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TECHNIQUES AND STRATEGIES TO IMPROVE
CONCEPTUAL AND SCHEMATIC DESIGN

by

Martyn C. Pendlebury

A Doctoral Thesis submitted in partial fulfilment of
the requirements for the award of Doctor of
Philosophy of Loughborough University

January 2000

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Abstract

TECHNIQUES AND STRATEGIES TO 
IMPROVE CONCEPTUAL AND SCHEMATIC 
DESIGN

by Martyn C. Pendlebury

Keywords: Concept Design, Scheme Design, Design Management, Process Modelling, IDEF0, Matrix Analysis, Planning, and Quality Function Deployment.

This research has investigated the management of the concept and schematic design stages with particular reference to brief development, the exchange of design and cost information between the client and designers, and the impact of early design decisions on construction. A critical review of current practice by both literature review and case study revealed that early stage design often failed to meet the expectation of clients leading to frequent redesign and inaccurate cost advice. Poor communication of information between all parties was primarily to blame. This led to the research combining the three elements, design, cost, and risk and developing a Scheme Design Process Model (SDPM) based on ADePT principles to provide designers for the first time the opportunity to:

- Accurately and systematically, plan ahead for the work required during the scheme design stage.
- Identify conflicts that lead to iterative problems.
- Mitigate iterative problems by identifying and recording the design risks source.
- Qualify the accuracy of the cost advice based on the progress of the design.
- Ensure closer cross-disciplinary cooperation.
- Reduce overall project timescale.

The research identified that a generic programme of work can now be produced that includes all major elements for the multi-disciplinary design team. The research provides a contribution to the design-modelling database by introducing and demonstrating flexibility between design stages. In addition to the SDPM the research has also addressed accountability within the decision making process by demonstrating QFD techniques that can be applied at various stages of early design.
# Contents

## TABLE OF CONTENTS

### Chapter One:

**INTRODUCTION**

1. **BACKGROUND TO THE RESEARCH**
   1.1 1
2. **AIMS AND OBJECTIVES**
   1.2 3
3. **RESEARCH METHODOLOGY**
   1.3 4
4. **RESULTS OF THE RESEARCH**
   1.4 5
   1.4.1 Introduction to Research Output ................................................................... 5
   1.4.2 Output Solution One ................................................................................... 6
   1.4.3 Output Solution Two ................................................................................... 6
   1.4.4 Contribution to Knowledge ......................................................................... 7
   1.4.5 Main findings ............................................................................................... 8
5. **GUIDE TO THIS THESIS**
   1.5 10

### Chapter Two:

**EARLY STAGE BUILDING DESIGN**

2. **INTRODUCTION TO EARLY STAGE BUILDING DESIGN**
   2.1 13
2.2 **DEFINING EARLY STAGES OF DESIGN**
   2.2.1 Design Stages ............................................................................................... 13
   2.2.2 Concept Design ............................................................................................ 16
   2.2.3 Scheme Design ............................................................................................ 16
2.3 **BRIEFING AND DEVELOPING THE BRIEF**
   2.3.1 The Client Brief ........................................................................................... 20
   2.3.2 Client Types ................................................................................................. 21
   2.3.3 The Design Brief .......................................................................................... 23
2.4 **DESIGN MANAGEMENT AND MANAGING DESIGN**
   2.4.1 Management of Design ............................................................................... 24
   2.4.2 Delivering Design ........................................................................................ 28
   2.4.3 Delivering Cost Advice ............................................................................... 28
   2.4.4 The Impact of Improved Cost Advice ........................................................ 30
   2.4.5 Planning Design ........................................................................................... 30
   2.4.6 Programming Design ................................................................................... 33
2.5 **VALUE ANALYSIS**
   2.5 35
2.5.1 Introduction to Value Analysis ........................................... 35
2.5.2 Value Management/Value Engineering ........................................... 36
2.5.3 QFD and Building Design ...................................................... 38
2.5.4 The Four Phases of QFD .............................................................. 39
2.6 RISK ANALYSIS 41
2.7 PROBLEMS WITH EARLY STAGE DESIGN 43
  2.7.1 During Briefing .............................................................. 43
  2.7.2 Design Team Communication .............................................. 44
  2.7.3 The Benefit of a Structured Programme ................................. 44
  2.7.4 Iterative Problems in Design ................................................. 45
  2.7.5 Problems Delivering Early Stage Cost Advice ......................... 46
2.8 TECHNIQUES FOR MODELLING DESIGN 47
  2.8.1 Introduction to Techniques for Modelling Design ................... 47
  2.8.2 Systematic Design ................................................................. 47
  2.8.3 Model Types ................................................................. 48
  2.8.4 Structured Analysis and Design Techniques ............................ 50
  2.8.5 Top-Down or Bottom-Up Approach ......................................... 50
  2.8.6 Entity-Relationship Diagrams ................................................. 51
  2.8.7 Hierarchical Input Process Output (HIPO) Diagrams .................. 52
  2.8.8 The JSD Method ............................................................... 54
  2.8.9 Data Flow Diagrams ........................................................... 56
  2.8.10 IDEF0 ................................................................. 58
  2.8.11 Summary of Techniques for Modelling Design ..................... 61
2.9 DESIGN PROCESS MODELS 62
  2.9.1 Introduction to Design Process Models .................................... 62
  2.9.2 RIBA Plan Of Work ........................................................... 63
  2.9.3 Process Protocol ................................................................. 63
  2.9.4 The BAA Project Process ......................................................... 65
  2.9.5 AMEC Construction Project Process ........................................ 66
  2.9.6 Building Research Establishments Building 16 ......................... 67
  2.9.7 The ADePT Detail Design Process Model ................................. 67
  2.9.8 Design Structure Matrix Analysis ............................................ 69
2.10 CONCLUSION TO EARLY STAGE BUILDING DESIGN 70
# Contents

Chapter Three:
RESEARCH OBJECTIVES AND METHODOLOGY .................................................. 75

3.1 INTRODUCTION TO RESEARCH OBJECTIVES AND METHODOLOGY 75
3.2 RESEARCH OBJECTIVES 75
  3.2.1 The Aim of the Research ................................................................. 75
3.3 METHODOLOGY 77
  3.3.1 The Methods of Research ............................................................... 77
  3.3.2 Stage One: Problem Formulation ..................................................... 77
  3.3.3 The Literature Review .................................................................. 78
  3.3.4 Qualitative v Quantitative Research Methods ............................... 79
  3.3.5 Case Study Research .................................................................... 80
  3.3.6 Interviews ...................................................................................... 84
  3.3.7 Stage Two: Improvements to Concept and Schematic Design .......... 85
  3.3.8 Archival Analysis ........................................................................ 87
  3.3.9 Action Research ........................................................................... 88
3.4 CONCLUSIONS TO RESEARCH OBJECTIVES AND METHODOLOGY 90

Chapter Four:
SHADOWING EARLY STAGE DESIGN ................................................................. 91

4.1 THE CONCEPT STUDY 91
  4.1.1 Introduction to the Concept Study ................................................... 91
  4.1.2 The Meetings ................................................................................. 95
  4.1.3 Summary of the Project Shadowing ................................................. 95
4.2 INTERVIEWING THE DESIGN DISCIPLINES 96
  4.2.1 Introduction to the Interviews .......................................................... 96
  4.2.2 Grounded Theory ......................................................................... 97
  4.2.3 The Interviews ............................................................................... 98
  4.2.4 Outcomes ...................................................................................... 100
4.3 CONCLUSION TO SHADOWING EARLY STAGE DESIGN 102

Chapter Five:
MODELLING SCHEME DESIGN .................................................................. 104

5.1 INTRODUCTION TO MODELLING SCHEME DESIGN 104
5.2 MODEL TYPE 105
Contents

5.2.1 Prototype Or Generic ................................................................. 105
5.2.2 Generic Content ........................................................................ 106

5.3 THE MODELLING PROCESS ............................................................ 106
5.3.1 A Prototype Scheme Design Process Model .............................. 106
5.3.2 Revising the IDEF0 Modelling Context ..................................... 109

5.4 THE MODEL HIERARCHY ................................................................. 110
5.4.1 Developing a New Hierarchy ..................................................... 110
5.4.2 Architectural Design ................................................................. 111
5.4.3 Structural Design .................................................................... 111
5.4.4 Mechanical Design ................................................................. 112
5.4.5 Electrical Design ..................................................................... 112
5.4.6 Risk Management .................................................................. 113
5.4.7 Cost Planning .......................................................................... 115

5.5 INFORMATION FLOW MODELLING .................................................. 116
5.5.1 IDEF0 and Information Modelling ............................................ 116

5.6 INFORMATION DEPENDENCY TABLES .............................................. 118
5.6.1 Producing an Information Dependency Table ............................. 118
5.6.2 Classifying the Information ....................................................... 118
5.6.3 Information Dependency Tables ............................................... 120
5.6.4 Verification and Validation of the SDPM ................................. 121

5.7 DESIGN STRUCTURE MATRIX ANALYSIS ....................................... 122
5.7.1 DSM Analysis of the SDPM ....................................................... 122
5.7.2 Building a Design Structure Matrix ......................................... 122
5.7.3 Partitioning the Matrix ............................................................. 124
5.7.4 Solving the Iterative Problems ............................................... 124
5.7.5 Testing and Verification ........................................................... 128
5.7.6 Interface between the SDPM and Detail Design ....................... 129
5.7.7 Project Outcomes ................................................................. 131

5.8 CONCLUSIONS ON MODELLING SCHEME DESIGN ...................... 133

Chapter Six:

VALUE ANALYSIS AND QFD .............................................................. 137
6.1 INTRODUCTION TO VALUE ANALYSIS AND QFD .................. 137
6.2 QFD AND THE HOUSE OF QUALITY .............................................. 138
6.2.1 The House of Quality in Detail ................................................. 138
## Contents

### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>Illustrative Guide to the Thesis</td>
<td>12</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Relationships in a Designer Led Project at Scheme Design. (Potter 1995)</td>
<td>18</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Stakeholders to a Project</td>
<td>21</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>Cost &amp; Value over Time</td>
<td>35</td>
</tr>
<tr>
<td>Figure 2.4</td>
<td>The Clausing Four Phase Model (Cohen 1995)</td>
<td>40</td>
</tr>
<tr>
<td>Figure 2.5</td>
<td>The Huovila Four Phase Model (Huovila et al 1995)</td>
<td>40</td>
</tr>
<tr>
<td>Figure 2.6</td>
<td>The Iterative Process of Design</td>
<td>45</td>
</tr>
<tr>
<td>Figure 2.7</td>
<td>The Process of Analysis, Synthesis, Appraisal and Decision. (Maver 1971)</td>
<td>48</td>
</tr>
<tr>
<td>Figure 2.8</td>
<td>The BS7000 model describing the relationship between brief evolution and design stages</td>
<td>49</td>
</tr>
<tr>
<td>Figure 2.9</td>
<td>Archers Prescriptive Model of the Design Process</td>
<td>50</td>
</tr>
<tr>
<td>Figure 2.10</td>
<td>A Typical Entity Relationship Diagram</td>
<td>52</td>
</tr>
<tr>
<td>Figure 2.11</td>
<td>Basic Notation for Entity Relationship Diagrams</td>
<td>52</td>
</tr>
<tr>
<td>Figure 2.12</td>
<td>A Typical HIPO Visual Table of Contents</td>
<td>53</td>
</tr>
<tr>
<td>Figure 2.13</td>
<td>A HIPO Overview Diagram Showing an Element of a Simple Pricing Procedure</td>
<td>54</td>
</tr>
<tr>
<td>Figure 2.14</td>
<td>Typical Jackson Structure Diagram</td>
<td>55</td>
</tr>
<tr>
<td>Figure 2.15</td>
<td>An Example of a Data Flow Diagram</td>
<td>57</td>
</tr>
<tr>
<td>Figure 2.16</td>
<td>IDEF0 Notation</td>
<td>59</td>
</tr>
<tr>
<td>Figure 2.17</td>
<td>IDEF0 provides hierarchal decomposition that is practical and rigorous</td>
<td>60</td>
</tr>
<tr>
<td>Figure 2.18</td>
<td>Process Model Comparisons</td>
<td>62</td>
</tr>
<tr>
<td>Figure 2.19</td>
<td>The Analytical Design Planning Technique (ADePT)</td>
<td>68</td>
</tr>
<tr>
<td>Figure 2.20</td>
<td>Possible Sequences for Design Tasks</td>
<td>70</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>Basic Types of Design for Case Studies (Yin 1981)</td>
<td>81</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>The Research Plan</td>
<td>87</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>Action Research Interacting Spiral</td>
<td>88</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Concept Study Frequentative Diagram</td>
<td>95</td>
</tr>
<tr>
<td>Figure 5.1</td>
<td>Hierarchy for Scheme Design</td>
<td>108</td>
</tr>
<tr>
<td>Figure 5.2</td>
<td>Stage 2 Model of Scheme Design</td>
<td>108</td>
</tr>
<tr>
<td>Figure 5.3</td>
<td>Restatement of IDEF0 Context for Scheme Design</td>
<td>109</td>
</tr>
<tr>
<td>Figure 5.4</td>
<td>The Architectural Scheme Design Hierarchy</td>
<td>111</td>
</tr>
</tbody>
</table>
Contents

