireland etc.) the RE either conducted telephone interviews or transferred the fields of the database into a simple HTML based email questionnaire form (at the request of those being interviewed).

4.4.3 Results Analysis and Dissemination – Objective Eight

The results of the employees’ survey and the project survey were collated into separate Microsoft Excel sheets (using various forms to represent the findings; see Fig 4.9) and related data from both sets, placed into a third Excel sheet. A variety of tests were then completed using sums, averages, medium, mode, correlation, and standard deviations. Where applicable, the collective results of this work were also compared with the observations of the case study to support or validate the findings and main conclusions in paper two (App, 2) such as:

- The main instigators of CPE usage (section 4.1);
- The best time to implement a CPE (section 4.3);
- Initial findings about protocols (section 4.4);
- The need for an internal protocol (section 4.5);
- Internal issues with coordination and management of information and communications (section 4.6);
- Loss of knowledge transfer within the company (section 4.7);
- Employees attitudes towards CPEs (section 4.8) created by a lack of training (section 4.9) and subsequent reversion to type (section 4.10).

The findings of the above research allowed identification for the potential to improve one element of ICT-enabled collaborative working practices, where deficiencies existed in the current development of procedures. Also substantiated was the need to develop guidance notes and a best-fit framework for facilitating improved procedure development; as proficient procedures enables successful and efficient utilisation of CPEs. The author presented the findings from the work to his industrial supervisors, various project teams and the executive board and a decision was taken to pursue improvements in this area.

4.5 Improvement via Collaborative Extranet Working Procedures – Aim Three

The following section discusses the work undertaken to achieve aim three and objectives nine to twelve.

4.5.1 Current Protocol Application, Main Requirements and Industry Reaction to Proposed Improvements – Objectives Nine to Eleven

The majority of the background information necessary to begin addressing these objectives was captured whilst conducting the previous research. However, further supplementary work was required, which included:

- Further communications with project contacts (especially EAs);
- Continuing observations taken from existing projects;
- Participation in the development of additional protocols;
- Collating as many available protocols documents from known projects;
- Undertaking training on different CPE systems (to further understanding the idiosyncrasies of working to different processes and workflow models).

**Figure 4.9** Evidence of research analysis for research aim two
As the original research had shown procedures to support CEW were inadequate, the author collated available documents (11 in total) from known projects, which were then examined, through a comparative study, to determine which issues were most often included. Next, the RE developed a list of factors that should be addressed within Extranet procedures, captured from the literature review, case studies and survey results. As clients and project teams often stated, the CPE system had been implemented to promote collaboration and ASPs promote their systems as ‘collaboration tools’, it was necessary to include items which required consideration to promote collaborative working (captured in research under collaborative prototyping). By comparing the two lists it was possible to start developing an appreciation of the reasons why protocols were inefficiently developed. To further develop and substantiate these emerging theories, the author then revisited his detailed notes taken from observations, and held a number of discussions with various EAs. The principle notion was that procedures only focused on how to use the system and failed to address the main requirements of collaboration, due to the influence of the parties responsible for their development (further reasoning to this argument see App. 3, Paper 3: sections 4.2, 4.3 and 4.4, pp. 147-151).

Now that a comprehensive list of requirements had been captured from the protocol survey (Table 4.2) it was necessary to sort and associate them in accordance with the varying levels of CPE usage to ensure the right amount of effort and resources were applied accordingly. Due to additional feedback received from ongoing discussions with

<table>
<thead>
<tr>
<th>Procedures</th>
<th>How important (No. of people)</th>
<th>Very Important</th>
<th>Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use CPE tools and system</td>
<td>16 x 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conducting EDM</td>
<td>17 x 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D model coordination</td>
<td>10 x 8</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conducting collaboration</td>
<td>15 x 7</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managing online relationships</td>
<td>11 x 10</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaborative contract duties</td>
<td>9 x 11 x 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Align QA &amp; project procedures</td>
<td>6 x 15 x 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managing online workflow</td>
<td>10 x 13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>4 x 15 x 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change Management</td>
<td>9 x 9</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data and software compatibility</td>
<td>11 x 11 x 1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPEP compliance monitoring</td>
<td>6 x 15 x 2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPEP strategy</td>
<td>7 x 16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy for CPE use</td>
<td>14 x 8</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project roles &amp; responsibilities</td>
<td>14 x 9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPE roles &amp; responsibilities</td>
<td>18 x 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training provisions</td>
<td>13 x 9</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow charts for procedures</td>
<td>6 x 13 x 4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical requirements</td>
<td>10 x 11 x 2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical support</td>
<td>10 x 10 x 3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual property rights (IPR)</td>
<td>12 x 11</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

x used to facilitate easy identification of the largest response in each case
project teams after completing the third paper, the protocol requirement list has since been updated to reflect easier identification of where effort should also be applied in relation to people, processes and technology (Fig. 4.10, p. 70). To test the industry’s reaction to the author’s proposals for a procedures best-fit framework and validate the research work, the RE developed a simple MS Word questionnaire (App. 7, p. 183) and applied the pilot methodology as described in section 4.4.2.3.

The target sample for the survey focused on senior/key management positions where project workers were responsible for management of the CPE and subsequent procedures development; who were identified throughout the past two years work. Additional information on the objectives of the questionnaire can be found in App. 3, Paper 3: section 5 (p.152), along with the main results and conclusions in sections 5.1-6.

4.5.2 Results Analysis and Dissemination – Objective Twelve

The findings of the research were disseminated firstly through a third paper, presented at the 22nd Conference on Information Technology in Construction. Additionally, the conclusions were collated with those from previous research and presented to the industrial and academic supervisors. This led to a recommendation by one industrial supervisor for the author to present them to the sponsoring company’s key personnel and the Chief Executive Officer. As result of this presentation, where the findings were eagerly debated and acknowledged, the RE was asked to continue his work at the company after concluding the EngD programme.

4.5.3 Early Stages of CPE Procedures Best-Fit Framework

The sum of the conclusions from secondary aims two and three were also used to formulate the CPE Initial Implementation Form (App. 8, p.193). The main aim of the form is to promote greater awareness and consideration of the key factors that impinge on the successful application of CPEs; therefore facilitating improvements in one of the core ICT-enabled collaborative working activities. Initially, the form was released for review by project managers and EAs within the engineering consultancy. After two revisions and subsequent reviews, the form was released to external project managers, EAs, experts within the subject field; identified by their participation in Project Extranets IV (2003) and V (2005) and key members of the main Avanti programme. A short, simple but clear email questionnaire (Table 4.3, p. 71) was attached to the form for all reviewers to complete. It was kept to minimum number of questions and simplistic options, to facilitate a high and rapid response; due to constraints of time and the need to include the results within the completed thesis. Questions one to five were included to determine if the form was suitable for use on a project, and if it would facilitate improvements in the current process and collaborative working. Questions six to nine were included to capture respondent’s views on the content of the form, whilst question ten allowed the author to identify who would like a copy of the completed form for use on projects (the real test).
### ICT-enabled Collaborative Working

#### People (40%)
- Collaborative champion
- Negotiations
- Change management & resistance to change
- Company & geographical cultural differences
- Developing & maintaining a collaborative ethos, mutual trust and respect
- Project roles and responsibilities
- Team working

#### Process (40%)
- Aligning organisational, project & CPE procedures
- Continuous improvement
- CPEP monitoring & compliance
- Early involvement
- Mapping & integrating common processes
- Partnering and long-term relationships
- Supporting collaborative contractual arrangements

#### Technology (20%)
- Technology champion
- Natural or open file formats
- 3D model integration

### CEW – Protocol Considerations Levels 1 & 2, plus:

**Level Three**
- CEW – Protocol Considerations Levels 1 & 2, plus:
  - Collaborative champion
  - Negotiations
  - Change management & resistance to change
  - Company & geographical cultural differences
  - Developing & maintaining a collaborative ethos, mutual trust and respect
  - Project roles and responsibilities
  - Team working

**Level Two**
- EDM – Protocol Considerations Level 1, plus:
  - Leadership
  - Teambuilding
  - CPE roles & responsibilities
  - Communication lines

- File Transfer – Protocol Considerations:
  - User Training
  - Set clear objectives
  - Inform workers why the system is being used

- Support system
  - Help Files
  - Update internal QA procedures
  - Upload/download procedures
  - File formats
  - File sizes
  - File naming conventions

- Technical support
  - System requirements
  - Viewers
  - Access permissions
  - Login details

### Other project specific requirements

---

**Figure 4.10** Levels of CPE operation and their respective protocol considerations
Table 4.3 CPE Initial Implementation Form - questionnaire survey questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Options (delete as necessary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How practical is the form for use within the project environment?</td>
<td>Very Practical / Practical / Neutral / Unpractical / Very Unpractical</td>
</tr>
<tr>
<td>2. Would the use of the form help project teams to capture and understand their responsibilities?</td>
<td>YES / NO</td>
</tr>
<tr>
<td>3. Would the use of the form improve setting-up and implementation of project extranets?</td>
<td>YES / NO</td>
</tr>
<tr>
<td>4. Would use of the form help improve the management of project extranets?</td>
<td>YES / NO</td>
</tr>
<tr>
<td>5. Would use of the form contribute to improving collaborative working?</td>
<td>YES / NO</td>
</tr>
<tr>
<td>6. Have any major issues been missed? If yes, what are they?</td>
<td>YES / NO</td>
</tr>
<tr>
<td>7. What items, if any, should be removed?</td>
<td>........................................................................................................................................</td>
</tr>
<tr>
<td>8. How could the form be improved?</td>
<td>........................................................................................................................................</td>
</tr>
<tr>
<td>9. Do you have any further comments that you would like to make about the form?</td>
<td>........................................................................................................................................</td>
</tr>
<tr>
<td>10. Would you like a copy of the completed form for use on future projects?</td>
<td>YES / NO</td>
</tr>
</tbody>
</table>

4.6 Additional Work

By September 2003, and in relation to the REs research into collaborative working via prototyping and project extranets, the author was asked by the sponsoring company to take on the role of internal collaboration consultant, which carried with it additional duties. It is important to include and discuss these, as they reveal further personnel development, a growing recognition of the author’s abilities (by others) within the subject field and because of their contribution to assisting the RE with his research. The main duties were:

- **Implement a collaboration software tool** – Autodesk Buzzsaw Standard, to facilitate internal collaboration and conduct trials into collaborative extranet working. Over the past two years, the author has managed the account; set-up and supported five internal projects; trained 38 people (within the sponsoring company) to use the system; provided support to system users; developed an internal network of expert users and investigated the potential of system use in other languages and countries, as well as examining the problem of language translation of protocols.

- **Participate in the Avanti ICT-enabled Collaborative Working programme** – as the company’s main representative to provide feedback on the organisation’s contribution under a satellite project into ‘collaborative piling’. The main aim of the work was to develop ‘best practice’ guidance procedures for using a 3D model to
co-ordinate pile, frame and Operation and Maintenance (O&M) information throughout the project’s lifecycle. Other duties included: completing the proposal; participating in and observing workshops, and working closely with the experts to create process maps and complete the guidance documentation. Due to involvement on the project, the author was invited to become a member of the Avanti Project Support Network and become trained as an Avanti consultant.

- **Participate in the PIECC project** – both as a representative for the company and as a contributor under the programme; aimed at reviewing the state-of-the-art in collaborative working, with the main focus on practice and technology.

Finally, to ensure maximum distribution of the knowledge and experience throughout the practice, the author built and maintained a web site on ICT-enabled collaborative working (Fig. 4.11).

![Figure 4.11 Screen shot of author’s website on ICT-enabled collaborative working](image)

### 4.7 Summary

This chapter has provided a comprehensive examination of the research undertaken to achieve the overall research aim and subsequent objectives, as outlined in the map of the research development process. It has explained how the various research activities have been used to collate knowledge, experience and theories on the subjects of
Collaborative Prototyping and Collaborative Extranet Working to enable identification of a proposed incremental improvement in ICT-enabled collaborative working. Furthermore, it presented a précis of additional work completed by the author, which was invaluable in ascertaining a deeper understanding and appreciation of the subject.
5. FINDINGS AND IMPLICATIONS

5.1 Introduction

This final chapter presents the main findings and conclusions of the EngD research project in relation to the three principle aims and by way of an overall conclusion to the work. It discusses the implications and impact of the work, as well as providing a critical evaluation of research. The chapter concludes by outlining a number of recommendations for consideration by the industry, along with requirements for future work.

5.2 The Current Application of Collaborative Prototyping – Aim One

The first aim the research project was to provide a state-of-the-art review of Collaborative Prototyping to establishing current developments and practices in collaborative working and 3D prototyping, along with determining the application of CP within the AEC industry. The following findings were drawn from the research work described in chapter four, section 4.3.2.

5.2.1 Collaborative Working - Current Practices

Despite recommendations for the industry to adopt more collaborative forms of working (especially ICT enabled) and subsequent effort to make them standard practice, those interview indicated that this had not yet been achieved. Confusion over what constituted ‘collaborative working’, a large number of methods reported as suitable for achieving the desired state and deficient information (on the benefits of using various methods and how to implement them) were cited as the main reason for this failing. One collaboration practitioner (interviewed as part of the research) stated ‘at present, there are too many alternative methods, practices and tools and this just confuses the issue’. It was apparent that even the industry champions suffered from this predicament, as they all gave very different answers when trying to classify modes of collaborative working. The above suggests that the industry’s message on the principles of collaborative working (and ICT-enabled collaborative working) is therefore erroneous and/or failing to reach the wider audience.

Through completing the literature review and questionnaire survey it was possible to establish the prominent collaborative working methodologies, ascertain the extent to which companies (within the research sample) used each of the techniques (Fig. 5.1) and how effective they were in facilitating collaboration (Fig. 5.2). It is important to note that surveyed companies were chosen based on their involvement with both ‘be’ and the IAI, and therefore they potentially had the greatest exposure and experience in all forms of collaborative working. This resulted in distorted figures that were considered higher than they would normally have been for a survey to determine their use across the industry as a whole.

The results demonstrated a large gap between the use of non 3D and 3D-based collaborative working techniques within responding organisations. Partnering was found to be the most successful form of collaboration with 53% of users indicating it
use was ‘very effective’; whilst the majority of other forms were deemed ‘effective’. The least effective and used approach was the Single Build Model. The limited response to ‘project team insurance’ was attributed to the finding that it is a relatively new phenomenon.

![Figure 5.1 Modes of collaboration techniques and their use by responding organisations](image1)

![Figure 5.2 Modes of collaboration techniques and their effectiveness (rated only by those who had used the technique)](image2)

5.2.2 Collaborative Working – Advantages and Disadvantages

Those interviewed agreed that there were many benefits to collaborative working, but presented different arguments as to what they were, including the potential to acquire up to 50% improvements in both project duration and costs. The following is a list of those benefits captured by the interviews:

- Elimination of problems in the design stages before projects go to site;
- Helping to install confidence that problems will not happen on projects;
- The creation of better team-working environments;
Findings and Implications

- A reduction of conflict on projects;
- Greater co-ordination, which in turn will help to increase project efficiency;
- Obtaining higher levels of quality in all areas of projects;
- Greater value buildings for clients;
- Greater efficiency throughout the whole project process.

The practitioners also stated that project teams should experience no disadvantages to the deployment of collaborative practices. Conversely, it was also established that organisations and projects were not implementing collaborative practices effectively and were therefore failing to realise the full potential offered by such methods of working. This was attributed to a lack of clarity and understanding of the various methods, plus barriers created by people’s attitudes, complacency, a lack of effort and some disciplines’ inability or reluctance to collaborate effectively. A large amount of emphasis was also placed on the difficulties associated with trying to get all stakeholders to work harmoniously, when some project members work harder to succeed at collaboration than others. A previously unidentified factor that also contributes to this issue is problems caused by companies who rush to adopt collaborative initiatives, in order to be seen as doing the right thing; rather than taking time to understand the requirements for correct implementation and utilisation. This was accredited to a fear of prospective lost revenue through not being at the cutting-edge.

5.2.3 Collaborative Working – Considerations

‘Six critical success factors’ were found to exist that required careful consideration for successful collaboration in construction:

1. Early involvement – considered the foremost important factor as participation of all parties at the design stages enables the issue of buildability to be overcome;
2. Selection by value – where companies are chosen on their ability to contribute to the overall project aims, rather than those offering the ‘lowest price’. Such companies invariably focus on their own needs and try to claw back profit through litigation;
3. Common processes and tools – where the utilisation of ICTs, such as Prototyping and Project Extranets, provide the greatest potential to aid collaborative working efforts; by enabling a single integrated approach to project and data management;
4. Performance measurements – through ‘Benchmarking’ and Key Performance Indicators (KPIs) to convey what is required and determine if it is being achieved;
5. Long-term relationships – to accrue experience through continuity, and to allow the application of continuous improvement to enable advanced performance;
6. Supporting collaborative arrangements – through non adversarial contracts i.e. NEC, PPC2000/3, and the be Collaborative Contract (beCC), which make possible the other five (additional information on these factors and the contract types is located in App. 1, Paper 1: section 5.1, p. 116).

The only mutual aspect between these factors and those previously recognised conditions for effective collaboration (Table 2.1, p. 31) was the need for ‘common processes’. The new factors appear to be more ‘in tune’ with collaborative working within construction, corroborating Kalay’s (2001) argument that collaboration in this industry is different to other sectors. However, they fail to provide consideration of all the essential requirements as substantiated by the variants in the original findings,
particularly those from the social science aspect of collaboration. It is therefore proposed that in order to enable the greatest chance of success, project teams would be best advised to consider all of the elements presented.

Additional advice afforded by the industry champions to clients and project teams was the need to understand that the use of collaborative practices on traditional procurement routes not specifically design to foster a collaborative environment, drastically reduces the chances of success. Kalay (1999) described these circumstances as less than optimal for collaboration. This situation was ascribed to clients and organisations reluctance to use new procurement routes due to a lack of proven ‘business benefits’ to their adoption.

5.2.4 Collaborative Working – Need to Quantifying the Benefits

The requirement exists for an ‘easy to follow business case and predictive tool’ to be developed that outlines the benefits of employing various collaborative approaches; so that clients and project teams can choose the most applicable form for success that meets their needs. This would also make those in the industry ‘sit up and take notice’. Work under the Avanti and PIECC initiatives can be seen as contributing to this requirement. However, one expert stated it would be extremely hard to demonstrate the benefits of collaborative working due to its nature and so many processes; it would be difficult to measure them all.

5.2.5 Collaborative Working - New Developments

Release of the ‘be Collaborative Contract’ (beCC) is seen as a significant move towards improving the success of collaborative working. It offers a non adversarial approach that provides incentives for correct working approaches and the penalising of undesired working practices. Project Team Insurance is expected to improve collaboration through sharing the responsibility of risk, although it is also expected to help reduce the costs of insuring project risk and therefore provide greater value for the client. ‘Element based file systems’ that allow multiple users to work on a piece of work simultaneously and the utilisation of the Internet and web-based collaboration tools were also identified by experts (although not discussed in detail). Additional information on the beCC and whether new developments will meet the industry’s requirements is included in App. 1, Paper 1: sections 5.6 and 5.7 (pp. 118).

5.2.6 3D Working Practices

The literature review revealed CAD technology is now the main modus operandi for producing construction information within the industry and that use of shared 3D models are recognised by many within the industry as having the potential to bring about significant improvements in the construction process. However, the consensus of opinion amongst the industry campaigners was that the industry makes very little use of 3D prototyping (somewhere between 0 – 5% of companies in the industry) and that many of the models demonstrated throughout the industry had been created in 2D and then transferred into 3D via special software applications after the design has been completed (which does not enable collaboration or constitute CP).
Responding organisations were found to have had the following experience in 3D working:

- 24% no experience;
- 24% had very little experience (1-2 projects);
- 39% had moderate experience (several projects);
- 13% frequent experience (majority of projects).

An examination of respondents’ reasons for using 3D on their last project (as shown in Paper 1: section 6.2, Fig.2, p. 123) found 70% of companies main motive was to enable visualisation of the product for client demonstration. However, the results also found organisations undertaking CP tended to have a more diverse use of 3D modelling, and were more likely to undertake model analysis for isolated parts of design (100%), clash detection (90%) and co-ordination of isolated section of the design (70%). Companies not adopting a CP approach only used 3D for the purposes of visualisation for client demonstration (63%) and marketing (58%). The industry champions gave ten reasons why they believe 3D working was not utilised more frequently within the industry, which organisations were then requested to rank in order to indicate why they did not undertake more 3D work. The results were as follows:

- Overcoming the 2D v 3D working culture;
- A perceived lack of demand for 3D working;
- The difficulties associated with persuading partners on a project to work in 3D.
- A lack of faith in the abilities of 3D software to produce what vendors’ state the software is capable of providing;
- Interoperability issues (non-compatible 3D software packages, which do not facilitate collaborative working);
- A shortage of skilled 3D resources;
- The belief that a 3D model takes longer and costs more than it does to work in 2D;
- A lack of evidence and examples to demonstrate the effectiveness of 3D working;
- The cost of purchasing specialist software;
- The cost and time associated with training.

The above shows that the respondents did not agree with the findings of the literature review, which highlighted the two main inhibitors of 3D working as interoperability and software ability; although these were placed 4th and 5th. Companies felt the biggest obstacle was overcoming a move from the 2D comfort zone to adopting a new approach, closely followed by a lack of demand and the problems of encouraging others to work in a new way. Both experts and respondents felt that these barriers could be overcome through:

- Clearly demonstrating that 3D prototyping can be done.
- A company successfully applying it to a project.
- Providing better educational literature to train managers on the benefits.
- Clients leading the way and requesting the use of 3D prototyping.
- Development of best practice guidance that outlines tools, techniques and procedures.
- Finding a solution to the problems associated with interoperability, which will allow for better integration and greater use of modelling/prototyping. Additional
conclusions on the issue of interoperability are given in Paper 1: sections 5.10 (p. 146).