Figure 5.5: The Structural Scheme Design Hierarchy ........................................................ 112
Figure 5.6: Mechanical Scheme Design Hierarchy ............................................................. 112
Figure 5.7: Electrical Scheme Design Hierarchy ................................................................ 113
Figure 5.8: The Risk Evaluation Hierarchy ......................................................................... 114
Figure 5.9: The Initial Cost Plan Hierarchy ....................................................................... 115
Figure 5.10: IDEF0v Diagram for A122 Foundations Design ............................................ 117
Figure 5.13: Information Classification Flow Chart (Newton 1995) ................................... 121
Figure 5.14: Examples of a DSM before and after Partitioning ........................................ 123
Figure 5.15: Tearing advice from the PSM (5.14) .............................................................. 124
Figure 5.16: The Initial Scheme Design Matrix .................................................................. 125
Figure 5.17: The DSM after Tearing ................................................................................... 127
Figure 5.18: Project Programme Information ..................................................................... 132
Figure 5.19: Example of the Trial Programme .................................................................. 132
Figure 6.1: The House of Quality Schematic (Clausing 1994) ........................................... 139
Figure 6.2: An Example of Phase Progression .................................................................. 140
Figure 6.3: The QFD of Requirement/Attribute Relationship for Workstations .............. 147
Figure 6.4: The QFD of Design Activity Relationships for Workstations ......................... 149
Figure 6.5: House of Quality for Customer Requirements ................................................ 155
Figure 6.6: House of Quality for Design Concept Evaluation .......................................... 158
Figure 6.7: House of Quality Design Characteristics Evaluation .................................... 159
Figure 6.8: House of Quality Evaluation of Design Activities ......................................... 161
Figure 6.9: The QFD Outline ............................................................................................... 164
Figure 6.10: An Example Building System Hierarchy ......................................................... 166
Figure 6.11: An Example of QFD on the System .............................................................. 166
Figure 6.12: An Example of QFD on the Element ............................................................ 167
Figure A.1: Commercial Explanation .................................................................................. xlix

LIST OF TABLES

Number Page

Table 2.1: The RIBA Plan of Work and its Stages ................................................................. 14
Table 2.2: Plan of Work Stages Aligned to meet the Design Management Stages of Early Stage Design (Gray et al 1994) ................................................................. 15
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Chapter One

INTRODUCTION

1.1 BACKGROUND TO THE RESEARCH

The design of modern buildings has become an increasingly complex activity. This is due in part to the greater demands by clients in terms of performance, quality, economy, and time. These demands together with the complex iterative nature of design have resulted in increasing challenges in building design and in the management of the design process.

Initial research undertaken in the Department (Newton 1995) in collaboration with large construction organisations showed that:

- The design process is information driven and that current planning techniques are ill suited for the planning, monitoring and controlling of building design.

- Current techniques do not accommodate the iterative nature of design nor do they adequately permit the choices of alternatives.

The previous research had centred on providing solutions at the detail stage of design where deliverables are clearly identifiable.

The aim of this research is to concentrate on the earlier conceptual and schematic stages of design and develop appropriate techniques that can contribute by improving both management of the design and the delivery of accurate cost advice.

This research was conducted in collaboration with AMEC Construction who manage their clients design requirements by offering a design only, design and manage, design and construction management or design manage and construct service from their Stratford upon Avon offices. It has been set up to focus on ways to improve understanding between designers both intra disciplinary and across the disciplines as the early stages of the design process are negotiated with the client. It is anticipated that this work will complement a previous collaborative research project into detail design (Austin et al 1999) and deliver tools that might integrate the design stages.

Developing the process tools that designers' employ during the course of their work to help understand requirements and plan design are seen as a key to improving efficiency for producing the design deliverables at the end of the respective design stages (Egan 1998).
Chapter One

It is important to state that this research does not intend to interfere with design thinking (Lawson 1980). Its intention is to reduce the amount of crisis management caused through poor planning and design iteration thereby facilitating design thinking by identifying appropriate timescales for design.

At the conceptual and schematic stages where the needs of the client are being assessed, clarified and confirmed the design deliverables remain consistent but the potential for redesign is much higher (Latham 1994). What is clear is that construction costs are largely determined during the early design stage of a project (Morton & Jagger 1995) and the design process at the very early stage is of commensurate importance. Cost management is an intrinsic part of the creative process in virtually every aspect (Bowen-James et al 1995). There is a continual need to make cost decisions as problems are tested, solutions are formulated and then presented back to the client to be agreed and signed off. The provision of sufficient detail to provide robust cost information will rely on the interaction and understanding between the parties at stakeholder, management and team level (Potter 1995).

This early stage design process presents both client and design teams with the opportunity to set out and define the method by which a project is to be designed and built. Accurate translation of information during the briefing process at this stage is crucial to the secure development of the project. The literature research has revealed that most problems continue to develop during the interpretive period between the client and the design team (Barrett & Stanley 1999) where the client relies on accurate information in order to make corporate decisions and sanction the work. Increasingly designers and their clients are seeking ways to understand and mitigate the risks associated with the initial design phases of new buildings (Edwards & Bowen 1995). Where information is not available to inform the client, advice in terms of the extent of the project risks in question may be considered an appropriate alternative. If early stage design is to be planned properly risk analysis must also become part of that process.

Techniques more commonly applied in other industries such as value analysis and quality function deployment have delivered opportunities to assess and audit the needs of clients. Value analysis in the form of Value Management and Value Engineering are now commonplace tools within building design (Connaughton & Green 1996). Value analysis by teams representing various functions follows a procedure of familiarisation with the
components and costs of a design and involves the development of a number of cost saving modifications (Cooper & Press 1999). Cooper & Press (1999) identified Quality function deployment (QFD) to be a particular example of one of a number of quality tools used by organisations to influence design. QFD seeks to identify those features of a product or service that satisfy the real needs and requirements of the customer. So far, QFD is increasingly employed during product design within other industries but is little used in building design. In an industry that often views innovation with suspicion, this phenomenon may not be a simple oversight. Further investigation into how QFD might be employed to audit and influence design decisions and an assessment of its potential during the early stages of building design is required.

The flow of information within the design process, its impact on timely and accurate cost advice, risk analysis and QFD has thus been identified as appropriate focus for investigation by the research. The remainder of this introductory chapter outlines the aims and objectives for the research; methodology followed, and delivers the results and findings together with a readers guide to the thesis.

1.2 AIMS AND OBJECTIVES

At the outset the stated aim of the research was:

To improve the management of the concept and schematic design stages with particular reference to developing the brief, the subsequent exchange of design and cost information between the client and designers, and the impact of early design decisions on construction.

Some specific objectives were set to help the research deliver an investigative response to that aim:

1. To investigate current briefing methods in engineering industries (including construction, manufacturing, aero/auto-motive and product design) in order to identify techniques that could improve best practice in the construction industry.

2. To examine how process modelling and matrix analysis techniques might assist in planning/management of the information flow (particularly the effects of changes), and to develop additional strategies.
Chapter One

3. To investigate how designers can provide information of appropriate detail and quality for the purpose of making cost estimates for both the client and the design team.

4. To identify how improved early design strategies could reduce constraints and conflicts during the construction process.

The objectives fall into two categories. The first category or phase in the research was an investigative process into current practice to identify current strengths and weaknesses during the early stages of design. The second phase required a research plan to introduce and test new strategies that can support designers and inspire confidence in their clients.

Category one must first answer the following questions:

1. How does the design process deliver building design to its clients?

2. What type of information do both the design teams and client need?

3. When and why do problems arise?

4. Where may the current process be improved?

Category two analyses the various responses to those questions before synthesising techniques to deliver appropriate solutions.

1.3 RESEARCH METHODOLOGY

The objectives of the research were achieved by employing the following methods.

- A thorough literature search to help with understanding the early stage design process.

- A participant case study of the brief taking process observing designers and stakeholders as they negotiate their needs and requirements during the brief taking and concept study for a new pharmaceutical research building.

- Participant studies at design review meetings to understand current levels of interaction between design disciplines.

- Qualitative interviews with design professionals to investigate their individual roles, corporate responsibility, management issues, multidisciplinary issues, other problems and issues with clients when working within the design and management arena.
Chapter One

- Investigation into appropriate modelling techniques and other tools suitable for incorporation into the research proposals.

- Development, testing and verification of emerging theories and modelling techniques with the industrial collaborator.

- Preparation and production of seminars, reports and papers describing the research project.

1.4 RESULTS OF THE RESEARCH

1.4.1 Introduction to Research Output

The overall aim of this research project, to improve the management of the concept and schematic design stages, was achieved by constructing a model of scheme design and developing other techniques to assist designers systematically plan and audit the early stage design process.

The research into early stage design highlighted a broad range of interrelated problems principle among these being poor coordination of information leading to a requirement for improved planning techniques. The key areas identified:

- Poor coordination of information within the multi-disciplinary design teams undertaking the early stages of design to be a major problem.

- Misunderstanding the requirements of others led to delays in delivering robust design and accurate cost advice to their clients.

- There is a need for improved planning techniques to aid communication between designers.

- Risk analysis has delivered improvements in the way team members negotiate their responsibility towards each other during later stages of design.

The research output consists of two solutions that were developed simultaneously in cooperation with the industrial collaborator through the application of action research techniques.
1.4.2 Output Solution One

- A Scheme Design Process Model (SDPM), based on ADePT and focussing on the interaction between design cost and risk elements was produced to diagrammatically identify information flows from which information dependencies were determined.

- Through systematically ordering the activities with a design structure matrix, a programme of work was produced.

- From the programme of work designers are advised which tasks by which discipline should be completed before the next may continue with certainty. An improvement to programming techniques during scheme design was clearly demonstrated.

- An investigation into an interface procedure between a model of detail design and the SDPM demonstrated how the two design stages could be integrated. The method created is now able to provide designers the flexibility they desire when differing project requirements need to be addressed.

- One of the principal objectives for the research was to improve the quality of information for the purpose of making cost estimates. This was delivered by introducing the cost section to the SDPM so that interaction between the two disciplines of design and cost can now be coordinated.

- Coordinating information through the SDPM may be considered an initial step in understanding the activities performed and the information required by those activities thereby promoting better cross disciplinary harmony as it identifies the responsibilities for delivering the information.

- Using a design structure matrix to prioritise the information input into it allowed the research to address the sometimes difficult to unravel iterations that result when dependent tasks simultaneously rely on the same information. The result is a deliberate and workable order of tasks emerging from a programme that would otherwise require considerable built in float to accommodate the accepted iterative processes inherent in building design.

1.4.3 Output Solution Two

- Investigating the working practices of designers as the SDPM was developed revealed their frustration in fixing design requirements and communicating design solutions. It
Chapter One

was found that neither value management nor value engineering adequately fulfilled the needs of both designer and client for delivering design statements to progressively fix design solutions as they emerge.

- The research into techniques used in other industries found that Quality Function Deployment (QFD) was able to capture the voice of the client and display a quantitative argument to qualitative requirements.

- The QFD techniques presented in this research enabled designers to visually examine their client's requirements systematically.

- The QFD techniques developed may be applied in a variety of instances to explain the design thinking behind solutions required.

- The research demonstrated how QFD could support design statements when auditing the design. QFD provides a quantitative design response to the client's qualitative requirements. This may be referred to when questioning the design development as part of the design documentation and quality assessment procedure.

1.4.4 Contribution to Knowledge

1. Combining the three elements, design, cost, and risk into a Scheme Design Process Model based on ADePT principles allows designers for the first time to:
   - Accurately and systematically, plan for the work required in advance of the scheme design stage.
   - Identify conflicts that lead to iterative problems.
   - Mitigate iterative problems by identifying and recording the design risks source.
   - Qualify the accuracy of the cost advice based on the progress of the design.
   - Ensure closer cross-disciplinary cooperation.
   - Reduce overall project timescale.

2. The research identified that a generic programme of work can now be produced that includes all major elements for the multi-disciplinary design team.

3. The research provides a contribution to the design-modelling database by introducing and demonstrating flexibility between design stages.

4. The research has demonstrated that QFD techniques can be applied to assist design audits and the process of generating design statements.
1.4.5 Main findings

During the investigative research into the early stage design process, several important conclusions were reached that provide justification for the improvements made to concept and schematic design. The conclusions formed constitute the main findings of the research and are listed below:

i. The main cause of problems associated with early stage design can be attributed to weak management and poor communication. These manifest in:

- Poor project coordination.
- Unclear strategies during the investigative briefing process.
- No central coordination of collected information.
- Project delay.

The process is information driven and the quality of the information shared between designers, stakeholders and the study teams could benefit by improving the communication of requirement and tools to promote empathy between participants.

ii. During briefing interrelated problems for both designer and client were uncovered where:

- There is no clear cross-disciplinary design manager/coordinator/leader.
- There is no dedicated client based project manager to drive issues and develop solutions.
- No coherent corporate strategy from the client.
- Too many closed relationships leading to rivalry and mistrust.
- Less assertive stakeholders could be overshadowed when investigating the brief.

There is a need for a clear framework to be in place before the design process commences. Improvements to multi-disciplinary team management might be achieved through developing a modelling methodology to encompass the design team as a unit rather than by discipline.
iii. Designers argued that the concept design stage must remain fluid in its approach to account for the many areas of negotiation, type and sophistication of client, type of cost advice required, location, building etc. A clear distinction remains between the negotiated conceptual stage and the schematic stages of design.

iv. Existing modelling methods applicable to model the flow of information within the design process do not meet with the research objectives or address the issues uncovered by the research.

v. The ADePT modelling method was identified as a suitable information modelling solution for detail design but to plan interaction between designers and cost planners at scheme design would require:

- Alternative diagramming techniques to correctly identify the source of information during scheme design.

- Links between design output and the cost plan to improve planning and accurate delivery of cost advice.

- An element for risk analysis that can be used to audit and monitor information and activities constrained by a particular building design.

vi. It was found that where modelling of scheme design helped plan the process designers also need additional tools to support some of the difficult decisions that need to be taken in partnership with their clients to provide consensus for the design solutions.
Chapter One

1.5 GUIDE TO THIS THESIS

Section One: Problem Formulation

Chapter One: Introduction

A background to the research, the initial aims and objectives together with a statement on the methodology followed to meet the objectives. This chapter introduces the results of the research and sets out the structure of the thesis.

Chapter Two: Early Stages of Building Design

This chapter discusses early stage design covering the briefing process and defining the concept and schematic stages, an explanation is given for the different strategies and terms used at concept and scheme design. The research discusses the problems and discusses findings from these stages. Procurement, management of risk and the delivery of accurate and timely cost advice are all issues affecting the design process; these are introduced under their respective headings. The applicability of existing process models from a variety of industrial arenas have their relative performance assessed and evaluated for use in early stage building design. This chapter also introduces ADePT, IDEFO, the use of an information dependency table, AMMP, PSM, programming techniques and QFD. Describing potential improvements to the early stage design process concludes the chapter.

Chapter Three: Research Objectives and Methodology

Restates the objectives following chapter two and outlines the methodology employed to meet them.

Section Two: Improvements for Concept and Schematic Design

Chapter Four: Shadowing Early Stage Design

The shadowing exercise of a concept study and its link to the scheme design stage is introduced. The first part of the chapter involved the investigation of a concept study and describes that study and the interviews conducted with the design team members. The second part aligns the problems uncovered during the concept study with the findings from the interviews with design professionals to make recommendations and form a strategy for modelling the scheme design.

Chapter Five: Modelling Scheme Design

This chapter explains the investigative procedure used to develop the scheme design model and the methods used to validate it with the industrial collaborator. The model links the
Chapter One

scheme design with both concept design and the detail design stage. It demonstrates the Design Structure Matrix analysis technique used for analysing the scheme design model and the production of detailed programmes. It shows the benefit of incorporating risk analysis and cost planning at scheme design. It explores the model’s potential to provide appropriate detail for making cost estimates for both the client and design team. Examples provided also show its potential to provide a generic process model at the scheme design stage.

Chapter Six: Value Analysis and QFD
Linking value analysis during the briefing process to the Scheme Design Process Model provides programmable opportunity for reducing risk. This chapter also demonstrates the value of QFD as an integral part of the value analysis used during early stage design.

Summary of the Research

Chapter Seven: Conclusions And Recommendations
This chapter concludes the research programme and provides suggestions for developing the techniques demonstrated into integrated process models for the construction industry.

Figure 1.1 on the following page provides an illustrative guide to the thesis.
Chapter One

PROBLEM FORMULATION

Background to the Research

CHAPTER ONE
Introduce Early Stage Design

Investigate Early Stage Design

CHAPTER TWO
Understand Problems

Develop Research Proposals

CHAPTER THREE
Research Methodology

IMPROVEMENTS FOR CONCEPT AND SCHEMATIC DESIGN

Observe the Process

CHAPTER FOUR
Gather Data

Develop ADePT for Scheme Design

CHAPTER FIVE
Introduce Cost and Risk Elements

Develop QFD Techniques

CHAPTER SIX
Suggest Solutions

PROJECT SUMMARY

Summarise the Research

CHAPTER SEVEN
Make Recommendations

The SDPM

APPENDICES

Other Data

Figure 1.1: Illustrative Guide to the Thesis
Chapter 2
Early Stage Building Design
2.1 INTRODUCTION TO EARLY STAGE BUILDING DESIGN

Early stage building design is a holistic title that covers several of the design stages. Within these early design stages are the methods and design processes used by designers to deliver designs to their clients. This literature review investigates early stage building design and defines these stages and the differing terms used to describe both the process and the participants. The literature review also investigates the client types and the effect different types of client have on early stage design. It compares techniques traditionally used to deliver design to the client across other engineering arenas and evaluates the concepts of using Quality Function Deployment (QFD) and Risk Management (RM) as part of that process.

Essential to the design process are; brief taking and brief development, the timely delivery of robust cost advice and the registration of risks to all parties. The literature review looks at the way cost advice is prepared and how design is managed as part of on going design manage and construct environment. It reviews process models and structured programming techniques used for planning design and in particular the ADePT methodology for its ability to deal with iterative problems during detail have been evaluated for use at this critical early stage in the building process.

2.2 DEFINING EARLY STAGES OF DESIGN

2.2.1 Design Stages

The design process in the construction industry has evolved over a long period from the early masons through to the great architects of the twentieth century. It was from the development of the atelier tradition and the birth of academies that institutes such as the Royal Institute of British Architects was formed. The RIBA saw a need to set out a Plan of Work (RIBA 1973) in an attempt to provide a model procedure for the methodical working of the design team. Its first edition was published in 1964. Inside the Plan of Work (Table 2.1), there are twelve stages set out to describe a logical course of action. Stages B and C are generally referred to as the Concept Design stages and D the Scheme Design stage. This research also uses the terms Conceptual and Schematic when discussing these two stages. It is then divided into four elements or parts that refer to the deliverables at each stage this
Chapter Two

research will concentrate on parts one and two. Further clarification of the design stages covered by the research is provided in section 2.9.1 where differing process models, which include those of the RIBA, are plotted against each other in Figure 2.18.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Inception</td>
<td>1. Briefing</td>
</tr>
<tr>
<td>B. Feasibility</td>
<td></td>
</tr>
<tr>
<td>C. Outline proposals</td>
<td>2. Sketch Plans</td>
</tr>
<tr>
<td>D. Scheme design</td>
<td></td>
</tr>
<tr>
<td>E. Detail design</td>
<td>3. Working Drawings</td>
</tr>
<tr>
<td>F. Production information</td>
<td></td>
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<tr>
<td>G. Bills of quantities</td>
<td></td>
</tr>
<tr>
<td>H. Tender action</td>
<td></td>
</tr>
<tr>
<td>J. Project planning</td>
<td>4. Site Operations</td>
</tr>
<tr>
<td>K. Operations on site</td>
<td></td>
</tr>
<tr>
<td>L. Completion</td>
<td></td>
</tr>
<tr>
<td>M. Feed-back</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: The RIBA Plan of Work and its Stages

The Plan of Work, which has currently gone under review by the RIBA (Section 2.9.2), states that it represents an outline method of working only. Designers, particularly designers of highly serviced buildings, have found the Plan of Work to fall short of meeting their requirements for a process that is used to order increasingly sophisticated cost advice required by a client prior to capital sanction. Lawson (1980) claimed the Plan of Work to be part of the architectural profession's propaganda exercise to stake claim as leader of the multi-disciplinary building design team and that from it we learn more about the role of the RIBA than about the nature of the architectural design process.

Gray, Hughes and Bennett (1994) redefined the Plan of Work to suit a particular process (Table 2.2). They were trying to achieve a better understanding of the pattern of contributions to the design and construction process typical on most design management projects. They describe two important stages during early stage design as being the approval of the functional brief and the approval of the scheme design. Briefing and design management are discussed later in sections 2.3 and 2.4 respectively of this chapter.
Chapter Two

Stage 1, the development of the brief is where the initial statement of need is developed by the designer and restated as the functional brief to be agreed and signed off by the client.

Stage 2, the functional brief is developed into the concept design for the project. A budget and a coordinated set of project information are prepared for the client’s approval. The scheme design that confirms the basic systems for the building is checked for feasibility. Value engineering and buildability studies are carried out and the brief fixed. Design solutions are produced that include planning arrangements, appearance, construction method, a comprehensive specification, together with detailed cost and time budgets.

<table>
<thead>
<tr>
<th>Architects plan of work stages</th>
<th>Services proposed</th>
<th>Design management plan of work stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Inception</td>
<td>Brief and information gathering</td>
<td>1. Brief:</td>
</tr>
<tr>
<td></td>
<td>Site appraisal</td>
<td>Statement of need</td>
</tr>
<tr>
<td></td>
<td>Advice on design work by specialist and other consultants</td>
<td>Brief Development</td>
</tr>
<tr>
<td>B. Feasibility</td>
<td>Feasibility studies</td>
<td>2. Concept design</td>
</tr>
<tr>
<td>C. Outline proposals</td>
<td>Outline proposals</td>
<td>Feasibility studies</td>
</tr>
<tr>
<td>D. Scheme design</td>
<td>Scheme design</td>
<td>Scheme design</td>
</tr>
<tr>
<td></td>
<td>Advice on affect of changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Planning application</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2: Plan of Work Stages Aligned to meet the Design Management Stages of Early Stage Design (Gray et al 1994)

A two-stage philosophy has also been adopted for this research, to draw a clear distinction between the negotiated conceptual stage and the schematic identifying of deliverables stage (Figure 2.18). The former being an iterative decision taking process of negotiation between the client and the design team that culminates with a concept design report. The latter being where the concept design undergoes further development, to consult with the regulatory authorities, to identify the spatial and material elements and to provide cost advice with sufficient detail for the design team to progress the design into the detail design stage. Between each stage is a point at which the client signs off and agrees the progress of the design. This provides design fixity where the client agrees not to vary the requirements. It also provides a cost gate where the client also agrees the budget and accepts the design cost.
The use of gates to delineate stages in the process (Sheath et al 1996) has been adopted as the most appropriate way to provide project review and design fixity. This is discussed further in section 2.9.3.

2.2.2 Concept Design

Concept design was defined (BSI 1989) as the design process in which concepts are generated with a view to fulfilling the objectives. There are different definitions from other industries in the aeronautical industry Chiesa & Magiore (1995) described it as not so well defined to allow the construction but accurate to allow comparison. It is used to compare products from rival firms or for choosing of the most suitable solution for subsequent development.

In the construction industry, conceptual design is the stage of the design process in which ideas and working principles for the product are conceived. Such ideas only need to contain that detail necessary to define the essential elements of the idea or concept. The concept design evolves over a period with many adjustments/revisions resulting from the continuing dialogue between client, designers and cost consultants (Aston et al 1989).

From the statements provided in the functional brief, the design team can develop the concept and outline proposals for the project. During the transitional period between the functional brief and the start of the scheme design, the brief is tested using value management and benchmarking procedures, feasibility studies are carried out, a cost plan is initiated and a programme of work is agreed. The process will deliver to the client one or more concepts for them to consider and sign off before the chosen scheme may continue on to the next stage.

2.2.3 Scheme Design

The purpose of scheme design is to develop the project sufficiently for the client to be sure that it will meet their requirements. British Standard 7000 part 4 (1996) required that scheme design provide a foundation for detail design through structured development of the concept. The requirements of the planning authority and other regulatory bodies need to be consulted (Connaughton & Green 1996). The design development process of negotiation with the client is similar to that carried out during the concept stage though there are now fixed points of reference and uncertainties have now largely been eliminated. It is a key point in the design process where the client and designers agree the scope of the work.
Chapter Two

Once the scheme has been agreed and all documents are 'signed off' by the client the next stage in the design process may continue with certainty.

At the scheme design stage the design team will have prepared (Gray et al 1994):

- Plans
- Cost plan
- Specification
- Elevations
- Programme
- Special studies and reports

The plans and elevations will normally be produced at no more that 1/100 scale but provide sufficient information when read in conjunction with the project specification for development at the later detail stage of design.

The cost plan generally provides the client with a cost certainty to within +/-10% accuracy of eventual construction cost.

A programme of work is produced to indicate time periods and resources for both design and construction.

Special studies and reports will be conducted to investigate inestimable project risks.

The design team and the relationships typically involved in a designer led project during scheme design are displayed graphically in Figure 2.1.