5.2.7 The Application of Collaborative Prototyping

A total of 61% of all respondents were aware of the concept of Collaborative Prototyping, whilst only 31% understood the benefits of using such an approach to facilitating collaboration and process improvements. Even less companies (26%), had tried to utilise it on their projects. The author anticipates that had the research sample been widened to encompass the whole industry, this last figure would have been dramatically smaller. When questioned about the effectiveness of CP as a collaborative working technique, 86% of those who used CP indicated that it had increased efficiency, whilst 14% felt unable to quantify how effective its use had been (assumption based on no response given); none signified that its use had been ineffective.

It was also found that 80% of companies using CP, had done so on a limited number of projects (under five) and 70% indicated they had only been able to achieve limited success; to complete parts of the model to help assist integration and coordination. Two companies reported having successfully completed most parts of the model and therefore had been in a position to use it to facilitate coordination, integration, and collaboration. One company stated they had been very successful and were able to control the entire process through development of a completed model.

All agreed that the application of CP as a collaboration technique had thus far enjoyed limited success due to a lack of established processes and companies not applying it frequently enough; therefore failing to gain enough experience. Furthermore, they also felt past attempts to use the method had been incorrectly approached, with one practitioner stating that its use has not been successful because ICT is not the main driver, nor should it be. The fundamentals of project collaboration must be in place first and only when they are in place, should ICT be considered. ICT is not a solution, it is an enabler. The findings of this section highlight that there is a lack of awareness on the subject of Collaborative Prototyping, which the industry needs to address if more companies are to understand, learn about and implement collaborative working based around 3D modelling. After all, companies cannot choose to research and implement those practices which they are unaware of.

5.3 The Application of Construction Project Extranets – Aim Two

The following section provides the key findings of the second aim, which was to investigate the use of CPEs to facilitate collaboration through examining the consultancy’s approach to working with multiple CPEs, along with the subsequent impact upon the company. Although the work was conducted within a single engineering consultancy, the findings are considered a true reflection of the industry’s approach to Collaborative Extranet Working, as the organisation is involved in a high percentage of the industry’s major projects, of which the research was based upon. The research also contributes to addressing the issue of missing empirical research within the subject area, the need for which was identified by Nitithamyong & Skibniewski
The literature review highlighted that more clients are endorsing the use of CPEs to improve project efficiency, due to their potential to enhance communications, integration and collaboration. However, the research found that only 28% of clients (out of 48 projects surveyed) had taken the decision to utilise a CPE. The Main Contractor was the leading instigator (52%) followed by the client (28%), project teams (12%) and the architect (8%). It was also established that an Extranet is most likely to be implemented at either stage ‘C’ or ‘D’ of the RIBA plan of Works (39% and 48% respectively). Just once, had a client implemented a CPE earlier than this, at stage ‘A’. Analysis of which procurement routes were used in conjunction with a CPE found a wide distribution between Design & Build (33%), Framework Agreements (23%), Traditional (21%) and Private Finance Initiative (17%). However, Partnering promoted as the most collaborative form of procurement, only represented 3% of the projects. No projects were found to employ the use of the new Be Collaborative Contract. The following is a list of the main conclusions drawn from this section of work:

1. The majority of clients are either unaware of the potential benefits to be gained through employing a CPE and/or do not consider them crucial to the successful delivery of a project. It is only upon appointment of other project members (usually with previous experience of working with CPEs) that clients become aware of the need to adopt a CPE.

2. The lack of empirical and factual data on the potential benefits and ‘pit falls’ to the deployment of a CPE and collaborative working techniques, can be determined as inhibiting further uptake by clients.

3. Main Contractors dominate the decision making process due to many of them ‘signing up’ to a single ASP in order to:
   - reduce the costs associated with buying access to a particular system;
   - provide continuity across all their projects;
   - enable ease of adoption and use for employees; and,
   - engender greater business benefits for the organisation.

4. Where project teams were asked by the client to choose and pay for a system, it was felt to be detrimental to the modern collaborative ethos, which prescribes equal share of profit or loss amongst all project stakeholders. The design teams felt the client was obtaining all the benefits at their expense.

5. As a result of the above, team members were seeking options to recoup monies including additional charges for working on projects with a CPE, or for provision of an Extranet Administrator (stating it was an additional resource and service that required payment for). Such actions would invalidate any potential savings gained from using the system and do not reflect a collaborative spirit.

6. There is also a tendency for project members to redirect charges back to the client through additional work costs, which reflects a more traditional and adversarial environment. This also defeats the purpose of collaborative working (as explained in the literature review).

7. Omission from the system selection/recommendation phase is considered a major disadvantage, as absent companies are unable to validate reasons why a particular system was chosen, influence the development of protocols and ensure full consideration of individual project needs (necessary for a stable collaborative state).
The literature review also outlined the fact that clients were implementing a CPE at the wrong stage, although no explanation was given as to the repercussions of this act. The research found that implementing a CPE after work had commenced was detrimental to the successful application of the system and collaboration, due to:

- Failure to consider early involvement of the necessary resources and tools to ensure successful conclusion of the project. The literature review showed that the earlier collaborative working is started, the larger the potential savings and benefits will be.
- Communications and information were not being conducted, coordinated and managed in the most efficient manner (determined through observations and survey findings).
- Documentation completed prior to system implementation was less likely to be available when required. Uploading it whilst new work was being undertaken on the system also caused confusion and required increased resources.
- Little or no time was afforded to test and learn how to work with the system, including time to develop more effective methods of working.
- The impact on time and resources lost to training at highly intensive work stages.
- A lack of time to develop appropriate procedures to ensure efficient use of the system.

This concurs with the argument promoted by several practitioners within the industry that clients’ and construction teams would experience greater success if they were to apply the CPE at the earliest opportunity, preferably before the project starts.

The above findings also reveal that clients and/or project teams are not heeding the warnings of Egan (1998) to ensure that the culture and processes are right before deploying ICTs to support them. Where the CPE had also been intended to promote collaboration, the project team appeared to rely solely on the system to ascertain efficient collaborative working. There was no evidence of a concentrated effort to further develop the collaborative culture and processes (as well as procedures) before enabling them with a collaboration tool. Observations found project teams more concerned with using the tool to enable project management and information exchange; rather than collaboration. This partially explains why such little attention is paid to developing adequate protocols to permit effective collaborative working supported by the use of the collaboration tool (discussed in section 5.3.1).

The preceding factors led project managers (within the engineering consultancy) to doubt their client’s claims that a CPE had been introduced for collaboration purposes. They believed that the real objective was to utilise the tool as a means of establishing more stringent surveillance and control over how companies worked. Frequently used terms to describe this situation included ‘a stick to beat the consultants with’, ‘a method of secret policing’ and ‘big brother’. Interviewees substantiated their comments by providing anecdotes of a past experience where problems had occurred with the client and/or project team due to use of the CPE. Nearly all recounted similar scenarios that related to disputes and the client’s inconsistent use of the internal audit system to resolve them. The majority of the company’s employees also displayed an unenthusiastic attitude toward collaborating via CPEs (when discussing the subject with the RE).
The employees’ survey showed that only 12% of workers felt the CPE had improved project team relationships (Fig. 5.3), whilst 63% indicated that it had made no difference to their levels of productivity (Fig. 5.4). Conversely, 58% of employees stated that they would be ‘happy’ or ‘very happy’ to work on a CPE again (Fig. 5.5), which demonstrated a certain amount of conflict.

Further examination and analysis of why this phenomenon occurred, recognised that it could be partly explained by the way project managers (some of whom displayed clear signs of technology phobia) openly expressed their pessimistic views of working with CPEs in front of their teams. As a result, less senior staff emulated this attitude to promote acceptance, solidarity and team harmony. However, the major causes of
disillusionment were ascribed to a lack of training and inadequate procedures (a protocol). This was validated by:

- The antipathy displayed by employees (throughout interviews, project meetings and surveys) at having to work without either.
- Employees’ responses to questions on their feelings about working with CPEs; Fig’s. 5.3, 5.4, & 5.5 show more negative answers were usually chosen by those without training in the majority of instances.
- Observation made on the four case study projects.

5.3.1 Protocols – Initial Findings

Overall, the research findings concurred with those of the literature review that a good protocol is crucial to the successful application of a CPE. However, the RE found that procedures must also provide guidance on how to achieve and support collaborative working via the CPE. It is also argued that admission of such a protocol, or use of a poorly developed one, is potentially the largest barrier to the efficient application of the collaboration tool and therefore the success of the project.

Despite industry warnings about the need to develop a good protocol, nine projects (with a total industry project value of £342m) were found to have deployed a CPE without procedures to aid the use and management of the system. Observations of employees working on projects with no protocol found a tendency for them to be significantly more disillusioned, frustrated and hostile towards working with the CPE system, even if they had received training. Further evidence on the impact of working without a protocol is demonstrated by way of project workers comments on their experiences in Paper 2: Table 3 (p. 135). Although the remaining 80% of projects had implemented some form of a protocol, they were all found to be ad-hoc, project-specific and inadequate. Project workers continually expressed their concerns about procedures not being adequate and the need for them to provide consideration of other critical issues such as information exchange, collaborative contractual relationships, workflow and collaborative working. This demonstrates that protocols/procedures (when developed) are failing to consider all of the necessary issues. The following were established as initial reasons for protocols not being sufficiently developed:

- A large number of the parties, who worked on the CPE, were not represented at the protocol development stage and therefore their project needs were not accounted for.
- Development was left to a small group of people who did not necessarily have the appropriate knowledge and experience to balance processes, people, technology and collaborative working methodologies.
- The absence of an industry best-fit framework (protocol) setting out procedures to guide project teams through the process.

The lack of an appropriate protocol creates numerous problems for the project team such as the mismanagement of project information. Examples of this included:

- Poorly set ‘permissions’ that enabled users to continuously change and upload information with little or no control.
58% of users placed information onto a system incorrectly, sending it to all parties ‘just in case’ they needed to see it, or because they were not sure who should view and comment on it.

Users were overloaded with vast quantities of irrelevant information. On average, 1.9 hours per week, per member was lost to checking information for relevance.

Team members turned off ‘notifications’ due to being deluged by emails throughout the day requiring ‘action’ for newly posted items, many of which had no relevance to their tasks.

As a result of the above, project workers (in different projects) were working on outdated information, missing critical changes, continually aborting work and undertaking rework; all problems that are supposedly negated by the application of the CPE. Project managers were also concerned about not being able to regulate the flow of information, missing critical information and reluctant to trust others to release information (in case it was incorrect, not relevant, or had legal implications). The importance of clarifying legal requirements for ICT-enabled collaborative working was identified in the literature review, and is therefore equally crucial for consideration within the future development of a best-fit framework for CPE procedure development.

Additional findings of the industry’s opinion on current protocol development along with a proposed outline of criteria necessary to build a best-fit framework of procedures are located in section 5.4.

5.3.2 Training

The project survey found that 23% of project teams had made no provisions for training the consultancy’s workers. However, more disturbing was the finding that even when provisions were made, 46% of employees had still not received any form of training on the system they were working on (Fig 5.6). Out of the remaining 54% of respondents, only 16% had received more than three hours of training and 77% of this training had been completed within the project environment (Fig. 5.7), surrounded by the pressures and interruptions of project working. Only 3% of respondents indicated that they did

![Figure 5.6 Amount of training received by employees on the CPE](image)

![Figure 5.7 Type of training received on the CPE system](image)
not need training on the system they were currently working on. The main reason given by workers for not receiving training was due to them ‘joining the project too late’ (see Fig 5.8), closely followed by ‘no time’. This shows that workers joining the project after the initial set up phase are less likely to receive training, whilst others are under pressure to just get on and ‘get the job done’ (a typical approach within the industry).

Finally, observations found that the combination of limited training and poor procedures not only created a negative attitude amongst workers but it led them to ignore/bypass the CPE system altogether; as they were confused about how to work on the system. On numerous occasions, the RE found workers ‘reverting to type’ and using their email to send information. Further proof of this was collated from the internal survey, which found:

- 89% of employees did not use the electronic redline and mark-up tools. Instead, 2065 drawings were printed off of CPEs (from various projects), marked-up by hand, scanned into PDF format and then uploaded back onto the system. True collaboration comes only through use of commenting, mark-up and communication features (CPN 2004b).
- 2691 drawings were printed off by employees to view. 93% of these were at A3 size and therefore not much larger than a standard 21 TFT monitor.
- 1934 drawings were printed off by employees to retain as a personal copy.
- 1277 drawings were printed off for paper archiving purposes (also partly due to out-dated Quality Assurance procedures and a lack of clarity of legal requirements).

5.3.3 Communication and Collaboration

Good communication is critical to both effective collaboration and the successful use of web-based technology; giving the right message to the right people at the right time, with speed, transparency and efficiency (CPN 2001). CPEs are also reported to facilitate improved communication (Hamilton, 2002b; Alshawi & Ingerige 2003; Nitithamyong & Skibniewski 2004) over more traditional forms such as email and telephone and therefore improve collaborative working. However, project workers offered the following explanations as to why they felt this was not the case:

- Problems are not always resolved as quickly on the extranet as they are by telephone calls, as not everyone is online all the time, which then causes delays.
- A telephone call allows a person to seek an answer and facilitates an understanding of how a person is reacting to the situation through human interaction and perception.
- Replacing traditional forms of communication (such as the telephone) with web-enabled forms (such as online discussion threads) was deemed counterproductive as it was less personal, and users could potentially be more belligerent.
• Limiting human interaction through electronic communication causes relationships and team working to breakdown.
• Collaboration requires constant human interaction as well as electronic communication – it’s not just about information exchange.
• The use of external email systems was faster and less complicated to work on than the extranet system.

5.3.4 Working with Multiple CPEs

The majority of issues causing concerning for the sponsoring organisation, with respects to working with CPEs, were predominantly related to those issues already discussed for single system working. However, four important factors were realised by the work that were also considered applicable for any company working with multiple systems:

1. There is a need to develop an internal generic approach to extranet working, in order to help employees understand how to comply with their own company procedures (set out in the Quality Management System) as well as those imposed upon them by the project and CPE system.

2. Internal procedures required updating with clearly defined processes for Collaborative Extranet Working that is generic enough to be applicable to any project and CPE. These are vital both as a means to improving the organisation’s approach to CEW, and in helping the company to express their own extranets requirements on projects in future.

3. Project teams required better information and guidance on the issues that must be considered when first starting to work on a client’s CPE system.

4. Better knowledge management of ‘lessons learnt’ from working with various CPE systems was required to enable capture of the idiosyncrasies of each application, along with users experiences, protocols, do’s and don’ts, and even which clients use which systems on all their projects. This would then support creation of individual system expert communities to service projects more efficiently in the future.

5.4 Proposed Improvement to Facilitate Efficient ICT-enabled Collaborative Working via CPEs– Aim Three

The third aim of the research project was to further review the application of protocols to support Collaborative Extranet Working. Establish the main requirements for a proficient procedures framework (that considered collaborative working as well as the how to use the tool). Then, determine industry reaction to the proposed framework for improvement. The following are the main conclusions drawn from the research work as described in chapter four, section 4.5.

5.4.1 Current Application of CPE Protocols

Current CPE protocols are usually derived from generic documents produced and supplied by the Application Service Provider (ASP) - the company supplying the CPE solution. This was due to:

• A lack of a generic industry approach and guidance;
• Project teams inexperience of and lack of understanding as to the requirements for procedures;
• The ASP providing a template and support for its development (as part of their services);
• The way in which the relationship developed between the adopters of the CPE and the ASP.

The RE found only one exception to this rule, that was where project teams decided to build their own ad-hoc, in-house extranet solution. Therefore, as no ASP was present in the process, no protocol template was available. Comparison studies of these two approaches found protocols created by ASPs were considerably more substantial than those developed by project teams for ad-hoc extranet systems. Those responsible for selecting and purchasing the CPE usually worked with the ASP (as shown by options 1, 2 & 3 Fig. 5.9) to further develop the generic template into an appropriate form for the current project. This is completed through a series of meetings, workshops or ‘postings’ (placing the document on the extranet for review). Once the main parties issues and project requirements have been addressed, those responsible for developing the CPEP may follow one of two courses of action. Either invite all other parties (currently contracted to the project) to read and comment on the proposed protocol; notifying the document administrator of any issues or specific needs e.g. exclusive folder for photos. Or, conversely, publish the guide without further consultation and request all other working parties to work to the procedures. This is contrary to the collaborative ethos, as protocols must be agreed from the beginning by all - it is a partnering process (ITCBP 2003). The ASP maintains an active role throughout the development process and will ensure that procedures being included within the protocol document are consistent with their systems abilities and procedures (e.g. inherent electronic workflow protocols). Perhaps the most difficult task facing any protocol development team is deriving a solution that satisfies each member’s project requirements, whilst still being acceptable to all others. This was never achieved on a single one of the projects surveyed, as a large number of the parties who were to work on the CPE, were not represented at the development stage, and therefore their needs were not accounted for.

5.4.2 The Main Requirements for CPE Procedures – A Best-Fit Framework

A good framework must provide equal consideration of individual company QA procedures, project procedures and the inherent protocols of the specified extranet system (as shown in Fig. 5.9). This was not found to happen and company procedures were generally sacrificed at the expense of the others. Therefore, organisations struggled to understand the benefits of working on a CPE, due to them having to duplicate work in order to satisfy both in-house procedures and those of the project. This sometimes created resentment, both towards the CPE and those championing its use. It also led to various organisations:
• Refusing to adopt the procedures and reverting to old methods of working e.g. company email and issuing paper copies (option A, Fig 5.10);
• Wrongly interpreting the procedures and developing and/or adopting inefficient modes of working; or
• Bypassing the CPEs audit system by using a single person to interface with the CPE (option C, Fig. 5.10).
• The author contests that if any of these three problems transpire, the protocol has failed its primary objective, to enable consistent and efficient collaborative working (option B, Fig. 5.10).
**Figure 5.9** The various protocol types and development teams

- **Option 1** (Client & ASP)
- **Option 2** (MC & ASP)
- **Option 3** (Design Team & ASP)

**KEY:**
- ASP = Application Service provider
- CPE = Construction Project Extranet
- DC = Document Controller
- ASAP = ASP Administrator
- CEA = Company Extranet Administrator
- E = Employee
- FM = Facilities Management
- QS = Quantity Surveyors
- PM = Project Manager

**Figure 5.10** The realities of working with or without current protocols and the desired approach

- **(A) Without Protocol**
  Uncontrolled and uncoordinated, sporadic use of CPE

- **(B) Desired Approach**
  Fully integrated and ICT-enabled collaborative working through appropriate protocol

- **(C) Current approach with protocol**
  Some control and constrained use of the CPE with limited collaborative working
A review of current protocols revealed a significant divergence between their contents and recommendations made by experts (CPN 2001, 2004a, 2004b, 2004c) along with those issues raised by project workers (captured by the author during the course of the research). A comprehensive list of factors that must be included and addressed within a best-fit framework of procedures is shown in Fig 4.10 (p. 70). Examination of the working protocols and experience gained from the development process found all procedures to include the majority of the items listed in levels 1 and/or 2, but none of those contained in level 3 (Fig. 4.10). Therefore, it is appropriate to argue that protocols are not proficiently developed to foster true collaborative working via the ICT tool.

As Project teams were found to utilise a CPE in one of three ways (see App, 3. Fig. 1, p. 147) it is important that a protocol is developed to match the chosen level of CPE application. This is because use of a CPE to conduct file transfers needs relatively simple procedures, whilst a protocol to aid EDM should be increasingly more detailed. A protocol to facilitate CEW would require considerably more detail, as collaboration is a highly complex process (as demonstrated within the literature review).

5.4.3 Industry Reaction to the Findings and Proposal

The following findings were gathered from the response to the electronic survey on CPE protocols (as discussed in 4.5.1 and contained in App. 3, Paper 3: section 5). They are based upon the opinion of 23 CPE workers (7 managers, 7 administrators and 5 document controllers) who between them have experience of working on 211 projects where a CPE was used. The main conclusions of this work were:

- Industry practitioners validated the author’s conclusions that protocols mainly focused on the use of the system’s tools, whilst other crucial issues were not included.
- Fifteen respondents (65%) indicated that current protocols were either unsuccessful at enabling more efficient working and saving time and money. The other eight (35%) specified their use had been ‘partly successful’ (see Table 1, p.152).
- All of the issues identified by the research and proposed for inclusion within a best-fit framework were deemed relevant by the practitioners; although some were considered more important than others (see Table 2, p. 153).
- Two previously undisclosed factors were also captured for inclusion. These were consideration of what to do when:
  - The CPE is unavailable and information requires publishing.
  - Project workers or organisations failed to follow the protocols, and what the penalties should be.
- 22 out of the 23 practitioners agreed that a good protocol is important to the successful application of a CPE.
- Respondents (who had been involved in the process of developing a protocol) indicated that they had found the process either ‘difficult’ or ‘very difficult’, due to:
  - Trying to get people to agree and work together (collaborate).
  - The lack of guidance and available expertise (best practice experience).
• Four given barriers to the successful creation of an extranet protocol, were ranked in the following order:
  1. A lack of best practice guidance, generic templates and guidance notes.
  2. Relying on the extranet system vendor to facilitate the process.
  3. Adapting an ad-hoc template from another project.
  4. A lack of necessary expertise to call upon.

• When asked to rank four known issues that hamper efforts to create a successful CPE protocol, respondents placed them in the following order:
  1. A lack of expertise and experience within those responsible for development.
  2. Not having all project team members involved in the process.
  3. Having to rush the process as the CPE was already being used.
  4. A lack of commitment to the process from project team members.

  Responses to this section suggest that there is a lack of participation in the process from professionals who are well versed at the ‘art of collaboration’. Furthermore, projects teams wanted to seek additional assistance or expertise, but were not sure what is available or where to obtain it.

• Respondents ranked four given services in the order they would most likely use them:
  o A generic extranet protocol (template document that can be adapted to individual projects).
  o A best practice guidance document (explaining how to develop an extranet protocol).
  o Specialist designated software (step-by-step guide with input boxes to complete).
  o Professional extranet coordination services (employing consultants to facilitate the process).

• The most popular format for the best-fit framework would be a web-based format with generic templates/documents that could be completed online (70%).

Finally, based upon reactions of the respondents to five key statements (formulated from the research), it can be demonstrated that findings of the research for aims two and three are valid within an industrial context. The majority of practitioners either ‘agreed’ or ‘strongly agreed’ with following five statements:

1. A poor CPE protocol leads to inefficient use of CPEs (96%).
2. Current CPE protocols are inadequate (78%).
3. The lack of a generic template and guidance documentation makes it difficult to develop practicable extranet protocols (70%).
4. Projects would benefit greatly from the availability of an industry approved, generic CPE protocol (74%).
5. The availability of generic protocol document would enable more efficient Collaborative Extranet Working (87%).
5.5 Early Stages of CPE Procedures Best-Fit Framework

The subsequent results were collated from the response to an electronic survey (as described in section 4.5.3) intended to ascertain the suitability of the CPE Initial Implementation Form (App. 8, p. 194). The form was developed to promote greater awareness and consideration of the key factors that impinge on the successful application of CPEs; therefore enabling an incremental improvement in one of the core ICT-enabled collaborative working activities. Sixty questionnaires were sent out to practitioners who had been identified through the preceding work and responded to previous surveys. Twenty-seven completed responses were received, producing a response rate of a 45% and the following results:

- 22 respondents (81%) found the form to be either ‘practical’ or ‘very practical’ for application in a project environment (Fig. 5.11).
- 23 practitioners (85%) indicated that the form would enable companies to capture and understand their responsibilities when working on the CPE.
- 20 respondents (74%) signified that they felt the form improve the setting up and implementation of CPEs.
- 74% of respondents also felt that the form would contribute to improving the way CPE were managed.
- Only 2 practitioners did not believed that the form would improve collaborative working, whilst 19 (70%) said it would. The remaining 5 delivered a verdict of ‘maybe’ or ‘not sure’.
- 25 respondents (93%) felt that no major issues had been missed. The remaining 2 indicated that depending upon which stage of the project the form was to be implemented at, although neither indicated what the implications of this might be.
- No respondents desired the removal of any items, although there were a number of universal comments between question seven and eight and nine e.g. ‘might be too long or could make it shorter’. Other comments related to making the form more specific to an individual organisation, which highlights the potential complications of trying to develop a generic protocol that would be applicable to all in all situations, especially as they are so many CPE systems available.
- Finally, 23 respondents indicated a desire to use the form on their future projects. This provides important proof that industry practitioners deem the form as a valuable aid to improving the future application of CPEs.

![Figure 5.11 How practical is the CPE Initial Implementation Form?](image)

5.6 Conclusion to the Research Project

Collaborative working enabled by ICTs has been substantiated by industry experts and champions as the principle mechanism for overcoming many of the sector’s inherent problems including its adversarial nature, fragmented processes and poor information
management. ICT-enabled collaborative working is also expected to promote the ascertainment of improvements in quality, competitiveness, profitability and client satisfaction. This is because the benefits to its application have already been proven in other industries (Saxon 2003).

5.6.1 Collaborative Prototyping – Aim One

The research project established that the use of shared 3D models (to facilitate Collaborative Prototyping) and Construction Project Extranets are currently the main methodologies used in endeavours to promote more efficient ICT-enabled collaborative working on projects. Investigations into this subject found that there is a large disparity between the number of companies who use traditional non-ICT based forms of collaborative working and those who a shared 3D model to promote collaboration. Around three quarters of the organisations surveyed indicated that they use Partnering, Supply Chain Management, Integrated Project Teams and Framework Agreements. In stark contrast, only 26% companies used Collaborative Prototyping, whilst less used the Single Build Model approach (13%). The main reasons for businesses not using a 3D model-based approach more frequently was due to the problems associated with overcoming the 2D v 3D working culture, a lack of demand, the failure by others to work in 3D, low confidence in the capabilities of current software and interoperability issues.

5.6.2 Construction Project Extranets – Aim Two

Conversely, the level of Construction Project Extranets application was found to equal those of traditional, non-ICT based collaborative practices. This demonstrates that they have become the de facto ICT-enabled approach to seeking improvements in project efficiency; due to their potential to enhance communications, integration and collaboration. However, the research also found that clients and project teams are not utilising CPEs efficiently, and are therefore not realising the maximum potential offered by such a tool. This failing was mainly attributed to use of inadequate protocols, which do not provide proper consideration of all the necessary issues to ensure successful implementation, application and management of the collaboration tool; as well as the development of the collaborative environment. The consequences of not establishing a proficient protocol create significant problems and make it difficult to manage project communications and information exchange. It also generates frustration amongst project workers due to a lack of instruction on how to achieve efficient use of the extranet system, the end result of which is hostility towards the use of the ICT tool and ‘reversion to type’. Collectively, these factors have a detrimental impact on the collaborative effort and subsequently the project team, client, companies and ultimately the construction industry.

5.6.3 Proposed Improvement – Aim Three

The author’s investigations have found that in order to overcome the above problem, project teams require the development of a best-fit framework of procedures that sets out the main factors for consideration, along with guidance on how to formulate proficient procedures. The research project has also established the essential criteria
necessary for the subsequent development of a framework, as well as the industry’s preference for a web-based toolkit. Finally, the proposed CPE Initial Implementation Form (developed as a first step towards a best-fit framework and to improve the future application of CPEs), has been approved by practitioners and therefore validates the importance of the research conclusions within an industrial context.

5.7 Implications and Impact of the Research

The bulk of implications and the ensuing impact of the research, particularly within the industry, have already been comprehensively covered in the preceding sections of this chapter. It is however salient at this point to provide recognition as to the impact of the research upon the sponsoring organisation. Based upon a presentation of the research conclusions and recommendations (as well as previously completed work), the Chief Executive Office invited the author to remain working at the company after completion of the EngD. The main responsibilities involve completion of the work already started, implementation of the proposed improvements and creation of an efficient ICT-enabled collaborative working environment within the company.

5.8 Critical Evaluation of the Research

The main limitations of the research project pertain to the enormity of the given subject matter; in as far as ICT-enabled collaborative working unites two very broad research topics within the one area. The application of ICTs was found to cover a wide spectrum of tools and potential uses. Collaboration required the consideration of a multitude of philosophies and necessitates work in the field of social sciences. Therefore, the confines of the work were considered to be:

- A deficient level of interface with the social aspects of collaborative working.
- The inability to include/compare the chosen ICT methodologies against others available approaches.
- The lack of inclusion of all the various ASPs due to the enormous numbers available within the industry.

5.9 Recommendations and Further Work

Based upon the foregoing research findings and conclusions, the following recommendations are submitted for consideration by the construction industry and where applicable, for future work:

1. To ensure efficient application and management of the CPE, clients, project teams and ASPs must work together to develop and implement proficient procedures on all projects.

2. Appropriate time and effort should be expended in the development of a protocol, and at the earliest feasible time. Doing so will encourage greater successful adoption of the system.

3. Teams responsible for developing procedures should identify which of the three levels of CPE operation is applicable and then ensure consideration of the appropriate factors (Fig. 4.10, p.70), especially for sustaining Collaborative Extranet Working.
4. In the absence of an industry defined framework, project teams are advised to adopt the principles of early involvement and ensure all parties are engaged in the development of a protocol at the earliest opportunity. Use of the CPE Implementation Form would also facilitate timely appreciation of the main factors to be addressed.

5. Protocols must provide equal reflection of companies, projects and extranet system procedures and not sacrifice one at the expense of the others.

6. Organisations whose work increasingly depends on collaborating via multiple CPEs should seek to develop their own internal framework; ensuring that it is generic enough for any project scenario, CPE system and subsequent future industry standard framework.

**5.9.1 Further Research**

1. The need exists to build upon the initial work of the research project to complete the development of a best-fit framework. Furthermore, it must involve and be validated by the widest range of disciplines and ASPs practicably possible; to ensure universal understanding and approval. It should also be presented to the industry in the form of a web-accessible application.

2. A system for measuring the benefits of using CPEs to facilitate CEW in conjunction with various procurement routes and contracts would facilitate better understanding of the associated risks and chances of success with each path.
6. REFERENCES


CPN. 2004b. Web Based Applications in Construction: Extranets for project collaboration, Members’ Report E4100, Report of a workshop organised by the Construction Productivity Network held at The CUBE Building, Manchester, UK.

CPN. 2004c. Web Based Applications in Construction, Members Report E4110, Report of a workshop organised by the Construction Productivity Network held at St James Park, Newcastle, UK.


ITCBP. 2003a. Adopting internet based project collaboration software, Making IT work for your business, Case Study IT039, IT Construction Best Practice, Davis Langdon Consultancy, London, UK.


McCrea, A. 2005. ‘Does the positive experience of firms like Somerfield mean project collaboration tools have really arrived?’, Construction Manager, July / August 2005.


7. BIBLIOGRAPHY


Construct IT. 1995. Bridging the Gap: an information technology strategy for the use United Kingdom construction industry, Anderson Consulting, BT and the DoE, HMSO, UK.


CPN. 2004e. The Journey to Improvement – Progress over the Last 10 Years and Trends for the Next 10 Years, Members’ Report E4127, Report on a workshop by the CPN held at Tanaka Business School, Imperial College, October, London, UK.

CRC. 2004. Construction 2020: A vision for Australia’s property and construction industry, Cooperative Research Centre for Construction Innovation, Queensland University of Technology, Brisbane, Australia.


IST. 2004a. A thematic priority for research and development under the specific programme ‘integrating and strengthening the European research area’ in the Community sixth framework programme, Information Society Technologies, 2005-06 Work Programme, European Commission.


Mitev, N. N. & Venters, W. 2004, Workshop on Information, Knowledge and Management: re-assessing the role of ICTs in public and private organisations’, UMISTa and the University of Pisa, 3-5 March.


Websites

http://cig.bre.co.uk/dataexchange/  https://pronet.wsatkins.co.uk
http://wok.mimas.ac.uk  www.4projects.com
www.arcom.ac.uk  www.asite.com
www.autodesk.co.uk  www.avanti-construction.org/
www.bcc.beonline.co.uk/  www.bentley.com
www.bentleyusers.org/microstaition.htm  www.bre.co.uk/
www.blis-project.org  www.buildingcentretrust.org
www.bsonline.bsi-global.com  www.cadastyst.com/cadastyst
www.buildonline.com  www.cadserver.co.uk
www.cadinfo.net  www.causeway.com
www.cadweb.co.uk  www.ciob.org.uk/ciob/
www.cerf.org  www.ciria.org.nccpt
www.ciria.org.uk  www.cnplus.co.uk
www.citadon.com  www.constructingexcellence.org.uk
www.cumincad.scix.net  www.constructware.com
www.dti.gov.uk  www.denaliusa.com
www.elsevier.com  www.efqm.org
www.excitech.co.uk  www.emerald-library.com
www.frameitech.com  www.extranetnews.com
www.itconstructionforum.org.uk/  www.itcon.org
www.leanconstruction.org  www.intranetjournal.com
www.lboro.ac.uk/it-aec/  www.leanuk.org
www.ncrisp.org.uk  www.navisworks.com
www.productioninformation.org/default.html  www.primaer.com
www.projectedge.com  www.prodaec.net
www.projectgrid.com  www.projecttalk.com
www.rib.org  www.pubs.acse.org
www.riba.org  www.sarcophagus.co.uk
www.startwright.com  www.steptools.com
www.strategicforum.org.uk/sftoolkit2/home/home.html  www.uk.bidcom.com
www.viecon.com  www.web4engineers.com
Appendix One: Paper One

ICT-enabled Collaborative Working
AN EVALUATION OF CURRENT COLLABORATIVE PROTOTYPING PRACTICES WITHIN THE AEC INDUSTRY

ABSTRACT: ‘Collaborative working’ and ‘prototyping’ have both been identified by many within the industry as two methods of working that can help organisations become more profitable and productive. However, when used collectively the potential exists to bring improvements to the Architectural, Engineering and Construction sectors through the eradication of waste and re-work. The concept of ‘Collaborative Prototyping’ provides a process that challenges existing cultural attitudes and working processes and advocates a change in the way conventional projects are managed, in order to achieve a more competitive industry. This paper presents the results of a study on the evaluation of current Collaborative Prototyping practices within the Architectural, Engineering and Construction Industry. It reviews existing collaborative methods of working along with current developments. An evaluation of the role of 3D modelling and prototyping practices has also been conducted, and the current levels of the industry’s use are established. This paper concludes that the industry makes little use of Collaborative Prototyping, and therefore at present does not maximise the potential that prototyping and collaborative working offer in improving working practices.

KEYWORDS: Collaborative Working, 3D modelling, 3D CAD, Prototyping, Collaborative Prototyping.

1. INTRODUCTION

The last decade has witnessed extensive discussion and documentation of the UK construction industry's inherent problems. Issues at the forefront of these discussions include a conservative culture, an adversarial nature, fragmentation, poor knowledge management, lack of process transparency and a lack of industry standards (for information exchange). As a result, there has been an acceptance by a predominant number of industry experts, (essentially over the past five years), that ICT has a vital role to play in helping to overcome some of these problems, and achieve those targets outlined by the Latham [1] and Egan [2] reports; two very significant reports that examined the performance of the UK construction industry and outlined areas for necessary improvements. Both reports draw on the experience of other industries that have successfully adapted organisational cultures, introduced new business processes, achieved significant cost reductions and generated major gains in productivity and quality [3]. In addition, Furthermore, the emergence of the information age and the ensuing increase in globalisation has also lead to construction organisations within the UK focusing on new ways of working to compete effectively.

To meet the ever-changing needs of the industry, various construction organisations, IT companies and research establishments are examining how to best utilise ICT solutions within the construction process to bring about business benefits. Two of the main areas these parties are concentrating on are collaboration and prototyping [4] as there are enormous benefits to be gained, in terms of eliminating waste and re-work for example, from using modern CAD technology to prototype buildings [2]. When looking to the future of construction and proposing ways for the industry to meet the demands of a rapidly changing market over the next twenty years, the Foresight report sees
Information and Communication Technology (ICT), 3D CAD Modelling and Collaborative Working as the main tools for reshaping the way we think and work. The report states ‘using ICT to share information across business processes, from marketing and procurement to design and site management, will allow more collaborative working and benefit everyone in the construction team’ [4]. The report also highlights that the use of 3D computer models will improve every aspect of construction; from client simulations, to predicting whole-life costs and even health and safety on site.

The above supports the argument that 3D modelling and Collaborative Prototyping are seen as two of the most significant areas for development, and will bring about efficient collaborative working. It is also evident that both prototyping and collaboration are key issues that are deemed extremely important for the future improvement of the construction industry. An evaluation of current Collaborative Prototyping practices within the AEC Industry is carried out in this paper. Existing collaborative methods of working are reviewed along with current developments in collaborative working. The roles of 3D modelling and prototyping practices are examined and finally the current application levels of Collaborative Prototyping are determined.

2. COLLABORATIVE PROTOTYPING

At present, it is difficult to precisely define the term Collaborative Prototyping (CP) due to the lack of a widely agreed common definition. The Concise Oxford Dictionary defines ‘collaborative’ as ‘working jointly’ and ‘prototyping’ as ‘a trial or preliminary version of a vehicle, machine etc’, or to make a ‘prototype of a product’ [5]. Therefore, a simple definition of CP is the joint working of project stakeholders to produce a prototype of a building. However, this does not provide enough detail. At present, the clearest definition is at present is provided by Teamwork as ‘the process by which a construction project can be delivered using integrated 3D modelling techniques and the evaluation and testing of those models whilst the project is still in the design stage’ [6]. They go on further to discuss collaborative working ‘as a design process based on a single model where all members of the design team have shared access to a single source of up-to-date information’. Kalay [7] states collaboration can be defined as the agreement among specialists to share their abilities in a particular process, to achieve the larger objectives of the project as a whole.

3. RESEARCH METHODOLOGY

The research was conducted as partial fulfilment of a MSc in Collaborative Prototyping and an Engineering Doctorate in ICT-enabled Collaborative Working Methodologies; both undertaken at Loughborough University. It used both quantitative and qualitative methods to capture and review Collaborative Prototyping. Semi-structured interviews were used to carry out exploratory research, understand existing principles, identify alternative ways of working within collaboration and 3D modelling, and capture emerging thoughts and ideas. A descriptive survey via an electronic questionnaire was also used to allow factual evidence about the concept to be collected and correlated, and to determine the application of Collaborative Prototyping within the Architectural, Engineering and Construction industry.
3.1 Rationale to Interviews

A first round of interview questions was devised based on the issues identified in a literature review and the research objectives. A trial form was e-mailed to a small group of academics and industrial managers (who were both known to the Research Engineer and had relevant expertise within the fields of collaboration and modelling) to gauge it for question types, style, content and compatibility. The returned comments were applied and the questionnaire was tested to establish a time frame for completion. The research sample for the interview stage (as for the questionnaire survey) were drawn from the following areas:

- A list of keynote speakers at the AEC Design Computing Conference 2002 [8].
- Senior members of the not-for-profit company ‘Collaborating for the built environment’ known as ‘Be’ (members details were accessed from www.beonline.co.uk/About/Members/members.asp). Be was formed in 2002 through the amalgamation of the Design and Build Foundation (DBF) and the Reading Construction Forum (RCF). Be is the largest independent construction supply chain body in the UK with over 100 members including clients, contractors, consultants, and specialists and manufacturers all committed to collaborating for sustainable improvement in the built environment through the research and delivery of change within firms [9].
- Senior managers of the UK regional chapter of the International Alliance for Interoperability (IAI), an alliance of organisations within the construction and facilities management industries dedicated to improving processes within the industry through defining the use and sharing of information [10].
- Directors and core members of the Business Round Table forum’s reTHINKING CONSTRUCTION initiative ‘Teamwork’, which is an educational initiative established by Virtual First Ltd to develop a new working model for building procurement [11].

Section one of the semi-structured interview questions was used to check the validity of each expert answers. This was achieved by providing details on each interviewee’s background and experience within the field. The aim of section two was to ascertain each individual’s perception of what constitutes present-day collaborative practices (non-ICT based), whilst section three captured their thoughts on emerging collaborative techniques. Section four was used to develop an understanding of 3D modelling and prototyping within the industry, along with the benefits associated with their use. Finally, section five determined what, if any, future developments there might be.

3.2 Rationale to Questionnaire

A questionnaire was developed and sent for review by a number of academic and industry experts and their comments and amendments included, before the final questionnaire was constructed using a word document and a visual basic form. It was felt that this format would allow the questionnaire to be sent electronically and help ensure a faster return and higher response rate, in order to overcome the constraint of limited time. The questionnaire incorporated ‘closed’ opinion questions using numerical rating scales, checklists, grid checklists and ranking. A short pilot study was carried out to test the form for response time and ease of use. A covering letter was attached to the
email questionnaire to explain the research, catch the audiences’ attention, and help obtain a higher response rate. The questionnaire aims were to:

- Examine the various types of organisations that replied to the questionnaire and analyse their main business function.
- Develop a picture of current collaborative working practices within the industry.
- Conduct a detailed study of 3D working in projects, understand the reasons why companies use 3D working and to establish why organisations do not use 3D working more often.
- Analyse the industry’s awareness of CP, determine the level of CP use and establish how successful attempts to utilise CP have been.
- Provide respondents with the chance to voice their opinions on CP (by way of open questioning at the end of the questionnaire).

4. ANALYSIS OF RESEARCH SAMPLE

4.1 Research Sample for Interviews

Of the ten requests made for interviews, five accepted. The following provides details of their experience and substantiates the reasons for choosing them as prime candidates:

- Interviewee one – is a Partner of a large international organisation and a director of Teamwork. He has over seventeen years engineering consultancy experience, five years experience in Collaborative Working, and has been involved in several Collaborative Prototyping initiatives.

- Interviewee two – after working as a Building Services Co-ordinator on several major projects (all in excess of £80m within a major organisation), he is now a Director of a small design co-ordination company. Experiences include managing a team of 3D co-ordinators on a £128m pharmaceutical laboratory, a small team in researching 3D Collaborative Working initiatives, and ten years of integrated project team working experience.

- Interviewee three – is a Project Architect who has written articles for bentleyusers.org, and has been involved with the Teamwork initiatives for three years. He has extensive experience of CAD management and working in 3D.

- Interviewee four – is currently the Chief Executive of a regional consultancy company which funds research into identifying the next generation of Collaborative Working. Other aims include helping organisations within the construction industry to deliver better Collaborative Working. The company has turned over £1m worth of fees in the past eighteen months and has over 100 members. He has eight years experience including, working with Sir Michael Latham to formulate best practice guides for Collaborative Working and Partnering.

- Interviewee five – is a Client Director of a small international consultancy in training, mentoring and benchmarking of Collaborative Working. He has twelve years of experience and has been involved in a great deal of research work.

4.2 Research Sample for Questionnaire

Sixty questionnaires were sent out via email to a wide range of companies through the AEC industry. Thirty-eight of these were completed and returned, producing a 63%
response rate. Of the thirty-eight companies questioned, only ten (26%) were found to have tested or used CP. Eleven out of the thirty-eight responding companies classed themselves as Main Contractors (29%) followed by seven Consultants (18%), and the rest consisting of Architects, Clients, Contractors and Engineers. The majority of respondents held the position of Directors (32%) followed by managers (24%), and the remainder (44%) consisting of twelve other roles at middle management levels. Responses from ICT managers were minimal (5%) and no respondents held a position that dealt specifically with collaboration or 3D working. However, as they all held either middle or top managerial positions within companies, the information provided can be judged as credible. The remaining sections of this paper present the findings from the interviews and questionnaire under their separate headings, and then discuss the main conclusions of the research.