Potter (1995) claimed that the work at this stage is mainly about defining the principles of the spatial arrangements, standards and construction methods. However, these may still undergo changes as the detail of the brief evolves and options are tested against the cost plan. The Plan of Work (RIBA 1973) stated that the brief should not be modified after the scheme design stage but in practice this is not always so. The National Joint Consultative Committee of Architects, Quantity Surveyors and Builders (1973) recommended that as briefing and design by nature often overlap, construction be best deferred until all decisions have been made and all design work completed for which adequate time should be allowed. In an ideal world, this would be an appropriate solution but due to the time and cost constraints imposed by the client and their business commitments this is rarely allowed to happen.
2.3 BRIEFING AND DEVELOPING THE BRIEF

In the preceding sections of this chapter on early stage design, we have seen how it is divided up into stages that produce deliverables for the client to agree or sign off before the following stage commences. A crucial part of early stage design is the understanding and interpretation of the client's needs and requirements. This is done through the briefing process. Briefing encompasses more than one stage in the design process.

The British Standard Institution (1995) defined briefing as:

The process of identifying and analysing the needs, aims and constraints (the resources and the context) of the client and the relevant parties, and the process of formulating any resulting problems that the designer is required to solve.

Briefing in the construction industry is the process of preparing a written brief or instructions that will facilitate the satisfactory accomplishment of a design task.
Chapter Two

There had been few authoritative works on the subject of briefing in the UK until the Building Research Establishment collected earlier research and sponsored a report on the subject (O'Reilly 1987). In a publication on guidelines for design teams the Ministry of Public Building and Works (1967) claimed that clients are often uncertain of their needs leading to frequent change of minds and that a closer collaboration between the design professions was seen as a solution. This prognosis has not changed much in 30 years as the Latham (1994) and Egan (1998) reports have confirmed. A recent publication sponsored by the DETR/EPSRC/LINK IDAC (Barrett & Stanley 1999) reached the same conclusion.

The responsibility for briefing has traditionally been placed on the designer. Then came work outlining the design responsibilities of the client in the form of the National Joint Consultative Committee of Architects, Quantity Surveyors and Builders (1973) that changed the emphasis to the client rather than take an impartial view of the whole. Briefing and the problems associated at the briefing stage of design have been discussed and addressed in one form or another over a long period. Salisbury (1980) addressed the issue for architects in his handbook claiming that they have been particularly self-critical on the subject of client briefing but that variation in client type and building requirement has made their task no less easy. Other agencies in the past have attempted to produce critical analysis looking at relationships and adversarial problems (Newman, Bacon and Dawson 1981). Their report stated that their findings were from a survey of architects and that client’s were likely to have a different view of the briefing process. However, they did make an important point in that the brief should be clear, provide systematic information and that all changes to the brief should be recorded, acknowledging a need for prescriptive solutions. Of further interest from their survey was their finding that the majority of architectural practices did not find the RIBA Job Book a useful guide to briefing. This is a reference to the Royal Institute of British Architects (RIBA 1973) Handbook, which has formed the basis of much academic comment (Section 2.9.2). The RIBA have however, defined the stages of the design process to which most practitioners will still refer to when given the task to design and construct new buildings.

O'Reilly & Brewer (1986) addressed briefing from the client’s point of view discussing the problems that arise from the client’s circumstances declaring the client’s circumstances are made worse by certain characteristics of building projects and that clients often fail to understand the challenging nature of building projects. Consequently, they appoint people
of relatively low status as representatives. Coles (1990) on the subject talked about central co-ordination and the use of consultants but claimed few clients want to deal directly with them. He also suggested that consultant teams be appointed as early as possible and that the client should be informed about the need for decisions and the consequence of inaction.

Little has changed in 30 years in the way briefing is conducted. Barrett and Stanley (1996) stated in their report on good practice in construction briefing, that very few buildings finish on time or at the right price and clients often criticise the fact that the finished building is not what they expected. They concluded that best practice reports of which there have been numerous over the years have provided little improvement or change in the way briefing is handled. However, Latham (1994) had refocused attention on briefing, calling for a new guide for clients, insisting on a distinction between the Project (Client) Brief and the Design Brief. He also called for additional time and space to be allowed, whether or not the project is designer-led, and for the client's wishes expressed in the Client Brief to be further tested on the question of feasibility for the purpose of the Design Brief.

The brief then may be delivered in two parts:

1. **The Client Brief**, which is presented to the design team in terms of the client's requirements. This can also be termed conceptualisation or the functional brief, which is investigated during the Concept Design stage.

2. **The Design Brief**, sometimes called a definition brief, which is a process by which the designer gathers all the information that will form the basis for detailed design. This is completed at the end of the concept design or during the early part of Scheme Design stage.

Together they form the main outputs of the briefing process, the preparation of information from which a building may be designed and built.

### 2.3.1 The Client Brief

A brief is taken from the client in terms of the client's initial requirements this is called the client brief. The instructions given in the client brief are then investigated and developed to form the functional brief for the project. In an ideal situation the client brief should concentrate on a clear balanced statement of aims, resources and context which is specific enough for action but permits design and construction options so that consultants can use
their skills and knowledge in these fields (O'Reilly 1987). The brief is the assembly of information both in general and specific terms, prepared for the purpose of the design of new buildings or for the alteration and refurbishment of existing buildings (Melville and Gordon 1983). Briefing and design form an interactive process, without a probing dialogue between architect and client, the brief will not evolve into an effective design (Blackmore 1990). Clients need to recognise the positive and sustained contribution they have to make and their responsibility to adhere to financial and programme targets. Murray (1990) identified that a major problem encountered by clients new to the construction industry is the lack of informed and impartial advice available to them during the early stages of briefing. Information on briefing has been readily available to advise clients about the process they are about to undertake (NEDO 1974), (O'Reilly 1987), (Parsloe 1990), (Wintour 1990), (Potter 1995) and (CIB 1997) but on review most contain a bias that discriminates against the inexperienced client.

2.3.2 Client Types
Two issues need to be raised with regard to clients: What do we call them? How do they vary? Clients may be termed customers, stakeholders, or user and there has been much debate on the use of the most appropriate title. A simple chart may help to convey the consensus drawn by the research (Figure 2.2).

![Figure 2.2: Stakeholders to a Project](image)

The following terminology has been adopted for this research:

**Client** - a person using the services of an architect or other professional person.

**Customer** - a person who buys goods or services from a business.

**Stakeholder** - a person with an interest or concern in something.
Chapter Two

User - a person who makes a practical use of a product (e.g. the building) or a service.

Clients vary considerably in type and ability to determine and convey their requirements for building works. Melville and Gordon (1983) claimed that the individuals and organisations owning an interest in property to be very varied indeed. They wrote about 'inexperienced' and 'experienced' client's and how briefs can take as many forms as there are client’s, from the basic requirements of the uninitiated private client to the highly detailed and technical brief from the expert client. The Chartered Institute of Building (Aston et al 1989) identified two broad categories of clients:

1. **Expert**, these clients have usually built on several occasions, have refined, and developed systems for ensuring that they get the best out of the building process. On other occasions, the expert client will specify a type of building that has not been encountered before. In this case, he will have experience in building, but will need to concentrate his efforts in specifying the particular nature of the project. Expert clients more readily use consultants to assist in formulating their ideas.

2. **Inexpert**, These clients are usually those who have not built before or have not yet developed or refined systems to ensure that they get the best out of the building process.

Newman, Jenks and Dawson (1981) in their survey found architects rated client’s inexperience and preconceptions as their most frequently occurring problem. Taylor and Hosker (1992) identified a further four different client types by addressing the requirements of the client:

i. Clients such as government or those who are regulated as government agencies. Crown buildings, hospitals and educational buildings usually fall into this category, where detailed briefing information is usually available.

ii. Those clients where the brief is established by consultation and in discussion with the client’s representatives usually adopting the guidance and checklists as set down in the firm’s procedure.

iii. Those clients who wish to establish a ‘full’ brief at the outset of the job as a basis for making strategic decisions in terms of site purchase and/or site development, or for the purpose of building selection.
Chapter Two

iv. Those developer clients where no detailed briefing is available other than the stated objective of maximising the investment. Office, retail or mixed-use developments fall into this category.

The levels of experience within each category vary considerably. Consequently, a different approach by the design team to each client is to be expected.

2.3.3 The Design Brief

Parsloe (1990) described the design brief in terms of an exercise in human communication, that is prone to the vagaries and psychological factors that can influence the perceptions of conversations and agreements. He went on to say that in the context that this communication takes place, between the client and expert adviser, it is of paramount importance that a relationship of mutual trust and co-operation exists.

The RIBA have described two stages, Inception and Feasibility, to the briefing process (Table: 2.1) but as previously stated the interaction with the client that normally takes place during briefing does not cease abruptly.

Barrett and Stanley (1999) recommended the underlying principle of deciding on as little as possible at each stage, seeing the process running throughout the construction project to leave flexibility on other issues for later consideration as more information becomes available.

The author has come to believe that principle to be impractical when considering a process model because where decisions are not made estimates are required in order to continue to the next stage in the process otherwise issues cannot be resolved. This point is revisited in sections 2.9.7-8. An alternative principle would be to decide on as much as possible as soon as possible, effectively having the same outcome, as it is possibilities that are being discussed but in this case placing an emphasis on taking decisions wherever possible in order to drive the process.

At a minimum briefing continues through the next two stages, Outline Proposals and Scheme Design. The Outline Plan of Work (RIBA 1973) acknowledges this, where it states after stage D. Scheme design, the 'brief should not be modified after this point'. At the end of each of these key stages, A through to D in the development of the design, there is opportunity for the design to be reviewed. A review check is a formal examination of the
design to confirm that the design meets with the client's brief and conforms to appropriate standards (Taylor & Hosker 1992).

The client brief is rarely sufficiently detailed to meet design requirements consequently; a design brief needs to be developed. BS7000 (1996) required the design brief to provide a comprehensive technical interpretation of the client brief for the component disciplines within the design team. The design brief is a document undergoing continuous developing as a pre cursor to detail design. At that point, the design must be sufficiently defined and frozen for the detail design team to produce all the information required for the construction process. It follows that a systematic development of all elements is required for this to happen. Although designers are still consulting with the client and project stakeholders as the design brief is produced, the focus is on preparing design information, cost estimates and assessing the design risks that the detail design team will encounter. Blythe (1995) claimed that without professional advice, design teams make their own interpretations of the brief and important issues can be overlooked. Wanting to freeze the brief yet making sure all issues have been explored is a common dilemma. Clear communication between designers within teams is therefore paramount. Decisions need to be made in logical order, this requires a systematic definition of design tasks and this approach should be carried through to define the responsibilities of all firms engaged on the project (Coles 1990) at this time.

2.4 DESIGN MANAGEMENT AND MANAGING DESIGN

2.4.1 Management of Design

Design management's prime responsibility is to control the design activity in a manner which ensures that projects are completed on schedule and within budget and that the resulting product can be delivered at the right price with the desired quality (Cook, P. et al 1989). BS7000 (1996) provided a framework for design management with guidance on management of the construction design process for all organisations and for all types of construction project.

The management of building design needs to encompass a wide scope of individual problems. Coles (1990) in his survey into design management practice provided an overall view of fault generation. He apportioned inadequacies in no particular camp and
Chapter Two

highlighted some of the areas in terms of ‘main source problems’ and ‘adverse effect on project & process time/cost/quality’.

The main source problems described by Coles (1990) manifest in:

- Financial constraints.
- Slow and uncertain authorisation.
- Inadequate briefing.
- Poor estimating or wrong design philosophy.
- Designer knowledge of construction time and cost.
- Inadequate staff or trained staff not available.

These have an adverse affect on project and process time/cost/quality resulting in:

- Late/inadequate specialist advice.
- Changes and indecision.
- Insufficient time allocation.
- Inadequate checking of design solutions.

His most significant findings found poor briefing and communication, inadequacies in the technical knowledge of designers and lack of confidence in pre planning for design work to be the root cause for the common consequences listed above. Coles (1990) also claimed the management of time and resources emerged as an important area of concern.

Morris (1991) identified the need to adequately consider and develop the project objectives, technical base and general strategic planning and for the design to be firmly managed in line with its strategic plans. In addition, it is important for management to make major and critical decisions and to measure the results to ensure objectives are met. Burton (1992) claimed the best and smoothest running projects are those that have been properly set up at the front end where a strong constructive team spirit has been created. Gray (1996) suggested better integration with the client organisation to achieve a flat organisation and minimise communication gaps.

25
Chapter Two

Clearly managing a team of experts brought together for a project requires additional skills in psychology and the art of communication to create a strong working relationship in the design team.

Austin et al (1995) claimed that poor information management and design planning are inextricably linked and argued that an improvement in design planning would facilitate the management of information.