5. INTERVIEW FINDINGS

5.1 Established Collaborative Working Practices

Three of the five experts expressed doubt as to whether or not established collaborative working practices existed at present. However, the remaining two experts were able to clearly define established collaborative working practices, although they did accept that they were not being implemented correctly. One interviewee (an expert in collaborative working) referred to the ‘six critical success factors’ for collaboration and provided the following information:

1. Early involvement of all project stakeholders – the least used but most important issue in achieving successful collaboration. One of the main arguments for early involvement is its ability to overcome the issue of buildability. By introducing manufacturers of specialist components at the earliest possible opportunity, the potential exists to dramatically reduce the amount of errors and waste later on in the construction phase.

2. Selection by value – in order to ascertain effective procurement, it is important that all project stakeholders go through the process together. Their coming together must achieve maximum value for the project and guarantee success based upon their previous experiences. According to the interviewee, awarding on ‘lowest price’ does not achieve this. It often means working with someone new in the supply chain (as they have submitted the lowest price to ensure work).

3. Development of common processes and tools – such as the adoption of project extranets, which allows for a single source of control over all project data. At present, there are too many alternative methods, practices and tools, which only add to confuse the issue, rather than provide a simple single solution.

4. Performance measurement – also known as ‘benchmarking’, which is not common place in the supply chain. The use of Key Performance Indicators (KPI’s) has become widespread and has developed much faster than ‘Partnering’. This is because companies realise the benefits of using a simple set of measures to determine how they are performing both internally and externally. Long-term relationships must be based upon the performance measurement of everyone, otherwise it is not possible to understand whether someone is achieving what is required of them. Furthermore, the use of performance measurement should be
extended to include all site activities, in order to help identify and eradicate waste and inefficient processes.

5. Long-term relationships – which should be built upon continuous improvement using performance measurement. Very few existing relationships within the industry demonstrate this characteristic at present. However, as there is a lack of this type of working, the most important step initially is to get companies to establish long-term relationships. In addition, this type of relationship assists with selection based on value rather than cost, and helps to retain valuable resources that have demonstrated achievements and gained crucial experience.

6. Supporting collaborative arrangements – by way of a contract that is not conducive to creating an adversarial environment. In the past, many partnering arrangements have been based on the traditional Joint Contracts Tribunal (JCT) forms of contract, which are is recognised as being very adversarial in nature. The Joint Contracts Tribunal was established in 1931 and has for over 70 years produced standard forms of contracts, guidance notes and other standard documentation for use in the construction industry [12]. Other available forms of contract provide different approaches to dealing with problems that arise and strive to maintain collaboration by preventing companies from entering into adversarial situations. These include:

- The New Engineering Contract (NEC) – a legal framework of project management procedures designed to handle all aspects of the management of construction projects. Its benefits – stimulus to good management, flexibility and simplicity – can be applied to any construction project, large or small [13].
- PPC2000 ACA Standard Form of Contract for Project Partnering – the first standard form of Project Partnering Contract, a direct result of the Government's Construction Task Force Report ‘Rethinking Construction’. It was launched by Sir John Egan, Chairman of the Construction Task Force, and provided the foundation for the project partnering process. It was amended in 2003. PPC2000/3 can be applied to any type of partnered project in any jurisdiction, with the support of an experienced partnering advisor or with appropriate legal or other professional advice on its implementation [14].
- The be Collaborative Contract (beCC) – a new form of contract for construction projects that underpins collaborative behaviour. Intended for use by parties, who genuinely want a contractual framework that assists a collaborative approach and seeks to identify and manage risks, rather than simply passing them under contract conditions and/or relying on ‘rule of thumb’ risk contingencies as sole protection against the unexpected [15]. The contract was developed over three years, included an extensive consultation period with all construction industry participants and was reviewed by a number of the top construction law firms.

The final interviewee also referred to these critical success factors, but also indicated that ‘open book accounting’ and ‘integrated project teams’ were also important factors.

5.2 Effectiveness of Collaborative Working Practices

There was a general consensus amongst the experts that collaborative working practices should be very effective, but in reality were not. Experts attributed this to companies concentrating on the fact that they wanted people to know they were using such practices, rather than focusing on implementing them correctly. This is substantiated by the reasons given as to why they are not as effective as they could be including;
people’s attitudes, complacency, a lack of effort and some disciplines’ inability to effectively collaborate. The experts also imparted some doubt as to how realistic companies’ success stories were.

5.3 Benefits of Current Collaborative Working Practices

Experts agreed that there were many benefits to collaborative working, but presented different arguments as to what they were. One stated that ‘an organisation should be able to gain up to 50% improvements in both cost and time’. The following is a list of those benefits captured by the interviews:

- Elimination of problems in the design stages before projects go to site;
- Helping to install confidence that problems will not happen on projects;
- The creation of better team-working environments;
- A reduction of conflict on projects;
- Greater co-ordination, which in turn will help to increase project efficiency;
- Obtaining higher levels of quality in all areas of projects;
- Greater value buildings for clients;
- Greater efficiency throughout the whole project process.

5.4 Current Collaborative Working Practices

The experts were in total agreement that project teams should experience no disadvantages when adopting current collaborative working practices. However, two experts articulated that it is difficult to get everyone to work harmoniously and that some project members work harder to succeed at collaboration than others. Additional conditions to be considered for successful implementation of collaborative working are:

- Everyone must be committed to the adoption of collaborative practices and work together to ensure success.
- They must be used alongside existing procurement systems, which are not specifically tailored to maintain collaboration.
- Currently, there are no ‘easy to use’ systems for capturing and reporting the benefits (business case) of their use and therefore, companies are slow to take them on-board.

5.5 Quantifying the Benefits of Collaborative Working

One subject continuously mentioned throughout the interviews was the need to develop an ‘easy to follow business case and predictive tool’. All expressed how vital it is to be able to demonstrate the benefits, in order to make the ‘industry sit up and take notice’. However, existing practices are very difficult to quantify due to the complex nature of combining a multitude of processes. One expert stated ‘it is extremely hard to demonstrate the benefits of collaborative working due to its nature. It involves so many processes; it would be difficult to measure them all’.
5.6 New Developments in Collaborative Working

One expert felt that the main developments in collaborative working will simply be ‘formalising them into best practice for the industry’ and ‘spreading their use’. This was supported by another candidate who responded by saying that existing practices are still unknown or not used by many organisations and any increase in the adoption of existing techniques will be a new development. Another expert identified the release of the ‘Be Collaborative Contract’ and the use of ‘Project Team Insurance’ as new developments. According to the interviewee, the Be Collaborative Contract was reviewed by Office of Government Commerce (OGC) and independent consultants, along with the JCT, NEC and PPC 2000, to determine how well they supported the Treasury’s way forward for collaborative working. The Be Collaborative Contract came top with a score of 85%, compared to the JCT with 25%, the PPC2000 with 60% and the NEC with 70% [16]. The aim of the Be Collaborative Contract is to provide incentives to reward project stakeholders for displaying the right working ethos and attitude, as well as attempting to curtail unwanted and wasteful working; and therefore increase the achievement of successful collaborative working. Project Team Insurance is expected to create shared responsibility for risk, reduce the costs of insuring project risks and allow savings to be passed onto the client, in order to provide greater value.

5.7 Meeting the Industry’s Requirement for an Efficient Collaborative Solution

When asked if any new developments would provide the industry with an efficient collaborative solution, most experts felt that they would, although not instantly. However, one expert felt that they would not, because the industry still has a long way to go before collaborative working is undertaken efficiently. As a result, it is argued that regardless of whether the answer to the above question is yes or no, a more important issue is the time it will take to implement any new solution, demonstrated by both sides of the argument. There is no the point in having a solution that will meet the industry’s needs, if it takes the majority within the AEC sector too long to realise and implement it?

5.8 The AEC Industry’s use of 3D Modelling and Prototyping

The use of CAD tools have become the standard technique for producing building documentation over the past twenty years. As a consequence of this the need to transfer CAD-information between the different participants in a construction project in digital form has become of vital importance [17]. It has also been substantiated in the introduction, that the application of 3D modelling and prototyping are now well recognised as having the potential to bring about improvements in project working processes within the UK construction industry. There has also been a large amount of research carried out into the possible uses of 3D and Virtual Reality (VR) to assist construction and collaboration [including 18, 19, 20 and 21].

Presently, CAD packages contain large libraries of parametric building parts, such as doors, windows, and structural components, which are used to organise building assembly and material information. This library of components contains 2D and 3D representations of the building parts that can be substituted in different viewpoints [22]. A CAD user can design in 2D and then automatically generate a 3D model, or design in 3D, and extract plans and sections. It is also possible to ‘pan’ and ‘zoom’ around
drawings in order to gain a better understanding of how the model fits together and identify clashes (known as clash detection) or problems, whilst visualisation techniques such as rendering and animations help to provide context and shadows that give the model a ‘photo realistic’ finish. This allows the viewer(s) to ascertain an enhanced perception of what the actual product would look like in real-life. Virtual reality models are interactive 3D models that can be experienced in real-time. The term virtual reality is similar to and sometimes used synonymously with visual simulation, digital mock-up, virtual prototyping, walk / flythrough, and 4D CAD [22].

A true CAD system should be able to draw from a company's natural knowledge base, the accumulated experience of the workforce [23]. It is also proposed that an open CAD system would be able to work well in a collaborative environment (where designers work on parts of a product at certain stages) if it has the following attributes [24]:

- **Network-oriented system** – running on a network or the Internet and open to all users.
- **Heterogeneous platforms** – since the users are distributed, their computer environments are possibly different to each other with various operating systems i.e. MS, MAC, Unix and Linux. Therefore, it would need to work on all operating systems.
- **System flexibility** – as there are many components in a building it is not possible to have one CAD system that encapsulates all, rather it should provide such capability to permit the adding of new components.
- **System stability** – a collaborative system has to solve the conflicts between system location distribution and the system integration management.

However, successful Collaborative Prototyping needs a comprehensive suite of tools for all disciplines to use, contribute and share information. The industry’s Holy Grail of working from a shared central model still appears to be some way ahead of where we are now [25]. When questioned about the use of 3D modelling and prototyping within a collaborative environment, experts identified the following benefits to their application:

- Working in 3D aids visualisation of problems before they occur on site, so that they can be eradicated, which is not possible in 2D.
- The client can ‘walk through’ the space and is able to visualise and understand the effects of their decisions, for example how a certain required finish either complements or detracts from a space. When done correctly it should stop the need for design changes.
- The ability to demonstrate different solutions without having to build them first, means that large savings can be obtained by limiting the need for late design changes.
- Clash detection of complex and expensive services helps to reduce project time and costs later on in the construction phase.
- Greater detail and co-ordination and ultimately better buildability.

Conversely, there was a common belief amongst all the experts that there is very little 3D modelling / prototyping being undertaken by organisations within the industry at present. They all believed that the figure would fall somewhere between zero to five percent of companies. The reasons given for such a limited use of 3D modelling were:

- It is difficult to overcome the existing 2D working culture.
• There is an unwillingness by companies to move out of their ‘comfort zone’ and try something new.
• People are reluctant to change their attitudes towards 3D working.
• Fear of change.
• A lack of understanding and education as to the benefits of 3D working.
• A lack of evidence and examples to demonstrate the effectiveness of 3D working.
• The belief that it takes longer and costs more to produce a 3D model.
• A shortage of skilled 3D resources.
• A lack of faith in the abilities of 3D software to achieve what vendors’ state the software is capable of providing (over hyping of software).
• Interoperability issues – separate, non-integrated 3D software packages, which do not facilitate collaborative working. Companies and even separate disciplines have to find ways for their software to interact with other applications on a model. This usually incorporates talking to the vendor or hiring a programmer to try and form a bridge between the packages, both of which need time and money.
• A lack of investment in developing the correct software, especially when compared to the aeronautical and automotive industries.

Three of the interviewees also presented the case that even when 3D working was demonstrated, much of it has been created in 2D and then transferred into 3D via special software applications after the design has been completed (which does not constitute CP). All the experts agreed that the application of 3D prototyping as a collaboration tool had not been very successful thus far, mainly because it is not an established process and companies do not use it enough or in the correct manner; as a model to facilitate the whole project process. One candidate stated that its use has not been successful because ‘ICT is not the main driver, nor should it be. The fundamentals of project collaboration must be in place first and only when they are in place, should ICT be considered. ICT is not a solution, it is an enabler’ [16].

5.9 Overcoming the Barriers to 3D Prototyping

The ensuing list was developed by collating all of the answers given to a question on how barriers might be overcome:
• By demonstrating that 3D prototyping can be done.
• By a company successfully applying it to a project.
• By providing better educational literature to train managers on the benefits.
• Clients leading the way and requesting the use of 3D prototyping.
• Development of best practice guidance that outlines tools, techniques and procedures.
• Finding a solution to the problems associated with interoperability, which will allow for better integration and greater use of modelling/prototyping.

5.10 The Issue of Interoperability

One expert stated that the issue of interoperability is ‘very important, data needs to be shared across platforms, not stalled by them. Collaboration can never really happen
until this issue has been overcome’. This was taken a step further by another who agreed with the initial statement but added that ‘it should happen within each supply chain, not necessarily across the whole industry’. The reason for this being, that it is easier to try to solve the problem at this level, rather than on an industry wide basis. At present, efforts to overcome this problem are mainly based on trying to utilise a single platform (AutoCAD or Bentley), along with appropriate software provided by either company on each project, to ensure maximum permissible integration amongst the different disciplines. However, this still does not resolve the problem as numerous companies use different applications to complete their section of the model. Companies would have to invest thousands of pounds on software and training, if they wanted to be in a position to work in any format, which is not a realistic option. One expert complained that ‘we will probably have to wait another twenty years before systems will talk to each other properly’. Although this may be an exaggeration, the statement does demonstrate the frustration felt by those within the industry about the lack of progress being made towards overcoming the issue of interoperability.

6. QUESTIONNAIRE FINDINGS

The following section presents the findings of the questionnaire survey under three main sections:

- Collaborative Working Practices
- 3D Working Practices
- Collaborative Prototyping Practices

6.1 Collaborative Working Practices

Throughout the course of the research, a number of collaborative methods of working were identified [2, 4, 6, 9, 11 and 26]. By carrying out a questionnaire survey, it was possible to ascertain the extent to which companies, within the research sample, used each of these techniques (as shown in fig.1). The radar chart demonstrates that 26% of those companies questioned had used CP. This figure is higher than the one expressed by industry experts during the interview stage, which predicted its usage to be somewhere between 0 – 10%. The authors attribute this to the small research sample, which was aimed specifically at companies who undertake collaborative activities. It is anticipated that should the research sample be widened then the figure would drop dramatically and fall into the 0 – 10% bracket. Partnering was found to be the most successful form of collaboration with 53% of users indicating that they find it to be very effective; followed by the use of Integrated Project Teams with 43%. The majority of those who use other forms of collaborative working find them to be effective. The least effective form of collaboration was the use of a Single Build Model.

6.2 3D Working Practices

A total of 76% of the companies in the questionnaire survey used some form of 3D working, 52% of these used 3D CAD on several or more projects over the past twelve months. Conversely, 24% of organisations did not use any form of 3D modelling. The questionnaire survey also revealed that there is a large demarcation between the uses of 3D based Collaborative Working and Non-3D Collaborative Working techniques within
the industry. More than three-quarters of the companies questioned have used Partnering, Supply Chain Management, Integrated Project Teams, Framework Agreements and Project Extranets. In contrast, only 26% have used Collaborative Prototyping, and only 13% used the Single Build Model approach.

![Figure 1](image)

**Figure 1.** Results of the questionnaire survey identifying the percentage of companies using various collaborative working techniques

Figure 2, demonstrates that 70% of the total responses stated their main reason for using 3D modelling on their last project was visualisation for client demonstration. The use of Single Build Models was least exploited (13%), followed by CP (24%). Furthermore, the results also show that the reasoning behind using 3D modelling was significantly different for companies that use CP to those who do not. The organisations that used CP tended to have a more diverse use of 3D modelling, and are more likely to undertake model analysis for isolated parts of design (100%), clash detection (90%) and co-ordination of isolated section of the design (70%). Non CP organisations use of 3D modelling tended to be limited and focused more on visualisation for client demonstration (63%) and marketing (58%). When questioned about the benefits of using 3D modelling for the various reasons stated above, 86% of those who used CP on their last project indicated that it had increased efficiency, whilst 14% were unable to quantify how effective its use had been. None felt that its use had been ineffective. In addition, 85% felt that using 3D modelling for client demonstrations had increased efficiency on their last project. However, in all cases, none were able to provide further evidence to justify their responses.
Organisations indicated that the following were reasons (in rank order) why they did not carry out 3D working more frequently:

- Overcoming the 2D v 3D working culture;
- A perceived lack of demand for 3D working;
- The difficulties associated with persuading partners on a project to work in 3D.
- A lack of faith in the abilities of 3D software to produce what vendors’ state the software is capable of providing;
- Interoperability issues (non-compatible 3D software packages, which do not facilitate collaborative working);
- A shortage of skilled 3D resources;
- The belief that it takes longer and costs more to produce a 3D model than to work in 2D;
- A lack of evidence and examples to demonstrate the effectiveness of 3D working;
- The cost of purchasing specialist software;
- The cost and time associated with training.

**Figure 2.** Respondents reasons for using 3D Modelling on their last project
Respondents felt that these barriers could be overcome through:

- Demonstrating 3D working can be achieved through external examples taken from other industries;
- Publication of best practice and success stories of 3D working;
- Provision of better literature to educate and train managers of the benefits;
- Clients requesting the use of 3D working.

6.3 Collaborative Prototyping Practices

As ascertained in figure 1, only 26% of those companies questioned indicated that they had used some form of collaborative prototyping. When questioned about their understanding of collaborative prototyping, 61% of respondents indicated that they were aware of the concept. However, this lead to the finding that nearly two-fifths (39%) of companies who are currently involved in major industry initiatives based around collaborative working and 3D modelling, were not aware of CP. The authors anticipate that this figure would escalate even further if the research sample were increased to cover the entire AEC industry.

Of the 61% of companies, who are aware of the concept of CP, over two thirds indicated that they have little or no knowledge or awareness as to the benefits associated with its use. Therefore, only 31% of companies from the research sample have revealed that they have extensive knowledge of CP. Surprisingly, of the ten companies who had used the concept, four stated that they only had limited knowledge as to the benefits of its use. It was also found that despite 26% of responding companies having undertaking some form of CP, in nearly all cases it use had only been applied to a one or two projects (60%) at most.

The findings of this section highlight that there is a lack of awareness on the subject of Collaborative Prototyping, which the industry needs to address if more companies are to understand, learn about and implement collaborative working based around 3D modelling. After all, companies cannot choose to research and implement those practices which they are unaware of.

7. RECOMMENDATIONS TO THE INDUSTRY

Based on the above findings, the following recommendations are suggested to help improve collaborative working and CP.

To ensure collaborative working has the greatest chance of success, companies within the AEC sector should adopt the approach as outlined by be, which identifies six critical success factors to effective collaborative working. If the industry is to improve through utilisation of CP, then it needs to consolidate all of the existing techniques into a generic procurement process. This will not only save time and money, but also increase success rates and ultimately help the industry become more efficient. A system must be developed which facilitates monitoring and reporting of information, captured by measuring the applications of various collaborative techniques on projects.
Current guidelines on 3D prototyping are patchy at best and non-existent at their worst. When greater knowledge of 3D modelling and prototyping has been correlated, the industry must define and implement a best practice approach to Collaborative Prototyping. The amount of information on existing best practice must be increased (but validated) and made more accessible to all.

The AEC industry must overcome the problems resulting from the current attitude and cultural barriers towards 3D working, by better educating the industry about the benefits of using 3D, for example through a series of industry-wide workshops. An initiative needs to be developed to provide incentives, in order to persuade more companies to work in 3D and ultimately increase the general uptake. Other industries have invested millions of pounds developing collaborative prototyping solutions to meet their needs; in contrast, the AEC industry has invested very little. If the industry wishes to gain the same level of collaborative working through 3D prototyping, it inevitably has to do the same. In addition, organisations must become firmer with and demand more from the IT industry regarding what it is they need, and then work with the software vendors to develop it. This would save the industry substantial amounts of time and money.

The AEC sector must introduce a form of training, which develops adequately skilled 3D workers who have specific knowledge of the construction process, rather than attempting to adapt graduates from other industries. Although their 3D skills are proficient, they do not understand the nature of construction, which ultimately limits their effectiveness.

8. CONCLUSION

Despite the extensive amount of work and effort expended to make collaborative working standard practice throughout the AEC industry within the UK, there still remains a lack of clarity on what constitutes collaborative working. Six factors were found to be crucial to the successful application of collaboration working. Conversely, it was established that companies are not implementing these correctly and are therefore failing to realise the full potential of the various collaborative techniques.

The ability to quantify the benefits of collaborative working practices are extremely difficult, due to the complexities associated with trying to combine a multitude of techniques to derive a plausible method for doing so. This led to the conclusion that the industry needs to develop an easy to follow business case and prognostic tool, which can be used to demonstrate the benefits and ultimately increase the uptake of collaborative working.

There is a large demarcation between the use of non-3D and 3D-based collaborative working techniques within companies in the AEC sector. Three quarters of the companies surveyed indicated that they use Partnering, Supply Chain Management, Integrated Project Teams, Framework Agreements, and Project Extranets. In stark contrast, only 26% used Collaborative Prototyping and only 13% used a Single Build Model approach. However, organisations which employed CP proved to have a more diverse use of 3D modelling, and are more likely to undertake model analysis for specific parts of the design, clash detection and co-ordination of isolated sections of the design. Non-CP companies’ main use of 3D modelling tends to be for demonstrations and marketing.
The main reasons cited by companies for not using 3D working more frequently are the problems associated with overcoming the 2D v 3D working culture, a lack of demand for 3D working and the failure by others to work in 3D on a project. Four ways of overcoming these barriers are: to demonstrate that 3D working can be done by using examples from other industries; the development of improved literature on the benefits and a best practice guide; and finally, clients requesting the use of 3D.

The research found that over half of the companies questioned are not aware of the concept of CP and less than one third have extensive knowledge of the subject. Where the method has been applied, the majority indicated that its use has been effective. However, in nearly all cases, it use had only been applied to one or two projects at most; with more than two thirds reporting only limited success.

Current CP practices do not use genuine collaborative working techniques to generate a prototype, in order to test the design of the product before its production begins. Consequently, the application of 3D prototyping has not been effectively applied as a collaboration tool, as a result of the lack of established processes and the limited and incorrect use of the concept by organisations.

If CP is to become a realistic option to procuring the successful completion of a project, the future must include the production of a ‘best practice guide’ informing companies how to undertake it. In addition, the AEC industry must work closely with IT developers to obtain better tools. These tools should facilitate the complete integration and co-ordination of data from all disciplines on a project. Although, it must be remembered IT is not the main driver, nor should it be, the fundamentals of project collaboration must be in place first and only when they are in place, should IT be considered [16]. Therefore, companies wishing to undertake CP should start by perfecting their collaboration processes, rather than attempting to implement prototyping techniques before they have been established.

9. REFERENCES


Appendix 1: Paper 1 – Collaborative Prototyping


Appendix Two: Paper Two

COLLABORATIVE EXTRANET WORKING VIA MULTIPLE CONSTRUCTION PROJECT EXTRANETS

ABSTRACT: A growing number of clients within today’s construction industry require project teams to use a Construction Project Extranet (CPE) in order to facilitate project information exchange and collaboration. This is mainly due to a reported ability to bring about potential savings of up to 10% in project cost. As a result, consulting engineers who collaborate with numerous clients and project teams are increasingly being expected to work on a multitude of different extranet systems. Whilst the benefits associated with using a single CPE along with ICT-enabled collaborative working practices are widely acknowledged and established, the implications for organisations undertaking Collaborative Extranet Working (CEW) via multiple CPEs are not. This paper reports on the main findings of a study to investigate the problems encountered by an engineering organisation when working on numerous extranet systems across various projects. The paper concludes by making a number of recommendations on how the industry and individual organisations can work more effectively and efficiently when dealing with multiple client driven CPE systems.

KEYWORDS: Collaborative Extranet Working, Construction Project Extranets, Protocols.

1. INTRODUCTION

The construction industry’s inherent problems along with the ability for the application of Information Communication Technology (ICT) to help overcome them have been well documented and deliberated over the past decade including: Latham, 1994; Egan, 1998; NAO, 2001; DTI, 2001; Mak, 2001; Teamwork, 2003. Due to the extensive amount of work in this field, a myriad of paradigms now exist on how the industry can best utilise ICT to improve quality, competitiveness, profitability and client satisfaction. However, since the turn of the millennium the concept of using a web-enabled Construction Project Extranet (CPE) to facilitate information exchange and collaboration has increasingly come to the fore. Using ICT in this manner, to share information across business processes, from marketing and procurement to design and site management, will allow more collaborative working and benefit everyone in the construction team (DTI, 2001).

From a standing start of just three or four years ago, methods of online project collaboration are starting to revolutionise the way in which construction projects are managed (Broyd, 2003). This is due to the fact that ICT-enabled collaborative working is the prime tool for driving a revolution in construction, as it has already worked in the aerospace, shipbuilding, automotive and process industries (Saxon, 2003). The application of this type of working via the web and its associated technologies has now been widely acknowledged by practitioners (Nitithamyong & Skibniewski, 2004). It also forms the nucleus of several concepts and is described by various designations including: Project-Specific Web Sites (Thorpe & Mead, 2001); Project Collaborative Extranets (Hamilton, 2002:1); Web-enabled Project Management (Alshawi & Ingrige, 2003); Online Project Management and Collaboration Tools (Unger, 2003); Web-enabled Project Management Systems (Nitithamyong & Skibniewski, 2004); Web-based Project Information Management (Stewart & Mohamed, 2004) Construction Project Extranets (Murphy, 2001 & Harvard, 2004). Other terms used by industry
practitioners include Internet-based Project Collaboration; Project Collaborative Extranets; Extranet Collaboration; Extranet Working and Project Extranet Working. As a point of reference, the remainder of this paper will use the terms Construction Project Extranet (CPE) to describe a web-enabled extranet system, and Collaborative Extranet Working (CEW) to express the method of using the Internet and a web-browser to access an extranet to facilitate online project information exchange and collaboration.

By extracting the main line of reasoning from the reviewed literature, it is possible to maintain that the fundamentals of CEW are the application of web-enabled technologies and appropriate project management techniques to facilitate online collaboration through better communication and workflow management, and thus ensure efficient information exchange to successfully deliver a project. Whilst the prescribed benefits of working with CPE have been comprehensively debated and are widely acknowledged (ITCBP, 2003:1; CPN, 2004:1; CPN, 2004:2; CPN, 2004:3; Martin, 2003), the barriers have received less consideration per se (CPN, 2001; Hamilton, 2002:1; Breetzke & Hawkins, 2003; CPN: 2004:2). In addition, all of the studies conducted thus far have been based on either individual case studies using interview techniques, or anecdotal evidence provided by success stories reported in the press. There has been no empirical research on a large scale conducted on this topic (Nitithamyong & Skibniewski, 2004).

Furthermore, past research has continually focused on the need for adopting such systems within a single project/system scenario. There has been no investigation into the impact of collaborative working with multiple CPEs within a single organisation. The remainder of the paper provides the key findings of research aimed at examining the issues faced by an engineer consultancy, when having to work with a multitude of different CPEs.

2. RESEARCH AIMS AND OBJECTIVES

The main aim of the research was to investigate the impact of working collaboratively via multiple CPEs in an engineering consultancy. This was achieved through:

- Investigating the organisation’s current approach and attitude to working with multiple project extranets.
- Surveying those projects where an extranet solution was deployed.
- Analysing the impact of the above on the organisation, its employees and project teams.
- Establishing the affects of having to work with different project specific standards and protocols from project to project.

3. METHODOLOGY

This research was conducted as partial fulfilment of an Engineering Doctorate in ICT-enabled collaborative working Methodologies at Loughborough University. It applied both quantitative and qualitative methods of research to provide a comprehensive study on the difficulties of working with multiple collaborative project extranets. An online descriptive questionnaire was used to survey the organisation’s employees about their experiences and to facilitate collection of factual evidence on the realities of CEW. In addition, a series of semi-structured email questionnaires, telephone interviews and
meetings with senior managers of the organisation were used to accomplish investigative research into how the company currently approaches working on CPEs.

4. CURRENT USE OF CONSTRUCTION PROJECT EXTRANETS

An initial survey identified 45 projects within the organisation that have included the application of a CPE with a total company fee value of £32m and a total industry project value of £2.3b. Over the past four years the engineering consultancy has had to collaborate on 19 different CPE systems. Table 1 identifies the four main systems used, along with their percentage share of projects, associated bid values and project values. During this time, there was no sudden explosion in the use of extranets, but rather a slow increase over a sustained period. The number of projects using a CPE has increased on average by 32% each year, whilst the amount of fees earned through CEW has increased at an average of 17.3% per year. Within the industry, the amount of work completed by a CPE in relation to project values has grown at an average rate of 71% a year.

Table 1. The predominant CPE systems used on projects within the engineering consultancy

<table>
<thead>
<tr>
<th>Construction Project Extranet System</th>
<th>Number of Projects (%)</th>
<th>Company Fee (£Millions)</th>
<th>Project value (£Billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asite</td>
<td>27</td>
<td>1.1</td>
<td>0.39</td>
</tr>
<tr>
<td>Information Channel by BIW</td>
<td>18</td>
<td>6.7</td>
<td>0.38</td>
</tr>
<tr>
<td>4Projects</td>
<td>13</td>
<td>9.7</td>
<td>0.26</td>
</tr>
<tr>
<td>Autodesk Buzzsaw</td>
<td>9</td>
<td>1.6</td>
<td>0.20</td>
</tr>
<tr>
<td>15 different systems on single projects</td>
<td>33</td>
<td>13</td>
<td>£1b</td>
</tr>
</tbody>
</table>

4.1 Main Influence in the Use and Choice of a Construction Project Extranet

The Main Contractor was found to be the principal instigator of recommendations for using a CPE on projects (52% of the cases). This was attributed to the fact that a large number have now ‘bought into’ a single CPE system, to reduce costs and service all of their projects, which they then specify as part of their contractual arrangements with the client. The client was next (28%), followed by the Project Team (12%) and then the Architect (8%). The engineering consultancy was only once involved in recommending and choosing a CPE system, as part of a design team looking to adopt a more efficient way of working. The repercussions of this led to each member of the design team contributing an equal share of monies towards purchasing a system. Whilst this is not the normal approach to procurement of a CPE, it may become one that clients increasingly desire in the future. One manager attributed the organisation’s omissions from the early decision making process to the company’s time of appointment, their position within the supply chain and the dominance of Main Contractors with their own systems. This was seen as a major disadvantage, as the company was unable to influence the development of subsequent extranet protocols and therefore, could not ensure that their own project ‘needs’ were considered.

4.2 Procurement Routes

Analysis of which procurement routes were used in conjunction with a CPE found a fairly even distribution between Design & Build (33%), Framework Agreements (23%),
ICT-enabled Collaborative Working

Traditional (21%) and PFI (17%). However Partnering, the most collaborative form of procurement only made up 3% of the projects. Furthermore, no projects were found to employ the use of the new Be Collaborative Contract (BeCC), which is a new form of contract for construction projects that underpin collaborative behaviour (Be, 2004). Supporting collaborative arrangements with an appropriate contract is one of the six critical success factors for collaborative working (Yeomans, 2003). Buckingham (2004) also states that other building contracts such as the JCT must be updated to include clauses to help greater extranet adoption. It can therefore be disputed whether the government, clients and project teams are really doing all that they can at present to support the adoption of CPE to facilitate CEW.

4.3 The Best Time for Implementation

Findings of recent research amongst 322 construction industry clients reveals that few building project groups are taking early decisions on how information will be controlled and exchanged by members of the team or if and how the project will make use of project collaboration tools (ITCBP, 2003:2). Two schools of thought presently exist on the best time to implement a CPE. The first, as early as possible, preferably before project work begins (CPN, 2004:2) and the second, when the amount of project activity warrants the associated costs of using a system. As part of the project survey, Project Leaders were asked to highlight against the RIBA Plan of Work (RIBA, 2004), regardless of procurement route, where the CPE was first implemented on their projects. Table 2 demonstrates that the majority of clients and construction teams are currently inclined to follow the latter, with most extranets being implemented at stage D.

Table 2. Stages of RIBA Plan of Works and where the percentage of projects implements a CPE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>J</th>
<th>K</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appraisal</td>
<td>Strategic Brief</td>
<td>Outline Proposals</td>
<td>Detailed Proposals</td>
<td>Final Proposals</td>
<td>Production Information</td>
<td>Tender Documents</td>
<td>Tender Action</td>
<td>Mobilisation</td>
<td>Construction to Practical Completion</td>
<td>After Practical Completion</td>
</tr>
<tr>
<td>4%</td>
<td>0%</td>
<td>39%</td>
<td>48%</td>
<td>17%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

However, it is argued by a number of industry experts that project teams would experience greater success if they implemented the CPE at the earliest feasible point. This would provide a more rigorous audit trail, force the issue of early involvement for all project members (another of the six critical success factor for collaborative working) and facilitate better project collaboration. The additional costs of employing a system earlier on would be compensated by a project team’s ability to allocate more time to:

- Develop a more conducive collaborative working environment, through consideration of each parties ‘project needs’ before commencing work.
- Learn and adapt to new ways of working with a new system at a far less critical time within the project process.
- Reduce the impact on time and resources lost during training, at a highly intensive stage of the design process.
- Optimise the efficiency of the system and to reduce mistakes before critical stages.
- Develop the appropriate protocols for enhanced project information exchange and collaboration.
4.4 Construction Project Extranet Protocol (CPEP)

The project survey found that 20% of the projects, with a total industry project value of £342m, had used a CPE without any form of Construction Project Extranet Protocol (CPEP) to aid CEW. Table 3, outlines the realities of working without a protocol by way of project workers comments on the experience. When questioned if a CPEP was available on these projects, employees replied with answers such as no, but it would have been useful to have one. Observations of employees working on projects with no CPEP found a tendency for them to be significantly more disillusioned, frustrated and hostile towards working with the CPE system, even if they had received training.

Table 3. Employees’ accounts of working on a project with a CPE and without a protocol

<table>
<thead>
<tr>
<th>Employees’ Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• I believe most of the problems we are encountering on this project stem from a lack of protocols on how to use the extranet”.</td>
</tr>
<tr>
<td>• The client was confused about how to use the system and we were not given a protocol on how to use it. Not many users understand what’s going on.</td>
</tr>
<tr>
<td>• The technology is there but no one knows how to use it properly. The site is not properly managed. It’s like attending a meeting where no one is in charge. The information is there but no one is controlling it, or maintaining it properly. No thought was given to the structure of the site.</td>
</tr>
<tr>
<td>• Delays in releasing protocol information and substantial revisions to the protocols well into the project caused a backlog of problems. Team members did not know in what way to use Project Extranet. There were disputes about when information was requested or given which were not easy to resolve.</td>
</tr>
<tr>
<td>• The Project manager believed that by having an extranet site, document control was taken care of. However the system needed to be correctly used, policed and supported with a sensible protocol.</td>
</tr>
</tbody>
</table>

Although the remaining 80% of projects had implemented some form of a CPEP, they were all found to be ad-hoc and client or project-specific. Furthermore, only 4 out of 65 workers questioned were able to show the Research Engineer where on the system the protocol was stored. Employees also expressed concern about how protocols focused on ‘how to use’ the designated extranet system and failed to consider other issues such as information exchange, contractual relationships, workflow and collaboration. The following were established as the main reasons for protocols not being sufficiently developed:

• A large number of the parties, who worked on the CPE, were not represented at the protocol development stage and therefore their project needs were not accounted for.
• Development was left to a small group of people who did not necessarily have the appropriate knowledge and experience to balance processes, people, technology and collaborative working methodologies.
• The absence of a generic industry template to guide project teams through the process.

It is critical that an early decision is made from the outset of the project on what electronic system is to be used and how it is to be controlled (ITCBP, 2003:2). It is also imperative to have a well-developed, clearly defined CPEP to facilitate implementation and management of the system, as well as providing guidance on how to work and collaborate via the extranet. The admission of a protocol or a poorly developed one
could arguably be the single largest barrier to the successful application of a CPE on a project; due to the many issues an effective protocol would help overcome.

4.5 The Need for a Company Construction Project Extranet Protocol (CCPEP)

Seven of the organisation’s senior managers indicated the need to develop a generic Company Construction Project Extranet Protocol (CCPEP). This was needed to help employees understand how to comply with their own company procedures, set out in the Quality Management System (QMS), along with those imposed upon them by the project and CEW working. The absence of clear internal procedures for extranet working was identified as a major cause of mistakes and subsequent rework to correct them. This also had a detrimental effect on CPE users’ confidence in the systems ability to improve the process. The QMS Manager acknowledged that internal procedures required updating with clearly defined processes for CEW that were generic enough to be applicable to any project and CPE. Development of a CCPEP was seen as invaluable both as a means to improving the organisation’s approach to CEW, and in helping the company to express their own extranets requirements on projects in future.

4.6 Coordination and Management of Information and Communications

One element that is important in all collaboration is communication (Augenbroe et al, 2002). It is the key to the successful use of web-based technology – giving the right message to the right people at the right time, with speed, transparency and efficiency (CPN, 2001). Additionally, information must be relevant, correct and controlled to ensure that project teams are working on the latest versions and do not waste time on trying to find or unravel poorly structured information. Together, appropriate communications and information exchange provide the basis for good workflow management. Whilst many employees agreed that a CPE had helped information flow faster, they also felt that its use had hampered or in some cases been detrimental to communication and relationships on the project. Employees reasoning for this were as follows:

• Problems are not resolved as quickly on the extranet as they are by telephone calls; as not everyone is online all the time, which causes delays.
• A telephone call allows a person to seek an answer and facilitates an understanding of how a person is reacting to the situation through human interaction and perception.
• Replacing traditional forms of communication (such as the telephone) with electronic forms (such as online discussions) was deemed counterproductive, as it was less personal, and could potentially be more aggressive.
• Limiting human interaction through electronic communication causes relationships and team working to breakdown.
• Collaboration requires constant human interaction as well as electronic communication – it’s not just about information exchange.
• The use of external email systems was faster and less complicated to work on than that of the extranet system.
Poor management of project information through the CPE system (both internally and externally) was attributed to a combination of the following factors:

- Poorly set user permissions enabled users to continuously change and upload information with little or no control.
- There were large numbers of people creating, manipulating and moving information on a system at any one time.
- 58% of users placed information onto a system incorrectly, sending it to all parties ‘just in case’ they needed to see it, or because they were not sure who should view and comment on it.
- Users were overloaded with vast quantities of irrelevant information. On average, 1.9 hours per week, per member was lost to checking information for relevance.
- Team members turned off ‘notifications’ due to being deluged by emails throughout the day requiring ‘action’ for newly posted items, many of which had no relevance to their tasks.

As a consequence of the above, project workers were working on outdated information, missing critical changes, continually aborting work and undertaking considerable amounts of rework. Project Leaders were constantly concerned about not being able to regulate the flow of information and missing critical information. They were also reluctant to trust others to release information; in case it was incorrect, not relevant, or had legal implications.

4.7 Knowledge Management

Due to the almost stealth like emergence of extranet working within the company, there has been a tendency to react to the needs of CEW on an individual project-to-project basis; rather than develop a standard approach, which has resulted in knowledge on each system and the ‘lessons learnt’ being lost. For example, one project team had developed an internal protocol to work with a particular extranet system, yet four further but separate projects all using the same system, were unaware of its existence. Project teams were ‘reinventing the wheel’ each time they set up on a project, and employees had to go through the same steep learning curve and mistakes already experienced by others. Knowledge transfer only happened when an employee worked on two projects simultaneously and used the same system, although this is not usually due to good planning. Better knowledge management for extranet working must be used to capture the idiosyncrasies of each system, along with users experiences, protocols, do’s and don’ts, and even which clients use which systems on all their projects. This should be used to create expert communities supported by expert users to service projects more efficiently in the future.

4.8 Attitudes to Construction Project Extranets

The predominant number of senior managers expressed doubt as to whether CPEs were really employed to facilitate project collaboration, despite their clients informing them to the contrary. Many felt their client’s real objective was to obtain a more stringent surveillance method to control how they worked. Terms such as ‘a stick to beat the consultants with’, ‘a method of secret policing’ and ‘big brother’ were often used to
describe the CPE. Others felt that they had no choice about having to work on a CPE and were resentful of this fact.

4.9 Training Issues

On 23% of the projects, clients and project teams had made no provision for training the consultant’s employees on use of the CPE. 67% of workers who stated that they found working on a CPE difficult, had received no training. 83% of users indicating that they found it easy to work with a CPE had received training. This demonstrates a relationship between training and a person’s perceptions about their ability to use a CPE. However, three quarters of employees were not happy about the quality of training they had received. More encouraging was the finding that 77% of training was received before a person began operating on a system.

4.10 Reversion to Type

Much is spoken about collaborative working and integrated teams, yet although the potential benefits are well understood, we still often hear about ‘reversion to type’ when problems arise or things get tough (CPN, 2004:1). This was also discovered to be true of CEW. Observations often found employees ignoring the CPE and reverting to exchanging information via company email, particularly when deadlines were tight or, they were not happy about working with new technology and processes. This was attributed to the lack of standards, clear processes, training and failure to manage resistance to change. Reversion to type not only creates additional work and invalidates the electronic audit system but also slows the whole process down. Furthermore, the company incurs unnecessary costs from the additional use of paper, ink, time and cost of human resources. The end result is a loss of benefits to the individual, the project, the company and ultimately the industry. In order for the construction industry to successfully embrace web-enabled project management tools, at a large scale, it must equally consider technology, process, people, procurement, legal issues and knowledge management (Alshawi & Ingirige, 2003 & Miroslaw & Skibniewski, 2004).

5. CONCLUSION

Since the turn of the new millennium, project teams have become increasingly reliant on the use of a CPE to help facilitate information exchange and collaboration. Whilst the benefits associated with using a single CPE are widely acknowledged, the implications for an engineering consultancy required to undertake CEW via multiple systems are not. Research into this subject has established a number of key findings:

- Having to collaborate via a large number of different systems on a regular basis and not having a generic approach to extranet working has led to many problems.
- It is not yet possible to identify which procurement route and accompanying contract are right for successful delivery of CEW. It is therefore difficult to understand and mitigate the risks of undertaking CEW on a client’s chosen procurement path.
- Not having input into the selection and implementation of CPEs on projects is a major disadvantage for the consultant, as they were unable to influence the
subsequent development of protocols to ensure that their own project needs were considered.

- 20% of industry projects (with a total industry project value of £342m) had used a CPE without any form of protocol to aid project teams in successful CEW.
- Existing protocols were ad-hoc, project-specific and focused exclusively on how to use the designated extranet system; failing to provide consideration of other critical issues. The majority of users also found protocols to be either unhelpful or unusable.
- There is no recognised generic industry template to aid project teams through the process of developing a protocol, necessary to ensure successful application of CPE and attainment of greater benefits for all concerned.
- The omission or use of an inefficient CPEP is the largest barrier to the successful application of a CPE on a project.
- Consulting organisations would benefit greatly from the development of internal protocols for CEW.
- Significant problems are created by poor management of project information and communications through the CPE, by both the internal and external parties.
- The need exist to prevent reversion to type, as a high proportion of users were not using the system or tools available to them and reverted to old working methods.