The management of design was once seen as a natural part of the architects’ appointment. In its classical form the customer first commissions an architect, the architect establishes the project brief and then produces an outline scheme design (Bennett 1991). The architect will usually be helped in this process by engineering design consultants and quantity surveyors, whose employment the architect recommends to the customer. When the scheme design is accepted a quantity surveyor would draw up a cost plan arranged in design elements to provide cost targets for each disciple within the design team. Traditionally the design team would consist of separate firms of architects, engineers and surveyors and this fragmented approach to design is managed by the architect. In order to meet the demands of current clients and their stakeholders using other methods of procurement has succeeded this traditional approach.

Procurement describes the contractual methods available to clients to secure the design and construction of their building projects. To set the arena in which this research is conducted a brief discussion on procurement is required. Latham (1994) concluded in his report that the basic decision on building procurement should precede the preparation of the outline project brief.

Associated with the RIBA plan of work the traditional procurement approach was seen to be complicated and slow to deliver accurate and timely cost advice to the client leading to the client often requiring contractors to tender and start building before the design work is completed. To address this and other problems faced by clients, designers and contractors building professionals developed alternative procurement methods designed to suit a variety of customer and building types. (Potter 1994) described these under two categories:

- **Multi-point** where the client enters into separate contracts for various aspects of design and construction, so dividing responsibility for the finished building, and
Chapter Two

- **Single point** where the client enters into a contract for design and construction service with a single organisation.

It is to the latter of these two that this research has concentrated specifically the Design, Manage and Construct route, as this was the process employed during the case study (Chapter Four). However, it must be stated that the requirements in terms of design remain primarily the same during early stage design it is the fee preparation or level of cost advice that is affected by different procurement routes.

A distinction needs to be drawn between the terms Design and Build (D&B) and Design, Manage and Construct as they both fall within the single point route. Lafford et al (1998) provided a review of D&B, in which they confirm that managing the design process in today's construction environment is about the interaction of client, contractor and-designer. They claimed D&B to be the realisation of a concept by a team of engineers, architects, clients and others working together and that D&B presents opportunities to optimise design with safety, economy and increased buildability. D&B gives clients the opportunity to select one of two different approaches to procurement - *time and cost certainty or value driven innovation*.

- **Time and cost certainty** can be achieved in the basic form of D&B (three phases) with a well-defined contractual interface between the client and the D&B contractor.

- **Value driven innovation** is best achieved through the fully integrated team approach (single phase), founded upon *partnering* relationships.

*Partnering* is a contractual arrangement between two parties for either a specific length of time or for an indefinite period. The parties agree to work together, in a relationship of trust, to achieve specific primary objectives by maximising the effectiveness of each participant's resources and expertise (Franks 1998).

Design and build has become an established method of procurement and clients feel comfortable using both the three-phase procurement and its *novated* variant.

*Novation* occurs when, in the context of building procurement, the client employs consultants to design and specify the proposed building to the extent that the client's needs are clearly stated, the client then novates his arrangements with the consultants to the contractor (Franks 1998).
Chapter Two

A distinction can now be drawn between D&B and Design, Manage and Construct by stating. Design, Manage and Construct procurement is where a consultancy organisation is appointed to provide Design and Build Management service for an agreed fee. The organisation is responsible for co-ordinating the design and the construction (Potter 1994).

2.4.2 Delivering Design

Latham (1994) discussed integration of the work of designers and specialists and citing an example he required urgent attention to the elimination of the muddle preventing architects or engineers delivering design. He also required better understanding between the client and the design team. If clients can clearly understand the outcome of projects at the design stage, their wishes can be better met. Delivering design is not just about meeting deadlines at particular cost gates (RIBA 1994) (Sheath et al 1996). It is also about the way design is delivered and that is information based.

Co-ordinated Project Information (CPI 1987) (Snook 1995) is concerned with the delivery of technical information prepared by designers but is generally applied at the later detail stage of design. Latham (1994) stated that as part of a full matrix of documents CPI should be made part of the condition of engagement for designers. He required a clearly defined practice to be in place at the earliest opportunity to facilitate this process. A clear strategy should therefore be decided upon as early as possible in the development of a project and the relevant responsibilities defined and agreed by the design team since the chosen strategy is likely to influence the subsequent design stages.

At the completion of the scheme design, a final development of the brief should include full design of the project by the architect, preliminary design by engineers, preparation of a cost plan and a full explanatory report (RIBA 1992).

2.4.3 Delivering Cost Advice

A total cost budget and programme will normally be prepared at the end of the concept design stage. This should also include a broad indication of how the available money is to be allocated to the various sections of the project. Called an Estimating Plan it will contain information relative to the cost enquiry. It asks if the client has provided a specification, as the cost advice will depend on standards determined by the client, i.e. the quality of materials to be used, the appointment and location of fittings etc. Where a clear specification has not been provided the design team will investigate the brief through
corporate and user group meetings to determine all the client's needs and requirements. It is during the conceptual stage of design that the basic cost decisions are made but it is at the schematic design stage that the design solution and cost framework are fixed (Swinburne 1980).

Delivering the cost advice is not simply a case of recording the anticipated costs as the design unfolds. Cost control starts at the inception of a building when the client wishes to know how much his idea is going to cost. Cost estimating is generally thought of and used as a method for design evaluation (Johnson 1990). In the early stages of design, this will generally be provided in terms of functional area cost per square metre. Throughout the design process there will be cost checks, the major cost checks will normally fall at the sign off points referred to in section 2.2.1. The cost advice will naturally achieve a greater certainty as the design is developed.

Traditionally the quantity surveyor carries out the task of providing cost advice and the cost planning operations. Judson (1970) stated that the designer must take an interest in the cost control process if it is not to degenerate into cost recording. One solution is to have an estimating and cost control section within the design office. However the seamless integration of the cost planner and the designer is not always easy as cost planners are seen by designers to control the design and designers are seen by cost planners as unrealistic when it comes to economy (Stone 1983).

Bowen-James (1995) identified three major problems in delivering robust cost information at early stage design:

1. The segregation of cost control knowledge from conventional design knowledge, this is where the application of economic evaluation methods cannot proceed until all the major design decisions have been made.

2. There is a lack of well-trained cost control experts involved in the design team. Evaluating the economic performance of a design at an early stage is a complex cognitive process and the major cost related decisions are being left to the architects and engineers.
3. Design information during early stage design is incomplete. Detailed drawings and project specifications are not available early enough to furnish the metrics and elemental details necessary for accurate cost assessment.

2.4.4 The Impact of Improved Cost Advice

Time spent at early design stage can potentially save large amounts of money on the project as a whole because design changes during later stages of a project can be expensive (Figure 2.3). Risk may also be mitigated with time so it is important to achieve a balance when estimating for design.

Value for money in building design depends on rational decisions, which according to Connaughton & Green (1996) means ensuring that:

- The nature of the problem is fully understood.
- Decisions are made in the light of agreed objectives.
- Different options for achieving the agreed objectives are considered.
- The options and their associated risks are carefully thought out.
- Decisions are made based on the best available data.
- Decisions draw on the widest possible range of expertise.

2.4.5 Planning Design

Planning design involves the systematic determination of the specific form of the product. It can be achieved through a variety of planning techniques used by the brief takers at the inception stage. The planning of building design can be both deterministic and stochastic in that action may be external to choice and determined by a random distribution of probabilities. Various techniques have been developed to assist with the generation of ideas and provide strong guidance to the designers. Dandy and Warner (1989) described how these techniques might be grouped into two categories:

1. Analytical techniques, such as attribute listing and morphological synthesis.

2. Free association techniques, such as brainstorming and the Nominal Group Technique.
Chapter Two

Through logical analysis of all the components, an individual working alone best applies analytical techniques whereas free association techniques are designed to encourage the free flow of ideas within groups.

Attribute listing is described as being most applicable in cases where there is an existing solution and ways to improve it are being sought. The steps involved are:

- List all the components or elements to the existing solution.
- List all the attributes of the product and its components i.e. weight, size, colour, shape, material, etc.
- Systematically change each attribute of the product and its elements in every possible way.

Morphological synthesis sometimes known as matrix analysis and based on general decision matrices (Beakley & Leach 1967) is used for the generation of unusual combinations of system functions the steps involve:

- Describe the problem.
- List all the major system parameters.
- List the alternative ways of satisfying each system parameter.
- Draw up a matrix with each system parameter as one dimension.
- Consider all possible combinations of ways of satisfying each parameter.

For basic decision making this form of analysis provides a systematic method for analysing the identified problems by aligning them against a series of solutions. However, unless the matrices are applied in an automated or computerised system as in a design structure matrix (Section 2.9.7) this form of analysis can be unwieldy and impractical.

Brainstorming (Rawlinson 1970) is a technique widely used to capture a broad spread of ideas by creating participant groups of between six and twelve people co-ordinated by a chair person with somebody to record the flow of ideas. The rules of a brainstorming session are:

- All ideas must be recorded.
Chapter Two

- No idea may be criticised or evaluated during the session.
- It is permissible to build on, expand, or combine the ideas of others.
- The emphasis is on quality of ideas produced.

Brainstorming has proved useful in a multi-professional team, valuing each member's contribution. However, the brainstorming session needs to be tightly co-ordinated by the chairperson in order to get the best results from the time allowed or allocated to its process.

Once the ideas have been recorded a further focussing session later is worthwhile to help flesh out the better ideas identified.

**Nominal Group Technique** (NGT) (Deason & White 1984) is different from brainstorming in that it encourages all participants to contribute in a non-competitive way. The groups are smaller and chaired by a leader who will introduce the problem. The steps involved are:

- Individuals generate ideas in writing.
- All ideas are recorded in a manner that does not identify the writer.
- Ideas are then clarified in discussion.
- A series of voting rounds are held to select a few recommended solutions.

Deason and White (1984) found the NGT to combine the idea generating efficiency and effectiveness in stimulating original thought of the brainstorming methods with the benefits, cooperation and cohesive strengths of group interaction.

Agreement on the techniques to be used for evaluating design requirements should be made between client and designers at the earliest possible time. The type of client and the project on which they are to be used will determine the combination of techniques used. Generally, the time spent on initial planning can be recovered by reducing the overall consultation period during the concept study and an improvement in the quality of information used to develop the design.

Planning design is a front-end activity performed during the initial briefing stages. It remains separate from the planning of the intra-disciplinary responsibilities of the designers.
although the two are intrinsically linked. It remains a requisite element and the building
design process cannot be conducted without the clear objectives determined at this stage.

Planning design and evaluation of the information uncovered are mutually linked. Value is
a major consideration and must be addressed by the client and design team, section 2.5 of
this chapter discusses Value Analysis and further methods used to capture and evaluate
early stage design.

2.4.6 Programming Design
Starting with the earliest meetings programmes are used to determine the course for the
design process. These programmes will inevitably be revised as the design is progressed
and further information about the client's need is uncovered. By sequencing a unique set of
detailed activities, it is possible to prepare an estimate of time and cost with a higher
probability of achievement than by examining the overall project scope (Callahan et al
1992). Before a programme can be determined, a plan of action using an appropriate
methodology must first be agreed (Section 2.4.5).

Programming techniques have evolved over a long period of time and can include
individual or combinations of Gantt charts, Critical Path Method (CPM), Programme
Evaluation and Review (PERT), Precedence Diagram Method (PDM), all of which have
been included within one computerised system or another to further enhance the process.
Callahan et al (1992) suggested that whereas computers may assist the planner by sorting,
storing, performing math and matching data, they do not provide the intellectual direction
and creative thought required to produce a schedule for a unique and complex construction
project. The following provides a brief description of these planning techniques; it outlines
their historic evolution and some of their advantages and disadvantage's when used for
managing projects.

Bar (Gantt) Chart and Linked Bar Charts were first proposed by Henry L. Gantt around
1900. The Gantt chart was for many years the primary tool used to control projects (Jewell
1986). The Gantt or bar chart is an excellent tool for determining resource conflicts and for
levelling resource commitment. Its main weakness is that it does not adequately reflect
interactions among activities. There are two types of bar chart non-linked and linked, the
difference between a bar chart and a linked bar chart (Aouad et al 1997) is that the former
does not show any connections between activities, whereas in the latter links between
activities are used to show constraints that exist among these activities. It may be used to present schedules produced by other planning methods PERT/CPM, ADePT (Austin et al 1996).

Activity on Arrow Networks (AOA) which include Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) are two management techniques that were developed to overcome the limitations of Bar or Gantt charts. PERT was developed for the US navy in 1957 to help manage the Polaris missile project. As a result, the project was completed ahead of time. The Critical Path Method (CPM) was developed about the same time by the E. I. DuPont Co. to meet its construction and project management needs. Gray (1981) provided an excellent history and methodology for PERT and CPM. It is important to note that PERT was developed as an event oriented technique, whereas CPM was developed as a task orientated technique. Using PERT the designer can estimate the expected project duration and the probability of completing the project on time, PERT/CPM is based on the analysis of activity on arrow project network diagrams whose nodes represent points in time (events) (Aouad et al 1997).