6. RECOMMENDATIONS & FUTURE WORK

Based upon the above findings, the following recommendations (for future work) are submitted for consideration by the construction industry:

1. Ascertain a system for measuring the benefits of using CPEs to facilitate CEW in conjunction with various procurement routes and contracts. This would facilitate better understanding of the associated risks and chances of success with each path.
2. Develop a generic industry recognised and accepted protocol to aid clients and construction teams in the production of their own CEW protocols.
3. Organisations whose work increasingly depends on collaborating via extranets should seek to develop their own internal protocols; ensuring that it is generic enough for any project scenario, CPE system and potential future industry standard protocol.
4. In the absence of an industry standard protocol, project teams would be well advised to adopt the principles of early involvement and ensure all parties are engaged in the development of a protocol at the earliest opportunity, if they are to secure maximum benefits from using a CPE.

7. REFERENCES

ICT-enabled Collaborative Working


ITCBP. (2003: 1) “Adopting internet based project collaboration software” Making IT work for your business, Case Study IT039, IT Construction Best Practice, Davis Langdon Consultancy, London, UK.


Appendix Three: Paper Three

PROVISIONS FOR PROFICIENT CONSTRUCTION PROJECT EXTRANET PROTOCOLS TO FACILITATE COLLABORATIVE EXTRANET WORKING

ABSTRACT: Construction teams within the industry are recurrently adopting Construction Project Extranet (CPE) systems to facilitate project integration and collaboration. When deciding to adopt a CPE, it is important to support their use with a clearly defined Construction Project Extranet Protocol (CPEP). Prior investigations found that the principal cause of their inefficient use was associated with missing, or poorly developed protocols. Project teams also cited the lack of a generic industry standard as the main reason for not being able to produce practicable CPEPs. This paper reports on the findings of a study, to establish the main requirements for development of a proficient CPEP and investigate the need for a generic toolkit to aid project teams. It identifies the key issues to be considered, along with the findings of a survey on current CPEPs. The paper concludes by proposing a set of recommendations for improving the way in which CPEP are produced.

KEYWORDS: Construction Project Extranets; Collaborative Extranet Working, Protocols.

1. INTRODUCTION

Construction teams within today’s AEC industry are becoming increasingly reliant on the deployment of Construction Project Extranets to facilitate project information exchange and collaboration; whilst individual organisations endeavour to use them as a tool for generating improvements in quality, competitiveness, profitability and client satisfaction. A survey conducted in the UK by The IT Construction Forum (2004) affirms that the use of extranets is growing rapidly, with nearly half of all respondents indicating they had used a project extranet to collaborate online (43% of the 373 responding firms). Within the context of this paper, the term Construction Project Extranet (CPE) refers to an extranet system, which is supplied by an Application Service Provider (ASP) and is subscribed to by a project team for a fee, either on monthly, yearly or project-to-project basis. Project members utilise the internet and web browser technologies to securely exchange and store project information via the ASP’s central repository. This is now the most commonly adopted method of implementing a CPE on a project, as systems are available ‘off the shelf’, can be setup within a short time frame and costs relatively little (when compared to the option of developing an ad-hoc system, which requires a great deal of expertise, resources, time and money).

The use of the web and associated technologies in such instances has now been widely acknowledged by practitioners (Nitithamyong & Skibniewski 2004) and is also described by various designations including: Project Specific Web Sites (Thorpe & Mead 2001); Project Collaborative Extranets (Hamilton 2002a); Web-enabled Project Management (Alshawi & Ingirige 2003); Online Project Management and Collaboration Tools (Unger 2003); Web-enabled Project Management Systems (Nitithamyong & Skibniewski 2004); Web-based Project Information Management (Stewart & Mohamed 2004) and Construction Project Extranets (Murphy 2001). A detailed précis on the evolution of CPEs along with an examination of their ever-increasing adoption within the USA is offered by Becerik (2004).
Within the UK, prior investigations primarily focused on understanding the impact of working with multiple CPEs within a single organisation, found that the principal cause of ineffective or inefficient use of CPEs stemmed from missing or poorly developed protocols (Yeomans et al. 2005). 20% of projects surveyed (with a total value of £342m) were found to have instigated the use of an extranet without a supporting protocol, despite many project members having to perform their duties in new ways. Additionally, although the remaining 80% of projects (with a total industry project value of £2.1 billion) had introduced some form of protocol, users reported that they were usually ad-hoc and inadequate; as they focused exclusively on how to use the designated extranet system and provided little or no consideration of the other essential issues such as how to attain effective integration and collaboration. Project teams cited the apparent lack of both a generic industry standard along with comprehensive guidance notes on how to undertake extranet working, as the main reasons for not being able to produce practicable protocols.

The remainder of this paper aims to contribute to the growing knowledge base on the subject of CPEs by providing the key findings of additional new studies, undertaken to evaluate the importance of a protocol in facilitating efficient Collaborative Extranet Working (CEW).

2. RESEARCH AIMS AND OBJECTIVES

The main aims of the research were: to investigate the need to develop a generic industry recognised and accepted protocol, to aid clients and construction teams in the production of their own; and to establish which material construction teams deem most crucial for inclusion within the proposed development of a generic protocol. This was achieved through:

- Surveying 48 projects, where 22 different CPE systems were deployed.
- Examining eleven different protocols that were already employed by project teams.
- Surveying CPE administrators and users who worked by existing protocols.
- Participating in the development and review stages of five different protocols.

3. METHODOLOGY

This research was conducted as partial fulfilment of an Engineering Doctorate in Collaborative Working Methodologies at Loughborough University. It applied both quantitative and qualitative methods of research to facilitate a comprehensive study on understanding the main issues surrounding current development and use of protocols, whilst also determining which issues are crucial to the development of a generic industry protocol. A descriptive questionnaire was used to survey CPE managers, administrators and document controllers to facilitate collection of factual evidence on the realities of working to existing protocols. A series of project studies and observations along with meetings with senior manages, ASPs, and other CPE experts were used to accomplish investigative research into how projects currently approach the development of protocols. To aid the acquisition of subject knowledge, the Research Engineer (RE) also conducted a literature review, participated in the development of five protocols and conducted collaborative extranet working trials whilst managing a CPE system (Buzzsaw Standard) with three live projects over the past 18 months. Other
activities included: attending UK industry conferences Project Extranets IV & V (PE 2003, 2004); attending extranet vendor presentations; undertaken training on four different systems; and administrator training on two. These activities have proven invaluable as a means of attaining firsthand experience and knowledge of the issues surrounding working with extranets and developing protocols.

4. OBSERVATIONS ON CONSTRUCTION PROJECT EXTRANET PROTOCOLS (CPEP)

The following section provides a précis of the key issues derived from an amalgamation of literature review findings, project observations and experience gained whilst participating in the process of developing Construction Project Extranet Protocols.

4.1 Varying Levels of Complexity in CPEPs

Project teams utilise CPEs in one of three main ways (see Fig. 1), either as a simple means of transferring files between parties (Hamilton 2002b), as a comprehensive Electronic Data Management (EDM) tool, or as a means to achieve project collaboration (Hannay 2004). Yeomans et al (2005) refers to the last of these options as Collaborative Extranet Working (CEW).

Figure 1. The three levels of CPE operation and the increase in complexity of each process (adapted from Hannay 2004).

In all cases, it is critical that an early decision is made from the outset of the project as to which electronic system is to be used and how it is to be controlled (ITCBP 2003a). Project teams should develop a set of procedures to assist workers in achieving effective use of the CPE and therefore ensure greater overall project efficiency. These procedures are often referred to as ‘extranet protocol’, ‘protocol document’ or a ‘Construction Project Extranet Protocol’ (CPEP). Attention to detail in the creation of procedures is vital (CPN 2001), although the scale of detail required, along with the amount of effort, resources and time expended should match the chosen level of CPE operation. Use of a CPE to conduct file transfers requires relatively simple procedures, whilst a protocol to aid EDM should be increasingly more detailed. A protocol for CEW will need to be substantially more detailed, as collaboration involves a high level of complexity (Austin et al. 2001) and is still not so fully developed that proper implementation planning can be ignored; strategic support through the process is still required (CPN 2001).

4.2 Main requirements of CPEPs

In order to determine the main requirements of a generic protocol, as well as formulate a questionnaire about their availability in current CPEPs, the RE conducted a review of existing literature in addition to surveying 11 project protocols.
A considerable difference was noted between the contents of operational protocols, which concentrated on the ‘nuts and bolts’ of how to use the designated CPE system, and recommendations made by experts (CPN 2001, 2004a, 2004b, 2004c) along with issues raised by experienced CPE users (Yeomans et al. 2005). Issues include: monitoring protocol compliance, overcoming resistance to change, process management, continuous improvement, organisational cultural management, teamworking, collaboration, interoperability, data ownership, resource management, contractual arrangements and Quality Assurance (QA). Figure 2, provides a comprehensive list of those items and issues a proficient CPEP should consider, whilst categorising them in accordance to the levels of operation for a CPE. In the case of CEW, all three levels would need to be taken into account. Examination of the working protocols and experience gained from the development process found all CPEPs to include the majority of the items listed in levels 1 and/or 2, but none of those contained in level 3 (see Fig. 2). Therefore, it is appropriate to argue that CPEPs are not proficiently developed to foster true project integration and CEW; despite clients and project teams indicating these as reasons for adopting the use of a CPE. To enable understanding of the reasons why protocols were not being adeptly formed, it was necessary to examine the role of ASPs in the initial stages of CPE adoption.

**Figure 2.** The levels of CPE operation and their respective protocol considerations

### 4.3 Influence of ASPs on CPEP Development

Only one out of the eleven protocol documents reviewed was not primarily developed and supplied by an ASP. In this case, the project team decided to develop an ad-hoc, in-
house extranet solution, which meant no ASP was present in the process. All remaining CPEPs originated from generic documents produced by an ASP. This was attributed to project teams’ inexperience of CEW, their lack of understanding as to the requirements and the relationship between the adopters of the CPE and the ASP. The way in which relationships are formed depends largely on one of the following sets of circumstances happening:

1. A client has previous experience of working with CPEs and specifies use.
2. A client (who has no previous experience of CPEs, but is knowledgeable about the benefits) requests that the project team investigates and recommends a suitable system.
3. An individual team member has experience of, or understands the benefits of CPEs and suggests/persuades the rest of the project team to adopt the use of a CPE.
4. The Main Constructor (MC), who has an arrangement with a particular ASP to service all of their projects, specifies use as part of their contractual arrangements.

As those within the first three instances were found to have relatively little or no long-term exposure to working with CPEs and lacked the necessary experience and expertise to understand how to implement and utilise a CPE to best suit their project needs, they would:

- Rely heavily on ASPs to provide the necessary expertise to setup and manage use of the system; due to their expertise in the use of the respective systems.
- Allow ASP administrators to provide generic protocol templates (formulated from use of their own system on past projects) and supervise project teams whilst revising them to suit current project needs.
- Believe that adopting a CPE and allowing the ASP to support the implementation of the system would naturally result in effective use of the CPE and lead to collaborative working (as the ASPs are selling tools to foster collaboration).

In the fourth instance, the main contractor has usually developed more experience both of working with extranets and with ASPs, due to the nature of the long-term arrangement between the two parties. As a result, protocols on these projects were more detailed and had considered a wider spectrum of issues; although they still did not include those specified for CEW (level 3, Fig. 2). Additionally, they were still based upon generic templates developed in the first instance by ASPs. It is therefore proffered that in cases where a rented CPE solution has been sought, ASPs are required to become the main drivers and facilitators of the CPEP development process; although in all probability that they are no more suited to delivering a proficient protocol. ASPs are adept at delivering protocols to assist users work on their particular systems, as they are experts in developing electronic systems. However, they are not experts in delivering efficient collaborative working based upon a collaborative contract and continuous improvement. This argument is corroborated by Bercerkik (2004) who found systems to be very document-orientated; which has led the industry to move towards shuffling electronic paper rather than electronic collaboration.

4.4 Development and Implementation of CPEPs

The following describes the archetypal approach to development and implementation of a CPEP on large construction projects. It is by no means indicative of all cases.
Parties responsible for purchasing a CPE will normally work with the ASP (as shown by the options 1, 2 & 3 Fig. 3) to further develop the ASPs generic template into an appropriate form for the current project. This may be completed through a series of meetings, workshops or ‘postings’ (placing the document on the extranet for review). Once the main members issues and project requirements have been addressed, those responsible for developing the CPEP may follow one of two courses of action. Either invite all other parties (currently contracted to the project) to read and comment on the proposed protocol; notifying the document administrator of any issues or specific needs e.g. exclusive folder for photos. Or, conversely, publish the guide without consultation and request all other parties to work to the procedures. The ITCBP (2003b) stipulates protocols must be agreed from the beginning by all - it is a partnering process.

The ASP maintains an active role throughout, mainly to provide advice, setup the system and deliver training. Nevertheless, they will also ensure that procedures being included within the CPEP document are consistent with their systems abilities and protocols (e.g. inherent electronic workflow procedures). Perhaps the most difficult task facing any protocol development team is deriving a solution that satisfies each member’s project requirements, whilst still being acceptable to all others. This was never achieved on a single one of the projects surveyed, as a large number of the parties who were to work on the CPE, were not represented at the development stage, and therefore their needs were not accounted for.

A good protocol must also provide equal consideration of individual company QA procedures, project procedures and the inherent protocols of the specified extranet system (as shown in Fig. 3). At present, this does not happen and company procedures are usually sacrificed at the expense of the other two. As a result, many organisations struggle to understand the benefits of working on a CPE due to them having to duplicate work in order to satisfy both in-house procedures and those of the project. This sometimes created resentment, both towards the CPE and those championing its use. It also led to various organisations:

- Refusing to adopt the CPEP and reverting to old methods of working e.g. company email and issuing paper copies (option A, Fig 4);
- Wrongly interpreting the CPEP and developing and/or adopting inefficient modes of working; or
- Bypassing the CPE’s audit system by using a single person to interface with the CPE (option C, Fig. 4).

If any of the above problems transpire, the CPEP should be determined as failing in its primary objective, to have everyone working in the same, integrated and efficient manner (option B, Fig. 4).
Figure 3. CPEP development and implementation options

![Diagram showing different options for CPEP development and implementation.

**KEY:**
- ASP = Application Service provider
- CPE = Construction Project Extranet
- ASPA = ASP Administrator
- DC = Document Controller
- CEA = Company Extranet Administrator
- FM = Facilities Management
- QS = Quantity Surveyors
- PM = Project Manager

Figure 4. Realities of working with or without current CPEPs

![Diagram illustrating the realities of working with or without current CPEPs.

**A** Without Protocol
- Uncontrolled and uncoordinated, sporadic use of CPE

**B** Desired Approach
- Fully integrated and ICT-enabled collaborative working through appropriate protocol

**C** Current approach with protocol
- Some control and constrained use of the CPE with limited collaborative working

---

Appendix 3: Paper 3 – Collaborative Extranet Working Protocols
5 CPEP QUESTIONNAIRE SURVEY RESULTS

An electronic questionnaire was sent to 159 individual CPE managers and administrators throughout the industry to question them about current CPEPs, to:

- Determine those issues currently being included within the protocol document.
- Gauge opinions on the success rates of CPEPs.
- Ascertain if additional issues were required for inclusion.
- Assess reaction to the planned development of a generic industry protocol and best practice guide.

23 people responded to the survey, providing a response rate of 14%. CPE managers (seven) and administrators (seven) were the largest responding groups, followed by CPE document controllers (five). Between all of the respondents, they had gained experience of working on 211 different projects where a CPE was used. 123 (59%) of these had developed and implemented some form of CPEP.

5.1 Findings on Current CPEPs

Table 1, demonstrates that current CPEPs focus most often on the use of the system and its tools, and sometimes covers issues such as EDM and electronic workflow. The majority of respondents also indicated that other crucial issues were not likely to be included; substantiating arguments made in section 4.2. When questioned about the ability of current CPEPs to helping project members work more efficiently on project extranets, and therefore bring about savings in time and project costs through effective CEW, nine people indicated that they felt protocols had been partly unsuccessful, eight people felt they had been partially successful, whilst 6 people felt they were very unsuccessful. Overall, the mean score found that CPEPs have been unsuccessful.

<table>
<thead>
<tr>
<th>Procedures required for effective CEW</th>
<th>How often (No. of people)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never</td>
</tr>
<tr>
<td>Use CPE tools and system</td>
<td>6</td>
</tr>
<tr>
<td>Conducting EDM</td>
<td>4</td>
</tr>
<tr>
<td>3D model coordination</td>
<td>18 x</td>
</tr>
<tr>
<td>Conducting collaboration</td>
<td>13 x</td>
</tr>
<tr>
<td>Managing online relationships</td>
<td>11 x</td>
</tr>
<tr>
<td>Collaborative contract duties</td>
<td>15 x</td>
</tr>
<tr>
<td>Align QA &amp; project procedures</td>
<td>16 x</td>
</tr>
<tr>
<td>Managing online workflow</td>
<td>6</td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>16 x</td>
</tr>
<tr>
<td>Change Management</td>
<td>16 x</td>
</tr>
<tr>
<td>Data and software compatibility</td>
<td>8</td>
</tr>
<tr>
<td>CPEP compliance monitoring</td>
<td>12 x</td>
</tr>
<tr>
<td>CPEP strategy</td>
<td>13 x</td>
</tr>
</tbody>
</table>

* x Used to facilitate easy identification of largest response
Respondents were also asked to specify how important it is to include information on the procedures outlined in section 4.2. None were determined as unimportant (Table 2), which signifies they all must be considered when developing a CPEP. Two additional items were also gained from a question asking if there were any additional items that should be addressed. These were:

- What to do when the CPE is unavailable and information requires publishing.
- Highlighting the impact of failing to follow protocols.

Both are important issues, and although they were not originally identified by the author as requiring individual recognition, it is recommended they form an integral part of any CPE strategy.

Finally, CPE users were asked how important is a good protocol to the successful application of an extranet system on a project. Fifteen (65%) responded by ticking ‘very important’. All but one of the remaining group said that it was ‘important’, with the single individual stating they were ‘neutral’.

Table 2. Respondents’ views on the importance of containing various procedures within a CPEP.

<table>
<thead>
<tr>
<th>Procedures</th>
<th>How important (No. of people)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Use CPE tools and system</td>
<td>16 x</td>
</tr>
<tr>
<td>Conducting EDM</td>
<td>17 x</td>
</tr>
<tr>
<td>3D model coordination</td>
<td>10 x</td>
</tr>
<tr>
<td>Conducting collaboration</td>
<td>15 x</td>
</tr>
<tr>
<td>Managing online relationships</td>
<td>11 x</td>
</tr>
<tr>
<td>Collaborative contract duties</td>
<td>9</td>
</tr>
<tr>
<td>Align QA &amp; project procedures</td>
<td>6</td>
</tr>
<tr>
<td>Managing online workflow</td>
<td>10 x</td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>4</td>
</tr>
<tr>
<td>Change Management</td>
<td>9</td>
</tr>
<tr>
<td>Data and software compatibility</td>
<td>11 x</td>
</tr>
<tr>
<td>CPEP compliance monitoring</td>
<td>6</td>
</tr>
<tr>
<td>CPEP strategy</td>
<td>7</td>
</tr>
<tr>
<td>Strategy for CPE use</td>
<td>14 x</td>
</tr>
<tr>
<td>Project roles &amp; responsibilities</td>
<td>14 x</td>
</tr>
<tr>
<td>CPE roles &amp; responsibilities</td>
<td>18 x</td>
</tr>
<tr>
<td>Training provisions</td>
<td>13 x</td>
</tr>
<tr>
<td>Flow charts for procedures</td>
<td>6</td>
</tr>
<tr>
<td>Technical requirements</td>
<td>10</td>
</tr>
<tr>
<td>Technical support</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual property rights (IPR)</td>
<td>12 x</td>
</tr>
</tbody>
</table>

x used to facilitate easy identification of largest response.
1 = very important, 2 = important and 3 = not important.
5.2 Developing CPEPs

Ten respondents had been involved in the course of helping project teams form a CPEP. All indicated that undertaking the task for the first time proved to be either a difficult or very difficult process. Two common themes were apparent throughout all of the reasons (provided in supporting statements) why respondents had encountered such an experience. Firstly, that the most problematic part of the process was trying to get people to agree and work together, (collaborate). The second was not enough guidance and a lack of expertise (best practice experience).

When asked to rank four given barriers to the successful creation of an extranet protocol, they were positioned in the following order:
1. A lack of best practice guidance, generic templates and guidance notes.
2. Relying on the extranet system vendor to facilitate the process.
3. Adapting an ad-hoc template from another project.
4. A lack of necessary expertise to call upon.

When asked to rank four known issues that hamper efforts to create a successful CPEP, respondents placed them in the following order:
1. A lack of expertise and experience within those responsible for development.
2. Not having all project team members involved in the process.
3. Having to rush the process as the CPE was already being used.
4. A lack of commitment to the process from project team members.

Responses to this section suggest that there is a lack of participation in the process from professionals who are well versed at the ‘art of collaboration’. Furthermore, projects teams wanted to seek additional assistance or expertise, but were not sure what was available or where to obtain it.

5.3 Requirements for A CPEP Toolkit

To appreciate what assistance project teams require in developing a CPEP, they were asked to indicate in which one of four services they would most likely use, if they were available. These were, in order:
2. A generic extranet protocol (template document that can be adapted to individual projects).
3. Specialist designated software (step-by-step guide with input boxes to complete).
4. Professional extranet coordination services (employing consultants to facilitate the process).

The survey then asked which format respondents would most like to see a CPEP toolkit presented in. Sixteen (70%) people chose a web-based guide with generic document that could be completed online.
5.4 Respondents Opinions to Key Research Findings

The final section of the electronic survey asked respondents to indicate their reactions to five statements, formulated from key findings of the overall research project. The statements were:

1. The use of poorly developed extranet protocols, or non use of them, leads to the ineffective and inefficient use of construction project extranets.
2. Current extranet protocols are ad-hoc, project-specific and inadequate, as they focus on how to use the designated extranet system but provided little or no consideration of other critical issues such as integration and collaboration.
3. The lack of an industry generic extranet protocol and guidance documentation, make it difficult for project teams to develop practicable extranet protocols.
4. Project teams would benefit greatly from the availability of an industry approved, generic extranet protocol toolkit.
5. The availability of a generic industry extranet protocol would facilitate more efficient collaborative extranet working.

As shown in Table 3, the majority of respondents agreed, or strongly agreed with all five statements. Whilst the low survey response means these statistics cannot be used to demonstrate an industry wide opinion, a strong grouping of responses to the five statements can be seen to validate the findings of the research.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>14</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>11</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>11</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>11</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

6. CONCLUSION

Application Service Providers (ASP) lease-based Construction Project Extranet (CPE) systems are increasingly deployed on construction projects as a means to facilitate project information exchange, integration and collaboration. However, existing research shows that clients and project teams are failing to realise the full potential of such systems (in terms of project cost savings) due to missing or poorly developed Construction Project Extranet Protocols (CPEP). Additional research conducted by the authors on the subject of CPEPs, their importance in assisting Collaborative Extranet Working (CEW), and the proposed subsequent development of a generic CPEP toolkit reached the following conclusions.

There are three levels of CPE operation, simple file transfers, Electronic Data Management (EDM) or CEW. Regardless of the level chosen, the project team will
need to develop a set of procedures (a CPEP) to help workers achieve effective use of the system; therefore ensuring greater overall project efficiency. The CPEP must also be tailored to suit the chosen level of operation. As the need increases for the CPE to facilitate collaborative working, so to does the need for greater strategic management and a more proficient CPEP; to ensure successful application of the system. The issues that an adept protocol should consider, in accordance with the CPEs level of operation, has been compiled and included within Figure 2 (p. A3-24). The relevance of these issues along with the importance of their inclusion within a CPEP was authenticated by the survey response.

All protocols must provide equal reflection of company, project and extranet system procedures. At present, company procedures are usually sacrificed at the expense of the others. The most difficult task facing a team trying to develop a CPEP is ascertainment of a document that satisfies the individual’s requirements, whilst still being acceptable to all others. Respondents who had participated in the protocol development process substantiated this. All indicated that undertaking the task for the first time proved to be difficult and most supporting statements mentioned the main issues were: trying to get people to agree and work together (collaborate), and the lack of available guidance.

Current protocols were found to partially unsuccessful at achieving effective working and delivering savings in project costs. They include the majority of items identified for undertaking EDM, but none of those listed for achieving CEW. Therefore, they are not sufficiently developed to foster true collaboration. This was attributed to the teams lack of experience in understanding what was required, along with their subsequent reliance on ASPs to manage the process. ASPs deliver protocols that mainly assist users to work with their particular systems, but lack consideration of other crucial issues. This has seen them contribute to the industry’s move towards shuffling electronic paper rather than helping to achieve electronic collaboration. Whilst a detailed listing of the main barriers, that hamper creation and implementation of a successful, can be found in Section 5.2, the two main issues identified by the survey were:

- A lack of expertise and experience within those responsible for development; and
- A lack of best practice guidance, generic templates and guidance notes.

When questioned about how project teams felt they could best be assisted in the process of developing a CPEP, the majority (16) stated that they would want a best practice guidance document (explaining how to develop an extranet protocol). They also indicated that a web-based guide with generic documents that could be completed online, would be the most desirable form of media.

The general consensus between those CPE managers, administrators and document controllers (who responded to the survey) agreed with the following statements formulated from the research:

- Poor CPEPs lead to inefficient use of CPEs.
- Current CPEPs are inadequate.
- The lack of a generic template and guidance documentation makes it difficult to develop practicable extranet protocols.
- Projects would benefit greatly from the availability of an industry approved, generic CPEP.
- The availability of such a document would lead to more efficient CEW.
7. RECOMMENDATIONS

Based upon the above findings, the following recommendations are submitted for consideration by the construction industry and where applicable, future work:

- Clients, project teams and ASPs must develop and implement CPEP on all projects, where a CPE is to be used.
- Appropriate time and effort should be expended in the development of CPEPs, and at the earliest feasible time. Doing so will encourage greater successful adoption of the system.
- Teams responsible for developing a CPEP should identify which of the three levels of operation is required and ensure consideration of the appropriate items (as outlined in Fig. 2).
- Protocols must provide equal reflection of companies, projects and extranet system procedures and not sacrifice one at the expense of the others.
- Clients and project teams would benefit from adopting external expert assistance on how to ascertain efficient collaborative working.
- ASPs should provide greater consideration of other critical issues surrounding the use of the system on a project, not just efficient use of their system. When selling a collaborative solution, it should ‘do exactly what it says on the tin’.
- The need exists to develop a best practice toolkit, which aids development and implementation of practicable CPEPs on projects. This should be presented to the industry in the form of a web-accessible application.

8 REFERENCES


Appendix Four: Collaborative Prototyping Interview Questions
SECTION ONE: YOU AND YOUR COMPANY

Questions:
1.1 What position / title do you hold?
1.2 How many employees does your company employ?
1.3 How would you describe your company?
1.4 What type of work is your company mainly involved in?
1.5 How long have you been involved with the concept of collaborative working?
1.6 What types of experience have you had in collaborative working?
1.7 What experiences have you had of working collaboratively using 3D modelling?
1.8 Does your company have a formal collaborative strategy (please explain why or why not)?

SECTION TWO: YOUR CONSIDERED OPINION ON ESTABLISHED COLLABORATIVE WORKING PRACTICES

Questions:
2.1 What would you determine as established collaborative working practices (not including 3D modelling)?
2.2 How effective do you believe these practices are?
2.3 What do you believe are the benefits of these existing practices?
2.4 What do you believe are the disadvantages of these existing practices?
2.5 Has your company been able to quantify the benefits / losses of working collaboratively (please give details)?

SECTION THREE: YOUR CONSIDERED OPINION ON DEVELOPMENTS IN COLLABORATIVE WORKING

Questions:
3.1 In your opinion, what would you determine are new developments in collaborative working (not including 3D modelling)?
3.2 What do you believe these new developments will do for collaborative working?
3.3 In your opinion, how could these developments have been better formulated?
3.4 Do you think these new developments will meet the industry’s requirements for an efficient collaborative working solution (please explain your answer)?
SECTION FOUR: YOUR CONSIDERED OPINION ON THE EXISTING USE OF 3D MODELLING AND PROTOTYPING WITHIN THE INDUSTRY

Questions:

4.1 What percentage of the industry do you believe use 3D modelling / prototyping to facilitate project collaboration?
4.2 What do you believe to be the reasons for this amount of usage?
4.3 What would you consider the main tools for 3D prototyping are at present?
4.4 How successful do you believe the application of 3D prototyping (as a project collaboration tool) has been?
4.5 What benefits do you believe have been attained by using 3D prototyping?
4.6 What do you believe are the main barriers to the use of 3D prototyping for project collaboration?
4.7 How do you think these barriers may be overcome?
4.8 Has your company been able to quantify the benefits or losses associated with using 3D prototyping (please give details)?
4.9 What is your considered view on the issue of interoperability and its importance to collaborative prototyping?

SECTION FIVE: YOUR CONSIDERED OPINION ON THE FUTURE OF COLLABORATIVE PROTOTYPING

Questions:

5.1 What do you consider is state-of-the-art in 3D prototyping?
5.2 What if any, do you believe will be future developments in collaborative working (non 3D model based)?
5.3 What (if any) do you believe will be future developments in 3D prototyping?
5.4 Do you believe that there is a need to develop further initiatives? If yes, what research / work would you like to see happen?
5.5 In your opinion, what do you believe needs to be done to develop a single industry wide project collaborative prototyping solution?

SECTION SIX. ADDITIONAL INFORMATION

Are there any additional comments that you wish to make which relate to the subject, but have not been brought out by the questionnaire?
Appendix Five: Collaborative Prototyping Electronic Questionnaire Survey
QUESTIONNAIRE

An Evaluation of Current Collaborative Prototyping Practices within the AEC Industry

Dear Sir / Madam,

Re: Collaborative Prototyping

I am currently investigating the application of collaborative working and 3D prototyping within organisations throughout the AEC industry as partial fulfilment of my Engineering Doctorate studies at Loughborough University.

This questionnaire has been sent to a large sample of organisations throughout the AEC industry. I hope the findings will enable me to obtain a better understanding of the exact extent to which Collaborative Prototyping is being applied.

I would be very grateful if you could spare ten minutes of your time to complete the attached questionnaire and then send it back to me at the following e-mail address S.G.Yeomans2@lboro.ac.uk. All information will be treated with the strictest of confidence and individual or company names will not be identified.

If you require any further information please do not hesitate to contact me.

Yours faithfully,

Steven Yeomans
BSc(Hons) MSc(Dist) ABIAT ICIOB
Research Engineer
Loughborough University
S.G.Yeomans2@lboro.ac.uk
Collaborative Prototyping involves all of the project stakeholders coming together to work collaboratively to develop a fully integrated 3D model/prototype of a product before it is built. The model is used to test, integrate and co-ordinate (through collaborative working) the production of the product.

SECTION 1. YOU AND YOUR ORGANISATION

Q1.1 What position / title do you hold?

Q1.2 How would you describe the size of your company?
- Small  - Medium  - Large

Q1.3 What is the geographical distribution of your company?
- Local  - Regional  - National  - International

Q1.4 Which of the following describes your company’s main business?
- Architect  - Client  - Consultant  - Construction Manager
- Contractor  - Main Contractor  - Project Manager  - Specialist Contractor
- Supplier  - M&E Engineer  - Civil Engineer  - Structural Engineer
- Other (please give details)

SECTION 2. YOUR COLLABORATIVE WORKING EXPERIENCE

Q2.1 Has your company taken part in any projects that have used one or more of the following collaborative working techniques?

YES  NO
- Partnering
- Supply Chain Management
- Integrated Project Teams
- Framework Agreements
- Project Team Insurance
- Project Extranets
- Single Build Model (central database built from other databases)
- Collaborative Prototyping (a 3D model used to test a design of product before it is built, and facilitate collaborative working, integration and co-ordination)
Q2.2 How effective did you find them (please only rate those which you have identified above)?

Partnering
Supply Chain Management
Integrated Project Teams
Framework Agreement
Project Team Insurance
Project Extranet
Single Build Model
Collaborative Prototyping

SECTION 3. YOUR 3D CAD WORK EXPERIENCE

Q3.1 How much experience has your company had of working with 3D modelling on projects?

- None (please go to Q3.5)
- Very little (we have used it on one or two projects)
- Moderate (we have used it on several projects)
- Frequent (we have used it on the majority projects)

Q3.2 Please enter a percentage for the following statements.

- % of our current projects involve the use of 3D modelling
- % of our projects (in the past 12 months) have used 3D modelling
- % of our new projects (in the coming 12 months) will use 3D modelling

Q3.3 What was the reason(s) for using 3D modelling on your last project (please tick more than one if applicable)?

- Visualisation for client demonstration
- Visualisation for marketing
- Visualisation for design aesthetics
- Analysis of isolated parts of the design (such as heat loss/gain)
- Clash detection
- Co-ordination of isolated sections of the design (such as plant rooms)
- Single Build Model (to allow single point data collection for all project information)
- Collaborative Prototyping (to test the design of a product before it is built)
### Q3.4 Did using 3D help to increase project efficiency (please only rate those which you have identified above)?

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>UNABLE TO QUANTIFY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Visualisation for client demonstration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visualisation for marketing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visualisation for design aesthetics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analysis of the design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clash detection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Co-ordination of isolated sections of the design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single Build Model</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collaborative Prototyping</td>
</tr>
</tbody>
</table>

### Q3.5 Please rank the following from 1 – 10 why your company does not use 3D modelling more frequently (1= most important reason 10= least important reason)?

- Time taken to create the model
- Difficult to get others on a project to work in 3D
- Cost of specialist software
- Lack of skilled 3D CAD operators
- Technology does not work as well as expected
- Interoperability issues
- Overcoming 2D v 3D working culture
- Cost and time taken for training
- Not enough demand for 3D working
- It is not relevant to our work
SECTION 4. YOUR COLLABORATIVE PROTOTYPING EXPERIENCE

Q4.1 Were you aware of the concept of Collaborative Prototyping before receiving this questionnaire?

☐ Yes    ☐ No

Q4.2 How aware are you of the benefits of using Collaborative Prototyping?

☐ No    ☐ Limited Knowledge    ☐ Extensive knowledge

Q4.3 Has your company ever been involved in Collaborative Prototyping?

☐ Yes    ☐ No (please go to section 5)

Q4.4 On how many projects have you tried to apply Collaborative Prototyping?

☐ Projects

Q4.5 How successful would you say you have been so far?

☐ Unsuccessful (unable to complete any part of the model)

☐ Limited Success (We were able to complete some parts of the model to help with integration, co-ordination)

☐ Successful (we were able to complete most parts of the model in order to facilitate some collaboration, integration and co-ordination)

☐ Very Successful (we were able to complete the model and use it to control the entire production process)

SECTION 5. ADDITION INFORMATION

Please use the box below for any additional comments you wish to make on the subject of Collaborative Prototyping.

_________________________________________________________________________

Please indicate if you would like to receive a copy of the summary report once the report has been completed.

☐ Yes    ☐ No

Thank you for taking the time to complete this questionnaire
Appendix Six: Collaborative Extranet Working Online Electronic Questionnaire Survey
## QUESTIONNAIRE

Collaborative Extranet Working  
Via Multiple Construction Project Extranets

**Have you ever used a project Extranet when working on a Buro Happold project?**

<table>
<thead>
<tr>
<th>Yes (Please complete the rest of the questionnaire, indicate voucher preference and then click submit)</th>
<th>No (Please click here to indicate voucher preference and then click submit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**YOUR ROLE WITHIN BUCO HAPPOLD**

### 1.1 Which office do you normally work from?

<table>
<thead>
<tr>
<th>Ahmedabad</th>
<th>Bath</th>
<th>Berlin</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

### 1.2 Which discipline do you work within?

<table>
<thead>
<tr>
<th>BH Management</th>
<th>Building Services</th>
<th>CoSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Engineering</th>
<th>Building Services</th>
<th>CoSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ITE / Urban Development</th>
<th>ITAC</th>
<th>Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other (please provide details)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>☒</td>
<td></td>
</tr>
</tbody>
</table>

### 1.3 What position do you hold?

<table>
<thead>
<tr>
<th>Associate</th>
<th>Grad. Technician</th>
<th>Senior Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design Manager</th>
<th>Group Director</th>
<th>Senior Technician</th>
</tr>
</thead>
<tbody>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drawing Coordinator</th>
<th>Group Manager</th>
<th>Technician</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineer</th>
<th>Partner</th>
<th>Trainee Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Graduate Engineer</th>
<th>Senior Associate</th>
<th>Trainee Technician</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other (please provide details)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>☒</td>
<td></td>
</tr>
<tr>
<td>☒</td>
<td></td>
</tr>
<tr>
<td>☒</td>
<td></td>
</tr>
</tbody>
</table>

### 1.4 Are you?

<table>
<thead>
<tr>
<th>Employed</th>
<th>Contracted</th>
<th>Other (please provide details)</th>
</tr>
</thead>
<tbody>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>

### Table: Extranet Access

<table>
<thead>
<tr>
<th>Extranet 1</th>
<th>Extranet 2</th>
<th>Extranet 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>
YOUR PROJECT EXPERIENCE

2.1 Please indicate how many Buro Happold projects you have previously worked on where a Project Extranet has been used?

- [ ] None
- [ ] 1
- [ ] 2 - 5
- [ ] 6 - 10
- [ ] More than 10

2.2 Have you had to work on two or more projects simultaneously and use different Project Extranets systems on the same PC?

- [ ] Yes
- [ ] No

2.3 Are you currently working via an Extranet on a project?

- [ ] Yes
- [ ] No

2.4 The project number(s) are:

<table>
<thead>
<tr>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
</tr>
</thead>
</table>

2.5 What type of protocol did your last project (or current project) use to aid information exchange and collaboration?

- [ ] Ad-hoc protocol written by members of the project team
- [ ] Industry recognised protocol (i.e. PIX Protocol or Information Management Strategy)
- [ ] It does not have one (please go to question 3.1)
- [ ] Don't know (please go to question 3.1)

2.6 When was the protocol introduced?

- [ ] Before the Project Extranet was used
- [ ] After the Project Extranet had started to be used
- [ ] Don't Know
2.7 Please indicate if how you feel about each of the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) The protocol helped improve the exchange of information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) The protocol helped improve project collaboration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) The protocol was compatible with the company Quality Management System</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) The protocol created additional work due to its incompatibility with the QMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) The protocol helped me to understand how to work with the Extranet system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

YOUR PROJECT EXTRANET EXPERIENCE

3.1 Which Project Extranet(s) have you used on Buro Happold projects? Please tick more than one if applicable

- 4Projects (4Projects.com)
- ActiveProject (Framework Technologies)
- architec.net (Architec Ltd)
- Asite
- Business Collaborator (Enviros Ltd)
- Buzzsaw Professional (ProjectPoint)
- Buzzsaw Standard (ProjectPoint)
- Cadweb (Cadweb)
- CAM Console (LoadSpring Solutions)
- Causeway Collaboration
- Citadon CW (Citadon)
- Constructw@re (Constructware.com)
- CX Solutions (Aconex)
- DOCS Fusion (Hummingbird)
- Documentum
- eBuilder (MP Interactive)
- eProject Enterprise (eProject)
- Edificium (Edificium.com)
- EManage Net (Microlar Systems Ltd)
- Indeco TMS (Indeco Ltd)
- Information Channel (BIW Technologies)
- Information Manager (ECL)
- IProNet (Atkins)
- LiveLink (OpenText)
- MH2.com (MH2 Technologies)
- OnlineBuildings (OnlineBuildings.com)
- Paragon (Vianovus.com)
- PrimeContract (Primavera Systems)
- ProjectCenter (Bricsnet)
- ProjectEDGE (Edgewater Services)
- ProjectGrid.com
- ProjectLink (Causeway)
- Projectmates (Systemates)
- ProjectNet (Bidcom)
- ProjectsOnline (BuildOnline)
- ProjectPlace.co.uk (Project Place Ltd)
- ProjectSolve (Company 39)
- ProjectTalk (Meridian Project Systems)
- ProjectVillage
- RS(UK)
- TDM (C3 Systems)
- the Project (Sarcophagus)
- Tririga IBS (Tririga)
- Viecon (Bentley)
- Vista 2000 (Market Street Technologies)
- WebWorks (Web4)
- Other (please provide details)
### 3.2 How often do you use the following Extranet features?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Don't Use</th>
<th>Hourly</th>
<th>Daily</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewers</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Redlining &amp; Markups</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Markup Commenting</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Discussion Threads</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Summary Notification</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Instant Change Notification</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>External Email Notification</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>RFI Manager</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Change Order Manager</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Task Manager</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>History / Audit Trail</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Search Facility</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Automatic Version Control</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Customised Reporting</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Summary Page</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Directory</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Calendar</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Synchronise Calendars</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Personal Information Page</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Meeting Manager</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Whiteboard</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Videoconferencing</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Batch Upload</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Xref Manager</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Archiving</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Cloning</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Remote Web Access</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
3.3 When compared to working via conventional procedures (on a project without an Extranet) which of the following Extranet functions would you say saves time, takes the same time or takes more time?

<table>
<thead>
<tr>
<th>Function</th>
<th>Don't Use</th>
<th>Saves Time</th>
<th>Same Time</th>
<th>More Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redlining &amp; Markups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Markup Commenting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion Threads</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFI Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change Order Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Document Tracking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Search Facility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic Version Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reporting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Calendar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meeting Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batch Upload</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Archiving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

YOUR PROJECT EXTRANET TRAINING

4.1 How much training did you receive on the last (or current) Project Extranet system?

- None (please go to question 4.4)
- 1 Hour
- 2 Hours
- 3 Hours
- Half-a-day
- A full day
- Other (please provide details)

4.2 What type of training was it? Please tick more than one if applicable

- Online - vendor training via the web
- Classroom - vendor and/or Extranet facilitator away from the project
- Project-based - vendor and/or Extranet facilitator
- On-the-job - assisted by a project team member
- Other (please provide details)
Appendix 6: Collaborative Extranet Working Employees Questionnaire Survey

4.3 When was the training received?

- [ ] Before I started using the Extranet on the project (please go to question 5)
- [ ] After I started using the Extranet on the project (please go to question 5)

4.4 Please indicate the main reason why you feel you did not receive training?

- [ ] Not required due to experience of working with other systems
- [ ] I did not know who to ask about receiving training
- [ ] There was not time for training
- [ ] No provisions were made for training
- [ ] I was not asked if I required training
- [ ] I joined the project too late to receive training
- [ ] Other (please provide details)

YOUR USER EXPERIENCE

5.1 Have you ever used another project member’s login details to access an Extranet system?

- [ ] Yes
- [ ] No

5.2 Have you ever allowed another project member to use your login details to access an Extranet system?

- [ ] Yes
- [ ] No

5.3 Have you ever added extra people on a project ‘to list’ when uploading information, just in case they might need to view the information?

- [ ] Yes
- [ ] No

5.4 Have you ever reviewed information that has been marked for your attention, only to find it has no relevance to your work?

- [ ] Yes (please go to question 5.5)
- [ ] No (please go to question 5.6)

5.5 How much time do you lose checking if information sent via an Extranet is relevant to you?

- [ ] Minutes are lost checking work for relevance, over a week
5.6 Have you ever printed drawings from an Extranet for any of the following reasons? If yes, please fill out the boxes in relation to the last occasion you did.