Activity on Node Networks (AON) typified by the Precedence Diagram Method (PDM) first presented by Professor John W. Fondahl of Stanford University who called the technique “circle and connecting line”. In 1961, J. David Craig first applied the name Precedence Diagramming Method to a version developed within the IBM Corporation. There are many differences between AOA and AON formats but the most important is that in AON nodes rather than arrows represent the activities in the diagrams. In addition to this PDM considers four logical relationships to use the concept of lag (days between) activities to create a more flexible tool. Callahan et al (1992) described this in detail and suggested that the CPM scheduler should select the format with which he or she is most comfortable. Understanding each format’s assets and limitations allows the scheduler to avoid some of the difficulties encountered in the development, updating and impact of CPM schedules.

In recent years, there have been many advancements and modifications to the basic network analysis techniques. Decision CPM, Graphical Evaluation and Review Technique GERT and advance on PERT, Q-GERT being a further refinement that can model queuing systems in a graphical form. Newton (1995) explained the applicability of network analysis to represent design and concluded that none adequately handle the iterative nature of
building design. However, their value for programming resources and durations remains unchallenged when the sequencing of detailed activities has first been agreed.

2.5 VALUE ANALYSIS

2.5.1 Introduction to Value Analysis

As part of the management of design, other issues such as the Value Analysis process also need to be addressed. This section considers two of the components used in value analysis, Value Engineering/Management and Quality Function Deployment. Both are employed to determine client/stakeholder requirements and provide solutions that enable designers to provide value to their customers. Figure 2.3 graphically displays the opportunity to improve value for money.

![Figure 2.3: Cost & Value over Time](image)

The value analysis process has been an established technique for over forty years. Value analysis and specifically value engineering was developed as a technique after World War II. The development work was done at the direction of the General Electric Company vice-president of purchasing, Mr Harry Erlicher, who observed that some of the substitute materials and designs utilized as a necessity because of wartime shortages offered superior performance at lower cost (O’Brian 1976).

Yoji Akao introduced the concept of Quality Function Deployment (QFD) in Japan in 1966. First used in Mitsubishi’s Kobe Shipyards in 1972, then developed further by Toyota and their suppliers QFD has been successfully demonstrated and used by Japanese manufacturers ever since.
Chapter Two

During the initial approach to a design problem, emphasis is placed on product formulation for the concept and embodiment of the design. QFD employs a mix of creative and systematic methods, which together can be used to resolve design problems and develop successful solutions. (Cross 1994) 'Quality Function Deployment is a direct translation from Japanese characters to the phrase ‘Hinshitsu Kino Tenkai’. In Japanese, this phrase means something like the strategic arrangement (deployment) throughout all aspects of a product (functions) of appropriate characteristics (qualities) according to customer demands. Cohen (1995) provided a chronological history of its development in industry.

2.5.2 Value Management/Value Engineering

Value analysis specialists use the terms value management and value engineering interchangeably however the term engineering has a very definite pre-established meaning in the design and construction arena. Its applicability to value analysis would imply a narrow operation not touching many of the activities of the client and stakeholder. Miles (1972) described value engineering as a disciplined action system, attuned to one specific need: accomplishing the functions that the customer needs and wants.

The term Value Management (VM) has been adopted in the UK rather than the US term Value Engineering (VE) differentiating between the broad management approach to value rather than the narrower focus on technical performance (Kelly & Male 1993). VE is viewed as only one of the components of the management of value. Other components in the value equation are the interactions between time, cost and quality in the context of the client’s strategic management process and subsequent value system. Value management has become an accepted term within Europe and particularly at the EU Directorate level.

Value analysis is split into two elements in building design, VM and VE. VM is defined as a structured approach to defining what value means to a client in meeting a perceived need by establishing a clear consensus about the project objectives and how they can be achieved. VE is defined as a systematic approach to delivering the required functions at lowest cost without detriment to quality, performance and reliability (Connaughton & Green 1996). It is considered as a design audit involving the selection of high cost areas and compares the elemental costs with the cost of cheaper alternatives (Palmer et al 1996). Nominally, both VM and VE are conducted as a workshop centred activity involving both stakeholders and designers. They are used to establish project objectives and achieve cost effectiveness. A central feature is the definition of all functions required by the customer.
into verb-noun statements; the function statements are then evaluated (Miles 1972) using a variety of techniques by the design team.

VM is conducted at the briefing stage to help identify the need for a project, its key objectives and constrains (VM1) and again during concept design to evaluate developing design proposals (VM2). VM1 and VM2 use many of the planning techniques discussed in section 2.4.5. It is during the scheme design process that VE is used. Locke et al (1994) provided an overview of team participants, tasks and deliverables in Table 2.3.

<table>
<thead>
<tr>
<th>STAGE</th>
<th>PARTICIPANTS</th>
<th>TASKS</th>
<th>DELIVERABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Brief</td>
<td>Client</td>
<td>Determine needs/wants</td>
<td>Rested brief</td>
</tr>
<tr>
<td></td>
<td>VM Co-ordinator</td>
<td>Set target ratios</td>
<td>List of creative ideas</td>
</tr>
<tr>
<td></td>
<td>Design Team</td>
<td>Set target costs</td>
<td>Target ratios</td>
</tr>
<tr>
<td></td>
<td>Cost Planner</td>
<td>Identify excess requirements</td>
<td>Target costs</td>
</tr>
<tr>
<td></td>
<td>Specialists</td>
<td>Function Analysis</td>
<td>Implementation strategy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generate / Evaluate alternative options</td>
<td>Risk Management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VM strategy</td>
<td></td>
</tr>
<tr>
<td>2. Concept Design</td>
<td>Client</td>
<td>Compare efficiency ratios</td>
<td>Evaluate alternatives</td>
</tr>
<tr>
<td></td>
<td>VM Co-ordinator</td>
<td>Compare target costs</td>
<td>Outline specification</td>
</tr>
<tr>
<td></td>
<td>Design Team</td>
<td>Identify excess requirements</td>
<td>Optimum layouts</td>
</tr>
<tr>
<td></td>
<td>Cost Planner</td>
<td>Function Analysis</td>
<td>Principle materials</td>
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<td></td>
<td>Planner</td>
<td>Generate / Evaluate alternative options</td>
<td>Approximate budgets</td>
</tr>
<tr>
<td></td>
<td>Specialists</td>
<td>Evaluate site opportunities</td>
<td>Notional programme</td>
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<td></td>
<td></td>
<td>Buildability reviews</td>
<td>Implementation strategy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Programme alternatives</td>
<td></td>
</tr>
<tr>
<td>3. Scheme Design</td>
<td>Client</td>
<td>Review efficiency ratios</td>
<td>Tested scheme</td>
</tr>
<tr>
<td></td>
<td>VE Co-ordinator</td>
<td>Review costs</td>
<td>Design strategy</td>
</tr>
<tr>
<td></td>
<td>Design Team</td>
<td>Function analysis</td>
<td>Cost Plan</td>
</tr>
<tr>
<td></td>
<td>Cost Planner</td>
<td>Generate / Evaluate alternative options</td>
<td>Implementation strategy</td>
</tr>
<tr>
<td></td>
<td>Contractor</td>
<td>Temporary works / buildability reviews</td>
<td>Programme</td>
</tr>
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<td></td>
<td>Specialists</td>
<td>Optimum Statutory Authority compliance</td>
<td>Alternative opportunities</td>
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<td></td>
<td>Programmer</td>
<td>Procurement strategy</td>
<td>Outline method statements</td>
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<td></td>
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<td>Early TC involvement</td>
<td>Cost effective tender package</td>
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<td></td>
<td></td>
<td>Life cycle costs</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.3: VM Participant Tasks and Deliverables (Locke et al 1994)
Green (1992) who commented that VM is merely a convenient label for a multi-disciplined decision conference which follows a structured format, promoted a Simple Multi Attribute Rating Technique SMART methodology for VM. It uses a combination of functional analysis and decision analysis matrices to evaluate stakeholder statements elicited through group brainstorming techniques. The technique outlined an easy to follow process and was founded on his belief that users will react against any approach which is perceived to be too mathematical. Its inclusion in best practice guides has seen it adopted as a standard for early stage design (Connaughton & Green 1996).

2.5.3 QFD and Building Design

Designers and developers have used QFD, also known as The House of Quality, in the past for planning building services and building layouts (Hauser and Clausing 1988). According to Akao (1990), “QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer’s demand into design targets.” In building design, the practice is to document solutions in terms of specifications and drawings instead of detailing client requirements. Clients are not experts and therefore cannot usually specify their requirements in terms of the characteristics that influence those requirements. Huovila & Seren (1995) identified that low customer involvement in the construction process and the lack of formal procedures in finding out customer’s needs may result in requirements that will not lead to optimal solutions. QFD may be employed to set targets to be achieved for the characteristics of a product in order to satisfy customer requirements (Cross 1994).

QFD as a technique lies within the Value Analysis (VA) process and helps to identify the needs of the customer in terms that the designer can use for communicating with other design professionals. Michaels & Younker (1994) prepared a table to illustrate this with a commonality matrix for QFD, Total Quality Management (TQM), Value Engineering (VE) and Concurrent Engineering (CE). They described how multidisciplinary engineering teams could deploy a systematic process of functional analysis to challenge requirements for the purpose of optimising designs and reducing cost.

Following the principles originally developed for manufacturing (Akao 1990), Cross (1994) set out a procedure for design teams in the engineering domain:

1. Identify customer requirements in terms of product attributes.
2. Determine the relative importance of the attributes.
Chapter Two

3. Evaluate the attributes of competing products.

4. Draw a matrix of product attributes against engineering characteristics.

5. Identify the relationships between engineering characteristics and product attributes.

6. Identify any relevant interactions between engineering characteristics.

7. Set target figures to be achieved for the engineering characteristics.

Hauser and Clausing (1988) described QFD and the House of Quality as a conceptual map that provides the means of inter-functional planning and communications. They showed how people with problems and responsibilities could prioritise them while referring to patterns of evidence on the house’s grid. They used the design of a car door to demonstrate this process.

Huovila, et al. (1995) using a modified version of the House of Quality applied their theories to three projects from which they identified the following as offering potential for the implementation of QFD in the construction industry:

- **Programming** - identifying customer’s requirements for the building and design objectives.

- **Design** - setting design objectives and construction drawings.

- **Production** - preparing construction drawings and production plans.

- **Construction** - developing production plans and construction phases.

Their plan was to use a modified version of the Clausing “Four Phase Model” (Figure 2.4) to demonstrate the applicability of QFD in the construction process. The Huovila model is shown in Figure 2.5.

### 2.5.4 The Four Phases of QFD

The “Four Phase” process is a model (Figure 2.4) that is used to explain the format of a complete QFD study. This model, known as the Clausing Model (Cohen 1995), or the ASI model taught by the American Supplier Institute has proven to be very effective in getting projects off the ground in the engineering domain.
Huovila et al (1995) concluded their report by stating: “QFD is not a substitute to expertise. It provides added value for an expert to distinguish the most critical demands and to discover the corresponding properties”. Further detailed explanation of QFD and the four-phase process is given in chapter six.

Suggestions have been made to combine the use of QFD in the VM/VE process to improve the concepts for customers and assist in product development. Ishimaru & Kodama (1994) used QFD to generate function orientated ideas and the VE process to determine optimum value with a methodology they called planning analysis. Sekimoto (1993) combined
Chapter Two

Functional Analysis with QFD to overcome shortcomings in the former to evaluate specifications and used QFD to investigate the relationship between each of the functional systems identified by functional analysis. Smith (1999) used QSFD to investigate the strategic need for office space addressing the facilities required when designing offices. Whereas Mallon & Mulligan (1993), Serpell & Wagner (1994) and Kamara et al (1997) focussed on QFD to process the customers needs no one focused on the specific needs of designers in relation to qualifying and auditing the deliverables from the building design. However, all demonstrated their potential for adding value in determining requirements.

2.6 RISK ANALYSIS

Risk management has been defined by the CIB (1997) as:

A systematic procedure used to identify, assess, control and manage risk on a project in order to minimise potential damage or loss.

The CIB in their report also require that a risk management strategy should be prepared by the project team once the project brief has been agreed by the project sponsor.

When developing the concept design and before a statement of scheme design the following risk related questions should be answered:

- What is the risk that costs will exceed budget and what action will be taken to remedy this?

- What are the risks of late handover and what action will be taken to avoid this?

- What other risks are there and how will they be managed?

These are client risks and it can be stated that ultimately the project risk will resolve to the client however, the identification and mitigation of those risks will fall to the project team and designers, as the brief is investigated. Risk for a wide range of practitioner’s generally falls into two stages (Thompson, and Perry 1992):

1. Risk analysis – this can be both qualitative and quantitative where first the source of the risk must be identified and secondly its effects must be analysed and assessed.