<table>
<thead>
<tr>
<th>a) Marking-up</th>
<th>Yes</th>
<th>No</th>
<th>Estimated No of DWGs</th>
<th>DWG Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>b) To view</td>
<td>Yes</td>
<td>No</td>
<td>Estimated No of DWGs</td>
<td>DWG Size</td>
</tr>
<tr>
<td>c) To have a personal copy</td>
<td>Yes</td>
<td>No</td>
<td>Estimated No of DWGs</td>
<td>DWG Size</td>
</tr>
<tr>
<td>d) For archiving</td>
<td>Yes</td>
<td>No</td>
<td>Estimated No of DWGs</td>
<td>DWG Size</td>
</tr>
</tbody>
</table>

5.7 Has another Buro Happold project team member ever asked you to print off drawings from the Extranet?

☐ Yes (please fill out the boxes to reflect the last occasion)
☐ No

Who was it for
Did they have access to the Extranet
Enter how many drawings
What was the main drawing size
For what purpose

5.8 Have you experienced difficulties with any of the following on your last project (or current project)? If yes, please try to complete as many of the remaining boxes in the grey section below each issue.

**Downloading client software** (software used to run the Extranet)

☐ Yes  ☐ No

Which Extranet system?
Reason for problem?
Estimated time taken to resolve the problem? Hour(s)
Number of people involved in solving?
Company IT support involved in providing solution?
## Appendix 6: Collaborative Extranet Working Employees Questionnaire Survey

### Installing client software (software used to run the Extranet)

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Which Extranet system?</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Reason for problem?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Estimated time taken to resolve the problem?</td>
<td>-</td>
<td>Hour(s)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Number of people involved in solving?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Company IT support involved in providing solution?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Conflicts caused by running two Extranet systems simultaneously on one PC

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Please identify the two systems?</td>
<td>-</td>
<td>&amp;</td>
</tr>
<tr>
<td></td>
<td>Please write brief details of the problem</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Estimated time to resolve the problem?</td>
<td>-</td>
<td>Hour(s)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Number of people involved in solving?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Company IT support involved in providing solution?</td>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Installing and using plug-ins (such as java viewers)

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Which Extranet system?</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Estimated time to resolve the problem?</td>
<td>-</td>
<td>Hour(s)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Number of people involved in solving?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Company IT support involved in providing solution?</td>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
### Printing drawings from an Extranet

- **Yes**
- **No**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please write brief details of the problem</td>
<td></td>
</tr>
<tr>
<td>Estimated time taken to resolve the problem (Hour(s))</td>
<td>-</td>
</tr>
<tr>
<td>Number of people involved in solving?</td>
<td>-</td>
</tr>
<tr>
<td>Company IT support involved in providing solution?</td>
<td>No</td>
</tr>
</tbody>
</table>

### Viewing Drawings

- **Yes**
- **No**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which Extranet system?</td>
<td>-</td>
</tr>
<tr>
<td>Please write brief details of the problem</td>
<td></td>
</tr>
<tr>
<td>Estimated time taken to resolve the problem (Hour(s))</td>
<td>-</td>
</tr>
<tr>
<td>Number of people involved in solving?</td>
<td>-</td>
</tr>
<tr>
<td>Company IT support involved in providing solution?</td>
<td>No</td>
</tr>
</tbody>
</table>

### Uploading / downloading documents & drawings

- **Yes**
- **No**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which Extranet system?</td>
<td>-</td>
</tr>
<tr>
<td>Please write brief details of the problem</td>
<td></td>
</tr>
<tr>
<td>Estimated time taken to resolve the problem (Hour(s))</td>
<td>-</td>
</tr>
<tr>
<td>Number of people involved in solving?</td>
<td>-</td>
</tr>
<tr>
<td>Company IT support involved in providing solution?</td>
<td>No</td>
</tr>
</tbody>
</table>

### 5.9 Did you use the Extranet support service offered by the Extranet Vendor on your last or current project?

- **Yes** (please indicate which Extranet System)
- **No** (please go to question 5.11)
5.10 How would you rate the support service?

- [ ] Very Good
- [ ] Good
- [ ] Average
- [ ] Poor
- [ ] Very Poor

5.11 Have you experienced any of the following issues with the above service?

*Please tick all that are applicable*

- [ ] Unable to find contact details
- [ ] Unable to gain response from email support line
- [ ] Unable to gain response from telephone support line
- [ ] Time for telephone support lines where out of my working hours due to support network being in another country
- [ ] Support was provided by a third party who did not have enough knowledge of the Extranet system to solve the problem

YOUR OPINION ON WORKING WITH PROJECT EXTRANETS

6.1 Do you find working with Project Extranets?

- [ ] Very easy
- [ ] Easy
- [ ] Neutral
- [ ] Difficult
- [ ] Very Difficult

6.2 How happy would you be to use a Project Extranet again?

- [ ] Very Happy
- [ ] Happy
- [ ] Neutral
- [ ] Not Happy
- [ ] Very Unhappy
6.3 Did working with a Project Extranet help you to be:

- [ ] Considerably more productive
- [ ] Slightly more productive
- [ ] Made no difference
- [ ] Slightly less productive
- [ ] Considerably less productive

You can use the space provided below to explain why you feel this happened:

6.4 Did working with a Project Extranet help you to minimise mistakes?

- [ ] Yes
- [ ] No
- [ ] Don't Know

You can use the space provided below to explain why you feel this happened:

6.5 How did working with a Project Extranet effect your relationships with external project team members?

- [ ] They were much better
- [ ] They were slightly better
- [ ] Made no difference
- [ ] They were slightly worse
- [ ] They were much worse

You can use the space provided below to explain why you feel this happened:
ADDITIONAL INFORMATION

Please use the space below to provide details of any additional information or comments you wish to make:

PRIZE DRAW

Please indicate which gift vouchers you would like if you are the lucky winner of the prize draw:

- [ ] Please give the money to the Buro Happold Charity Fund
- [ ] Marks & Spencer
- [ ] Homebase
- [ ] HMV
- [ ] Sainsburys
- [ ] Tesco
Appendix Seven: Collaborative Extranet Working Protocol Questionnaire Survey
QUESTIONNAIRE

Requirements for the Development of a Generic Construction Project Extranet Protocol to Aid Collaborative Extranet Working

Dear Sir / Madam,

Re: Research into Collaborative Extranet Working Protocols

I am currently investigating the relevance of construction project extranet protocols to facilitate collaborative extranet working within the AEC industry as partial fulfilment of my PhD studies at Loughborough University.

An initial survey undertaken by the Research Engineer found that the principal cause of ineffective and inefficient use of construction project extranets emanates from missing, or use of poorly developed protocols [1]. In addition, project teams cited the apparent lack of both a generic industry standard and comprehensive guidance notes, as the main reasons for not being able to produce practicable construction project extranet protocols.

The following questionnaire has been sent to a large sample of organisations throughout the AEC industry. I hope the findings will enable me to obtain a better understanding on the role of protocols and establish which issues construction teams deem most relevant in the proposed development of an industry generic protocol.

I would be very grateful if you could spare ten minutes of your time to complete the attached questionnaire, save it and then return it to me at S.G.Yeomans2@lboro.ac.uk. A copy of the key findings will be made available to all responding parties. All information will be treated with the strictest of confidence and individual or company names will not be identified.

All completed questionnaires returned before the 30th March 2005 will be entered into a prize draw for £25 worth of vouchers (of your choice). The winner will be announced on the 9th of May.

If you require any further information about this study, please do not hesitate to contact me.

Yours faithfully,

Steven Yeomans
BSc(Hons) MSc(Dist) ABIAT ICIOB
Research Engineer
Loughborough University
S.G.Yeomans2@lboro.ac.uk
Section 1 – About You

Q1.1 What position / title do you hold?
[..............................................................]

Q1.2 Which of the following represents your main role on projects?

- [ ] Architect
- [ ] Main Contractor
- [ ] Quantity Surveyor
- [ ] Other [.................................] < Please provide details here

Q1.3 How many projects you have worked on where a construction project extranet was used?
[......] projects

Q1.4 How many of the above projects provided guidance documentation (an extranet protocol) to assist with working on the project extranet?
[......] projects

Section 2 – About Extranet Protocols

Q2.1 How frequently you have found extranet protocols that contain procedures on ‘how to’:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Never</th>
<th>Seldom</th>
<th>Often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use the project extranet system and its tools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage electronic information exchange</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordinate and manage a 3D model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduct online project collaboration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage online relationships</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain a non-adversarial environment (contractual activities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Align project extranet and individual company quality procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage online project workflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achieve continuous improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undertake change management and avert resistance to change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure software compatibility (overcoming interoperability)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor the project teams’ compliance with extranet procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify and resolve unforeseen issues from use of the extranet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q2.2 How practical are current procedures at explaining what to do in each of the following areas?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Very Practical</th>
<th>Practical</th>
<th>Not Practical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use the project extranet system and its tools</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Manage electronic information exchange</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Coordinate and manage a 3D model</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Conduct online project collaboration</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Manage online relationships</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Maintain a non-adversarial environment (contractual activities)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Align project extranet / individual company quality procedures</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Manage online project workflow</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Achieve continuous improvement</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Undertake change management and avert resistance to change</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Ensure software compatibility (overcoming interoperability)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Monitor the project teams’ compliance with extranet procedures</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Identify and resolve unforeseen issues from use of the extranet</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Q2.3 How important is it to include information on the following issues within a protocol?

<table>
<thead>
<tr>
<th>Issue</th>
<th>Very Important</th>
<th>Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use the project extranet system and its tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage electronic information exchange</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordinate and manage a 3D model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduct online project collaboration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage online relationships</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain a non-adversarial environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Align extranet / individual company quality procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage online project workflow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achieve continuous improvement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undertake change management / avert resistance to change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure software compatibility (overcoming interoperability)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor the teams’ compliance with extranet procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify / resolve unforeseen issues from use of the extranet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy for using the project extranet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defining general project extranet roles and responsibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project extranet coordinators/administrators responsibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training provisions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow charts of procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software requirements, installation and setup</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintaining extranet site security</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project extranet technical support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual property rights</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q2.4 How successful would you say current extranet protocols are at helping project teams to work efficiently on project extranets and bring about savings in time and project costs?

☐ Very successful
☐ Partly successful
☐ Partly unsuccessful
☐ Very unsuccessful

Q2.5 How helpful would the following be when undertaking the process of developing an extranet protocol?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Very helpful</th>
<th>Helpful</th>
<th>Not helpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signing a (non legally binding) collaborative project charter agreement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding the process through process mapping activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying and reducing process waste with lean thinking principles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value Management and Value Engineering workshops</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q2.6 Are there any additional items that you feel should be addressed within extranet protocols?

[..................................................................................................................]

Q2.7 How important is a good protocol to the successful application of an extranet system on a project?

☐ Very important
☐ Important
☐ Neither important or unimportant
☐ Unimportant
☐ Very unimportant

Section 3 – Developing Extranet Protocols

Q3.1 Have you ever participated in the development of an extranet protocol?

☐ Yes
☐ No (please go to Q3.4)

Q3.2 How easy was the process of developing an extranet protocol, the first-time-around?

☐ Very Difficult
☐ Difficult
☐ Easy
☐ Very Easy

Q3.3 Please provide brief details on why you chose your response to Q3.2

[..................................................................................................................]
Q3.4 Please indicate, in priority order, how much of a barrier the following issues are to the successful development of an extranet protocol? (Please allocate numbers 1 – 4 to the following reasons, where 1 = the main barrier, 2 = the second main barrier etc.)

[......] A lack of best practice guidance, generic templates and guidance notes
[......] A lack of necessary expertise to call upon (no consultants to obtain guidance from)
[......] Adapting a ad-hoc template form another project
[......] Relying on the extranet system vendor to facilitate the process

Q3.5 Please indicate, in priority order, which of the following issues are most likely to hamper efforts to develop a successful extranet protocol? (Please allocate numbers 1 – 4 to the following reasons, where 1 = the main reason, 2 = the second main reason etc.)

[......] Having to rushed the process as the project was already being used
[......] A lack of expertise / experience within those responsible for development
[......] Not having all project team members involved in the process
[......] A lack of commitment to the process from project team members

Q3.6 Are you aware of additional barriers to the development of extranet protocols?

☐ No
☐ Yes [.................................................................] < please provide details here

Section 4 – Development of Extranet Protocol Toolkits and Services

Q4.1 Please indicate, in priority order, which of the following services you would use on a project to develop a more efficient extranet protocol, if they were available? (Please allocate numbers 1 – 4 to the following reasons, where 1 = use first, 2 = use second etc.)

[......] A best practice guidance document (explaining how to develop an extranet protocol)
[......] A generic protocol (template document that can be adapted to individual projects)
[......] Professional extranet services (employing consultants to facilitate the process)
[......] Specialist designated software (step-by-step guide with input boxes to complete)

Q4.2 Please indicate which of the following formats you feel an extranet protocol toolkit would be best presented in? (please tick only one)

☐ Licensed software application
☐ A published guide in paper format with forms suitable for photocopying
☐ A web-based guide to be completed online, with the ability to save/ print completed forms
☐ DVD with the ability to complete, print and save forms
☐ CD-Rom with the ability to complete, print and save forms
☐ Collection of word formatted documents that can be adapted to our company house-style
☐ Excel formatted documents that can be adapted to our company house-style
☐ Other [.................................................................] < please provide details here
Q4.3 Are there any additional tools or services that you believe should be developed to aid project extranet working?

☐ No
☐ Yes [............................................................] < please provide details here

Section 5 – Statements on Extranet Protocols

Please indicate your reaction to the following statements by ticking the appropriate boxes

5.1 The use of poorly developed extranet protocols, or non use of them, leads to the ineffective and inefficient use of construction project extranets.

☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

5.2 Current extranet protocols are ad-hoc, project-specific and inadequate; as they focus on how to use the designated extranet system but provided little or no consideration of other critical issues such as integration and collaboration.

☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

5.3 The lack of an industry generic extranet protocol and guidance documentation make it difficult for project teams to develop practicable extranet protocols.

☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

5.4 Project teams would benefit greatly from the availability of an industry approved, generic extranet protocol toolkit.

☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

5.5 The availability of a generic industry extranet protocol would facilitate more efficient collaborative extranet working.

☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree
Section 6 – Additional Information

Please use the space below for any additional comments you wish to make on the subject of extranet protocols and collaborative extranet working.
Please provide details here > [.....................................................................................]

Please indicate if you would like to receive a copy of the summary report once completed.
☐ Yes
☐ No

PRIZE DRAW - Please indicate which gift vouchers you would like to receive if you are the lucky winner of the £25 prize draw:

☐ Please donate to Comic Relief
☐ Please donate to the Tsunami Fund
☐ Negotiate a deal as I live outside the UK
☐ Marks & Spencers
☐ HMV
☐ Sainsbury
☐ Tesco

Thank you for taking the time to complete this questionnaire.
Please save it and then return to: S.G.Yeomans2@lboro.ac.uk
Appendix Eight: Construction Project Extranet Initial Implementation Survey Form
## Construction Project Extranets – Initial implementation survey form

**This aim of this form is to allow Company Name to formally capture and respond to the prerequisite requirements of collaborative working via the Construction Project Extranet (CPE) systems as predetermined by Clients Name(s) on the Project Name project.**

Your participation in completing the form will enable us to better contribute to the successful adoption and application of the extranet system. Where items have not already been examined, we would like to offer these for your further consideration.

<table>
<thead>
<tr>
<th>Item</th>
<th>Part 1. General Information</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Has a CPE system been specified?</td>
<td><img src="" alt="Yes (go to 3)" /> <img src="" alt="No (go to 2)" /></td>
</tr>
<tr>
<td>2</td>
<td>Is it possible to participate in the process of trialling and selecting a CPE system?</td>
<td><img src="" alt="Yes" /> <img src="" alt="No" /></td>
</tr>
<tr>
<td>3</td>
<td>Has the CPE system been obtained from an Application Service Provider (ASP) or is it a bespoke system?</td>
<td><img src="" alt="Bespoke" /> <img src="" alt="ASP" /></td>
</tr>
<tr>
<td>4</td>
<td>Please provide contact details of the CPE application service provider:</td>
<td>Phone: <img src="" alt=" " /> Email: <img src="" alt=" " /> Web Address: <img src="" alt=" " /></td>
</tr>
<tr>
<td>5</td>
<td>What is the name of the specified CPE system?</td>
<td><img src="" alt=" " /></td>
</tr>
<tr>
<td>6</td>
<td>Who will be responsible for the implementation of the CPE system?</td>
<td><img src="" alt="Client" /> <img src="" alt="Main Contractor" /> <img src="" alt="Application Service Provider" /> <img src="" alt="Design Team" /> <img src="" alt="Other" /></td>
</tr>
<tr>
<td>7</td>
<td>Who will be responsible for the facilitation of the CPE system throughout the project?</td>
<td><img src="" alt="Client" /> <img src="" alt="Main Contractor" /> <img src="" alt="Application Service Provider" /> <img src="" alt="Design Team" /> <img src="" alt="Other" /></td>
</tr>
<tr>
<td>8</td>
<td>At what stage / date is the use of the CPE system expected to start?</td>
<td>Stage: <img src="" alt=" " /> Date: <img src="" alt=" " /></td>
</tr>
<tr>
<td>9</td>
<td>What is the principal driver for using a CPE on the project?</td>
<td><img src="" alt="File Sharing" /> <img src="" alt="Electronic Data Management" /> <img src="" alt="Project Team Integration" /> <img src="" alt="Collaborative Working" /> <img src="" alt="Other" /></td>
</tr>
</tbody>
</table>
## Part 2. Extranet System and Training Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Are we required to contribute to the purchase of the CPE system?</td>
<td>Yes (go to 10)</td>
</tr>
<tr>
<td>11</td>
<td>How much are we expected to contribute and how often?</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Does use of the CPE system require training for employees?</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>Are we expected to pay for our employees to be trained?</td>
<td>Yes (go to 14)</td>
</tr>
<tr>
<td>14</td>
<td>How much will the training cost?</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>How long is the training expected to take?</td>
<td>Hours</td>
</tr>
<tr>
<td>16</td>
<td>What format will the training take?</td>
<td>ASP specialist</td>
</tr>
<tr>
<td>17</td>
<td>Are there any additional costs we are required to contribute to? If yes, what are they?</td>
<td></td>
</tr>
</tbody>
</table>

## Part 3. CPE Protocols

<table>
<thead>
<tr>
<th>Item</th>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Are the procedures for CPE system implementation, use and management completed (a Construction Project Extranet Protocol)?</td>
<td>Yes (go to 20)</td>
</tr>
<tr>
<td>19</td>
<td>Is it possible to participate in the protocol development and/or review process?</td>
<td>Yes</td>
</tr>
<tr>
<td>20</td>
<td>Which of the following procedures will be covered by the protocol?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use of the systems tools</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Coordination of 3D model information</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Achieving collaborative working</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Managing online relationships</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Contractual Obligations</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Alignment project and company QA procedures</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Managing workflow online</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Achieving continuous improvement</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Change management – avoiding reversion to type</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Interoperability issues</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Monitoring system use and compliance</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>CPE implementation strategy</td>
<td>Yes</td>
</tr>
</tbody>
</table>
21 Where can the protocol document be located?

22 Does the project intend to utilise any of the following?

<table>
<thead>
<tr>
<th>Information Management Strategy Framework</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIX Protocol</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CPIC – Production Information: a code of Procedure for the Construction Industry</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Avanti Design Management Toolkit</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Other ____________________________________</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

## Item Part 4. CPE System Specific Information

### Response

<table>
<thead>
<tr>
<th>Item</th>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>Do you require provision of full time dedicated CPE administrators for the project?</td>
<td>Yes</td>
</tr>
<tr>
<td>24</td>
<td>What level of access rights will they be given?</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Does the system need to be adapted to meet the needs of the project?</td>
<td>Yes</td>
</tr>
<tr>
<td>26</td>
<td>Are any of the following technical support systems available?</td>
<td>Online support</td>
</tr>
<tr>
<td>27</td>
<td>How accessible are technical systems?</td>
<td>Office hours only</td>
</tr>
<tr>
<td>28</td>
<td>Is access to technical support free?</td>
<td>Yes</td>
</tr>
<tr>
<td>29</td>
<td>What type of security does the CPE system employ?</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>What data backup procedures does the CPE system employ?</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Does the use of the CPE system require local software installs?</td>
<td>Yes</td>
</tr>
<tr>
<td>32</td>
<td>Are additional plug-ins i.e. java viewers required?</td>
<td>Yes</td>
</tr>
<tr>
<td>33</td>
<td>Please list or provide details of all types and sizes of installs required.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 8: CPE Initial Implementation Survey Form

34 How often is the system upgraded? □ Monthly □ Quarterly □ Annually □ Other __________________________

35 Is the CPE system available in other languages? □ Yes □ No

36 Are there any known IT issues that we should be aware of i.e. correct firewall or java settings? Please list or provide appropriate literature. □ Yes □ No

<table>
<thead>
<tr>
<th>Item</th>
<th>Part 5. Additional items</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Will all project members be required to use the system?</td>
<td>□ Yes (go to 38) □ No (go to 39)</td>
</tr>
<tr>
<td>38</td>
<td>Do all project members have sufficient IT capacity?</td>
<td>□ Yes (go to 39) □ No (go to 38)</td>
</tr>
<tr>
<td>39</td>
<td>What are the procedures for information exchange and communications in these instances?</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Who owns intellectual property rights of information placed onto the system?</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>What are the archiving procedures and how often should they take place?</td>
<td></td>
</tr>
</tbody>
</table>

From: [Company]  
To: [Company]  
Date sent:  
Answer required by:  
Date received:  
Answer sent on:  

197