2. Risk Management – where the management responds with policies to mitigate and control the identified risk from the analysis stage.
Latham (1994) stated that risk could be managed, minimised, shared, transferred or accepted and that no project is free of risk. The client should decide on how much risk to accept and can do this only if they are informed of the risks involved. Clients rely on advice from advisors and managers both at the inception and during the process of design.

Risk Management is currently the focus of much attention in the construction industry as a logical continuity to the emergence of Total Quality Management (TQM) and the partnering philosophy introduced in its wake. Carter et al (1994) claimed TQM to be focussing attention on getting things right first time but this in turn reduces contingency reserve consequently design work is costing more than it should. Their prescriptive advice is to change management style and re-educate the organisation to make explicit provisions for risk with justifying documentation. Others like Edwards & Bowen (1995) cited inability to communicate the risk perceptions of the parties engaged in the risk management business and claimed the manner in which risk is communicated between parties to be a major factor.

For a background into risk management in construction, Edwards & Bowen (1998) provided an analytical review of risk literature between 1960 and 1997 and gave an overview of categorised project and construction risk. They concluded their review by suggesting that there is a need to investigate risk attitudes (i.e. risk profiling) among project participants in multi-structure organisations.

The conceptual phase of a new construction project has been identified as the most important for making decisions, as it is here that the greatest degree of uncertainty about the future is encountered. Uher & Toakley (1999) claimed that attitudes of decision makers in the construction industry to risk uncertainty are generally known but little information is available about their attitudes towards the use of risk management as a systematic decision making tool. The majority of respondents to their survey identified themselves as risk evaders with a reluctance to manage risk. Discussing the management concepts and practices in use they also identified that a code of ethical conduct, TQM, time management and risk management to be the most frequently used concepts but that only half the respondents actually used it. Consultants to the industry being the most frequent users of risk management.
Chapter Two

Typically, qualitative analysis is used in the UK construction industry to compile a list of main source of risk for each work package on large projects with between five and ten main risks being identified for each. There are three common techniques applied for compiling risk issues (Thompson and Perry 1992):

1. Check lists of risks from previous experience.
2. Interviews with key project participants.
3. Brainstorming with the project team.

Brainstorming is considered essential where possible as it benefits the design team to understand project problems and potential responses to the risks. Strategies may be identified at an early stage and monitored as the design is progressed.

Computerised quantitative analysis using mathematical models and analytical techniques may then be used to produce realistic cost-benefit analysis and budgets. This will then help the risk manager to provide:

- Estimates of uncertainty in predicting the cost and duration of activities.
- The probabilistic combination of individual uncertainties.

It may be concluded from current reports that a systematic risk process should be a feature in any model of early stage design.

2.7 PROBLEMS WITH EARLY STAGE DESIGN

2.7.1 During Briefing

If the brief is to be clear and provide information with all changes to the brief recorded (Newman, Bacon and Dawson 1981) a systematic method for taking the brief must be adopted. That clients often fail to understand the challenging nature of building projects (O'Reilly & Brewer 1986) must be a testament to the way the process is communicated by the brief takers. Coles (1990) suggested that consultant teams be appointed as early as possible and that the client should be informed about the need for decisions and the consequence of inaction. Designers should concentrate on a clear balanced statement of aims, resources and context in the assembly of information both in general and specific terms. Coles (1990) identified problems when choosing an appropriate team, capturing user requirements, establishing an effective process of communication, defining standards of
Chapter Two

performance, agreeing a programme of work and agreeing the appropriate fee for the
design. Barrett & Stanley (1999) suggested five key areas that should be addressed when
making improvements during briefing:

1. Empowering the client.
2. Managing the project dynamics.
3. Appropriate user involvement.
4. Appropriate team building.
5. Appropriate visualisation techniques.

Each of these has been uncovered separately during this literature review. It is clear that
finding an appropriate methodology that can encompass all and is transferable from one
project to another would help to improve the process considerably.

2.7.2 Design Team Communication

Cockshaw (1995) stated that the integration of professionals within multi-disciplinary
design organisations has been greatly improved in recent years and separatism is in decline.
There are still language and cultural problems with each discipline having their own
approach. This is not a new phenomenon, Le Corbusier (1946) when he spoke of letting the
work of man ring in unison with universal order or standardisation being an essential
adjunct to the successful design, recognised this as one of the shortcomings within the
architectural profession. These cultural practices are rooted in the institutionally prescribed
methods developed through years of separate practice. Rogers (1995) identified this as an
educational problem and stated that it is too narrowly focused and there is still not enough
bridging between the institutions. Clearly, these problems are inherent within building
design and whereas education may help in the end, current problems need to be addressed.

Latham (1994) called for more integration and Egan (1998) built on this with
recommendations for design teams and suppliers to work together using computer
modelling to improve the efficiency of the process. Egan (1998) also required designers to
develop a greater understanding of how they can contribute value to the project process.

2.7.3 The Benefit of a Structured Programme

Designers already use prescriptive programmes and techniques for brief taking but
structuring the programme of work is a different process. Clients, the other stakeholders
Chapter Two

and designers need to understand their respective responsibilities if time scales are to be met for delivering solutions and robust cost advice. Communication can be prone to vagaries and other psychological factors that can influence the perceptions of conversations. Simple tools that can be adopted and used to reach agreements and promote a relationship of mutual trust and co-operation may help. With current techniques it is easy to overlook issues that can prevent client satisfaction so more frequent checks against requirement would help. Decisions need to be made in logical order; this requires a systematic definition of the design tasks and the information that is required for those tasks.

2.7.4 Iterative Problems in Design

Gray et al (1994) talked about iterative evaluation and referred to a continuous whirling process model of design as problems and solutions are negotiated. At concept design stage, it is an iterative process between stakeholders and designers. These negotiations can be lengthy as the options are measured against cost and suitability. It will require separate process solutions to those employed at schematic stage. During scheme design there is considerable iteration during the intense creative activity of evaluation of alternative strategies for the building, the iterations here are between design team members as they await information from one another to enable the respective designers to complete the next logical stage of their work. A simple example of design iteration is given in Figure 2.6.

![Figure 2.6: The Iterative Process of Design](image)

There are also other influences at scheme design, the client is still very much involved and there are now suppliers and specifiers to consult. Scheme design will have inherited clear
identifiable problems because by now an option will have been chosen by the client for further development so by identifying the elements within that option; a clear hierarchy of dependent tasks will evolve. The iteration at this stage is about the repetitive process used to fine-tune the design to meet those requirements agreed when the option was chosen.

2.7.5 Problems Delivering Early Stage Cost Advice

Identified from the literature research the following problems were seen as giving the greatest concern when preparing cost advice at early stage design.

1. Cost planners are seen by designers to control the design and cost planners see the designers as unrealistic when it comes to economy.

2. The segregation of cost control knowledge from conventional design knowledge, this is where the application of economic evaluation methods cannot proceed until all the major design decisions have been made.

3. There is a lack of well-trained cost control experts involved in the design team. Evaluating the economic performance of a design at an early stage is a complex cognitive process and major cost related decisions are being left to the architects and engineers.

4. Design information during early stage design is incomplete. Detailed drawings and project specifications are not available early enough to furnish the metrics and elemental details necessary for accurate cost assessment.
2.8 TECHNIQUES FOR MODELLING DESIGN

2.8.1 Introduction to Techniques for Modelling Design

This section investigates some of the principal techniques used for modelling design starting with a brief explanation about systematic design and types of model. Planning design in section 2.4.5 has broadly discussed techniques used to systematically determine requirements and section 2.5 discussed the way value analysis is used to prioritise those requirements. During the design process, those requirements form the information that is generated by and transferred between designers and consultants until a design task is completed. There are many design tasks and each will require information, sometimes the information will be unique and sometimes repetitive and techniques evolve into models of how to process the information. In order to control and monitor this process of design a broad variety of techniques are available to designers to represent and study the design procedures. Because the design process deals with vast amounts of information computers are increasingly used to manipulate the techniques.

2.8.2 Systematic Design

In his paper on systematic design, Jones (1963) reviewed the developments of the previous decade and proposed a method of systematic design that recognised the intuitive and irrational aspects of thought. It provided a systematic means of organising the design process so that logical analysis and creative thought could proceed in their own ways. Principally he noted that systematic design involved three distinct stages, analysis, synthesis and evaluation.

Analysis: Listing of all design requirements and the reduction of these to a complete set of logically related performance specification.

Synthesis: Finding possible solutions for each individual performance specification and building up complete designs from those with least possible compromise.

Evaluation: Evaluating the accuracy with which alternative designs fulfil performance requirements for operation, manufacture and sales before the final design is selected.

A complete picture of the design method requires both a decision sequence and a design process or morphology and there is a need to go through the process of analysis, synthesis, appraisal and decision at increasingly detailed levels of the design process. Figure 2.7 on the following page describes this process graphically.
The model acknowledges that the design process is an iterative process that will be infinitely variable dependant on the solution sought. Design problems at a basic level or activity within concept or schematic design may require an input in the form of feedback from a more sophisticated level or activity further into the design process. Such inputs will have an affect on decisions already made so an appropriate allowance must be made for this when modelling the process.

Design techniques have evolved through the need by practitioners and academics to study how a number of diverse disciplines exchange the information that forms the process of communication between designers and their clients. Models can be text based, graphical and physical or a combination of all these styles. The models can be normative, requisite, descriptive and prescriptive.

2.8.3 Model Types

**Normative** models describe what should be seen to occur in an ideal world of complete information; it establishes a norm with optimal solutions.

**Requisite** models begin with an acceptance that realities are defined through interaction between people and their environment with each person developing their own model, which reflects their subjective experience and perception. In order to develop a requisite model group discussion and consensus building has to take place to provide a shared social reality.

**Descriptive** models are just that, they describe current practice. McDonnell (1997) described a descriptive method as being a systematic grammar network that can generate descriptions of the design situation and that meaning is given by making contrasts in some
Chapter Two

contextual setting. Cross (1984), referred to a sequence of activities that typically occur to define a descriptive model of design. The simple descriptive model in Figure 2.8 describes the essential activities a designer should perform; it is used in BS7000 (BSI 1996) to represent the relationship between brief evolution and design stages.

![Diagram of brief evolution and design stages]

Prescriptive models attempt to prescribe a better more appropriate pattern of activities such as suggesting guidelines for improving practice, essentially taming down the normative models. They are usually associated with providing the user with guidance or a particular methodology to be followed. The emphasis being on performance specifications logically derived from the design problem. For example, Jones (1963) description of using analysis synthesis and evaluation is shown using Archer's model (Archer 1965) in Figure 2.9. It includes interactions with the world outside the design process like the brief, the training and experience that are shown as external to the design process.
Chapter Two

Although similar to the descriptive model in appearance, the prescriptive model (Figure 2.9) generates several alternative design concepts by building up the best sub-solutions to make a rational choice of the best of the alternative designs. A simple prescriptive text model is that used in the RIBA plan of work (RIBA 1973), it prescribes a logical format for architects to follow. The RIBA plan of work is discussed in more detail in section 2.9.2.

![Diagram of Archer's Prescriptive Model of the Design Process](Archer 1965)

2.8.4 Structured Analysis and Design Techniques

Methodologies generally follow a multi-phased approach starting with a formalised checklist of tasks created using a structured analysis technique that is supported with extensive documentation. This top down concept is then enhanced using a data centred or prototyping approach (Bingham & Davis 1992). It is important for this research to investigate the respective strengths and weaknesses of these methodologies for modelling early stage design.

2.8.5 Top-Down or Bottom-Up Approach

Top-down refers to a two-step approach where first, the problem is examined and a plan of attack is proposed then the second step is where the problem outlined is progressively refined into its sub-components and so on (Martin & McClure 1985). Bottom-up is also a
two-step process but here the general functional and data components are first outlined and then step two combines the low level components to form high level components in a process called concatenation. The concatenation process stops when the set of functions and data structures constructed from the elements are able to solve the problem.

The top-down approach is usually considered the better method for developing structured models but both methods can offer a hierarchical framework for structured development. These may be combined to provide a more practical approach. Yourdon & Constantine (1979) suggested a strategy when developing computer programming in which the input side of the program is developed top down and the output side is developed bottom up so that testing may be performed using live data.

2.8.6 Entity-Relationship Diagrams

Having mentioned top-down approaches to modelling the following describes the alternative methodology. Entity relationship diagrams also known as an ERD or E-R diagram is a network model. The ERD describes the stored data layout of a system at a high level of extraction but not the functions used to create the data. It may be used to illustrate data structures and relationships of a system model to users who may not be interested in the day-to-day operational details of a system. For example managers who wish to know how the business is run, how the data is related to other data or who is allowed access to the data. It highlights relationships between data stores that may be created in a Data Flow Diagram (DFD) (Section 2.8.9) that would otherwise only be seen in the process specification. A typical ERD is shown in Figure 2.10 on the following page.

Each of the rectangular boxes corresponds to a data store and focuses the reader on the data needed. ERDs can be used to discover the functions required by a DFD. In the example given, it can be seen how the data object types correspond in a relationship, indicated with a diamond shape. The design brief has a directed relationship with the design process; all other relationships are multidirectional.
Figure 2.10: A Typical Entity-Relationship Diagram.

Figure 2.11 provides the basic notation that may be used when creating ERDs (Martin & McClure 1985). ERDs provide an excellent vehicle to interrogate the information held within a design model, thus it represents a 'bottom up' approach to modelling. The major disadvantage with this technique for modelling the design process is that it does not describe the information that flows between the design activities.

Figure 2.11: Basic Notation for Entity Relationship Diagrams

2.8.7 Hierarchical Input Process Output (HIPO) Diagrams
HIPO diagrams were developed by IBM in the 1970s unlike ERDs they present a high level view of the functions of a system as well as the decomposition of functions into sub-functions. They are constructed on 'top down' design principles so that each level of chart
in the package is a sub-set of the level above. Originally developed to help the technical aspects of computer systems design they may also be used when considering the overall system (Bingham & Davis 1992).

There are three levels of chart, the visual table of contents (Figure 2.12), overview diagrams (Figure 2.13) and detail diagrams that define each step to a finer level. HIPO diagramming can be a useful modelling tool, because they look like familiar organisational charts that describe the hierarchy of a process. However, this diagram technique does not show the information flow between activities used by, or produced by the system. In summary, it will be useful tool for identifying the functions within the design process but it is unsuitable for detailing the flow of information between functions at early stage design.

![Diagram](image-url)

Figure 2.12: A Typical HIPO Visual Table of Contents
Chapter Two

Figure 2.13: A HIPO Overview Diagram Showing an Element of a Simple Pricing Procedure

2.8.8 The JSD Method

Jackson (Jackson 1975) diagrams provide a graphical means of showing the hierarchal structure of a single object rather than concentrating on the relationships between different objects. It is based on the analysis of data structure rather than data flow (Yourdon & Constantine 1979). JSD places emphasis on modelling the actions of the system in terms of their effects on the input and output data streams, rather than on using the direct functional tasks as the basis for the design model. As such, it is compositional rather than top-down in its form, and in some aspects, it also comes close to the object-based paradigm (Budgen 1993) i.e. it is neither ‘top down’ nor ‘bottom up’ in its methodology. It is based on the concept of modelling sequential processes as it develops a hierarchy of modules that are a mirror image of the hierarchy of data associated with the problem. The basic idea is to model a system in terms of a set of processes. Each process should be based on one entity, and it should contain all actions relevant to this entity. Primarily designed for the development of computer systems but because its values have been compared to DFD and IDEFO (Floyd 1986), it is included in this review.
Chapter Two

The '*' is used to show iteration

The 'o' is used to show an 'either-or'

Figure 2.14: Typical Jackson Structure Diagram

The model in Figure 2.14 shows a typical Jackson data structure diagram. It indicates that entity X (Foundation Design) consists of zero or more occurrences of A, followed by a B followed by an E. Data element B consists of either C or D. Data element D could be null component indicated by a '-' in he corner of the box when the action choice is 'to do' or 'to ignore'. An entity is an object (either physical or abstract), which, will cause activity in a system or will be affected by the systems activity, or both. An entity is always the root of an Entity Structure Diagram (ESD), therefore there can only be one entity in an ESD. An action is an event which happens to an entity or which is carried out by an entity. Each action can be decomposed into smaller actions. The JSD method consists of three stages: the modelling stage, the network stage and the implementation stage.

1. The **modelling stage**, results in a set of ESD's. As a further part of the modelling stage, the designer has to identify those attributes of the actions and entities that are of interest to the modelling.

2. The **network stage** actually consists of two phases, the initial model phase and the elaboration phase. In the initial model phase a model of the system as a whole is constructed, by linking the ESDs created in the modelling stage. In the elaboration phase, this initial model will be refined to provide more detail.
Chapter Two

3. The implementation stage is based on making a study of the text of the requirements specifications, augmented as necessary by questions and interviews with the client. One strategy involves analysing the text of the requirements specifications in terms of the constituent verbs and nouns.

Using JSD to model design provides a functional viewpoint, a behavioural viewpoint, model time ordering and hierarchical structure of diagrams but it does not indicate the flow of information between individual designers and the client that is required by this research.

2.8.9 Data Flow Diagrams

Data flow diagrams (DFDs) show the logical interrelationships between processes and the way in which the data moves to support the processes (DeMarco 1978). They are both prescriptive and descriptive in that they depict what needs to take place in a process and at the same time show how that process is carried out. Of further benefit:

- The hierarchal diagrams may be decomposed to provide increasing levels of detail that remains consistent with the higher level DFD and:
- The logical structure allows a data dictionary to be rigorously produced.

Demarco (1979) provided a definition for the four notational symbols used in DFDs and these are given in Table 2.4.

<table>
<thead>
<tr>
<th>Symbol Name</th>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data-Flow</td>
<td>→</td>
<td>The arrow or named vector that shows the direction of the data in movement.</td>
</tr>
<tr>
<td>Process</td>
<td></td>
<td>The bubble that represents an activity that transforms data.</td>
</tr>
<tr>
<td>Data-Store</td>
<td></td>
<td>A straight line showing a file or database where the data is at rest.</td>
</tr>
<tr>
<td>Source or Sink</td>
<td></td>
<td>A box portraying a net originator or receiver of data outside the domain of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the study.</td>
</tr>
</tbody>
</table>

Table 2.4: DFD Notation Symbols

DFDs have become a core technique in the approach to systems analysis and design.
Chapter Two

For an example of DFD technique, Figure 2.15 shows the top level of a scheme design model produced later in this research.

DFDs have been used by for dealing with large amounts of project data. Abou-Zeid (1995) found it to be an adequate tool for documenting project communication and defining the shared data between project participants. Austin et al (1995) used DFD techniques with a Computer Aided Software Engineering (CASE) tool. Used to identify and record data relating to the functional primitive tasks at concept and schematic design stages, they found that the combination of data flow modelling and discrete event simulation techniques can produce a powerful tool for assessing the impact of change within the construction design process. Newton (1995) used DFDs to model building design when creating his ADePT methodology (Section 2.9.7) after concluding DFD to be the most suitable technique. The most significant characteristics of DFD for modelling design are their graphic portrayal of information flows between activities. However, DFDs can be confusing when dealing with diagrams with activities containing large amount of information as can be seen in Figure 2.15. To overcome this the diagrams may be partitioned, i.e. each of the activities in Figure 2.15 may be broken down to display its primitive functions or lower level activities (parent-child). All activities can then be balanced where all dataflow entering or leaving a child diagram must be represented on the parent by the same data flow. DeMarco (1978) claimed that this top down approach provides a big picture view that users may read from the abstract to the detailed and that it provides robust continuity when analysing the model.
disadvantage with DFD is that it does not distinguish between the different sources of information found when modelling building design; this will be discussed in section 2.8.10.

2.8.10 IDEFO

This section describes the modelling technique IDEFO, and its application for modelling design. Originally called Structured Analysis Design Technique (SADT) (Marca & McGowan 1987) and developed by Douglas Ross at SofTech (Ross 1977) who claimed:

> It was intended to provide a concise, precise, human and machine-readable written format that itself models the boundary, behaviour and substance of any chosen subject, expressed in its natural language.

The US Air Force funded the first automated SADT tool for use in Integrated Computer Aided Manufacturing (ICAM) standardising the SADT methodology and calling it Integrated Computer-Aided Manufacturing Definition (IDEFO). IDEFO has become the accepted name for this methodology and this research uses the term IDEFO interchangeably when also discussing the SADT methodology. The IDEFO techniques comprise of the basic functional methodology, together with rules, syntax, diagram and model format, text presentation as well as structured model validation, document control procedures and interview techniques (Colquhoun et al 1993). The IDEFO method is based on a notation for specifying activities in boxes and Input, Control, Output and Mechanism (ICOM) arrows that represent a flow of data.

> Under control, input is transformed into output by the mechanism.

Inputs are typically things such as resources consumed or transformed by a process.

Outputs are typically things created by the transformations of the inputs by the process.

Controls are the standards, policies, guidelines, etc., that guide the process.

Mechanisms are the agents (people, manual tools, automated tools, etc.) that accomplish the actions delineated within the process.
Figure 2.16 provides an abstract view of this IDEF0 notation. An IDEF0 model comprises of a set of related activity diagrams presented in node number order that represent the subject under scrutiny. Box and diagram boundaries must match and the resulting hierarchic, interconnected collection of diagrams is a model. The model is decomposed in the same way as with DFD where rigorous consistency is achieved between parent and child diagrams.

The depth of the model hierarchy is determined by the amount of detail required where a high level diagram represents the whole subject and each lower level diagram shows a limited amount of detail about a well-constrained topic (Ross & Schoman 1977).

Figure 2.17 demonstrates the IDEF0 rigorous decomposition of model hierarchy. IDEF0 was created for defining requirements; it does so through contextual analysis of the technical and operational criteria. It provides a functional specification and by identifying the design constraints provides prescriptive solutions to processes. Colquhoun et al (1993) provided a state of the art review of IDEF0 concluding that the technique offers the flexibility of structured functional analysis to increase the quality understanding of the information to be represented in a design model.
Figure 2.17: IDEF0 provides hierarchal decomposition that is practical and rigorous.

IDEFO and DFD are the most widely used analysis techniques. Yadev et al (1998) differentiated between the two in terms of their application for information requirement determination by saying:

- IDEFO is used to produce a functional model that is a structured representation of the object being analysed and that it provides five elements, function, input, control, output and mechanism to do this.

- DFD is used to show the flow of data through a system and uses three concepts, those of dataflow, data-store and process to model the flow of data.

They made no definitive statements except to say that of the two teams used to examine each technique the DFD method was found to be easier to use but that their analysts exhibited higher confidence levels in the IDEFO models. This reflected their analysis of syntactic correctness where IDEFO scored 82.5 per cent correct against 75 percent for DFD. Syntactic rules ensure that the structure in parent diagrams is consistent in the decomposed lower level diagrams. The following points illustrate how IDEFO may assist research into early stage design:

- Thinking in a structured way about large complex problems.
Chapter Two

• Identifying team responsibility with effective division and coordination roles.

• Documenting results and decisions in a way that provides a complete audit.

• Controlling accuracy and quality through frequent review and approval procedure.

• The planning, management and assessment of team effort and progress.

2.8.11 Summary of Techniques for Modelling Design

The list of modelling tools discussed in this section is not a complete one and none of the working techniques has been covered in detail. It has reviewed the approaches to modelling and those techniques more commonly applied to create structured information models. The techniques discussed provided a digest for this research to consider before choosing a modelling methodology.

In order to address the problems identified by the literature review in section 2.7 a methodology that can deliver a structured programme to improve early design strategies is required. Through presenting a clear strategy that identifies team requirements, a more coherent working practice might evolve. The modelling methodology will need to:

• Describe the process being modelled and provide a top down analysis under the, design, cost and risk elements of design.

• Identify the design activities for each of the design disciplines.

• Show the deliverables from each activity in a bottom up manner before culminating in the final design stage output.

• Display the information requirements and identify the information source needed by each activity.

It was found in this investigation that of all the techniques for modelling design each are able to address the process of design but only the DFD and IDEF0 techniques are sufficiently detailed to examine the information flow requirements in a structured manner to meet those requirements. Both DFD and IDEF0 are available as computer aided modelling programmes to generate, manipulate and organise system-modelling diagrams and to manage system-modelling projects. Of the two methodologies, IDEF0 provides a clearer diagrammatic picture and its ability to identify three separate input sources to the activities provides an advantage over the DFD technique.
2.9 DESIGN PROCESS MODELS

2.9.1 Introduction to Design Process Models

Davenport (1993) described a process to be a specific ordering of work activities across time and place, with clearly defined inputs and outputs. He also noted that unless designers or participants can agree on the way work is and should be structured, it would be very difficult to systematically improve, or effect innovation in, that work. Platt & Blockley (1994) referred to the enactment of a set of purposeful tasks carried out over time, using resources and resulting in deliverables. So a process model can be a prescriptive tool that demonstrates systematically the way work is and when used it will help improve and innovate that process. Thus far, this review has looked at the early stage design process and methods or techniques that can be used to help model the process. This section will review significant developments and the more specific methodologies that have been created to help improve and bring innovation to the design process. Each model has taken a slightly different view of the work stages during early stage design.

| Process Model Alignment with the Design Stages during Early Stage Design |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| A Inception Budget Cost         | A Appraisal      | 1. Conception of Need | A Inception      | 2 Inception Budget Cost |
| B Feasibility                   | B Strategic briefing | 2. Outline Feasibility | B Feasibility   | 3 Feasibility Stage +/-50% Order of Cost |
| C Outline Planning Approval     | C                | 4. Outline Conceptual Design | C               | 4 Concept Design +/-20% Order of Cost |
| Outline Planning Approval       | Outline Proposals | 5. Full Conceptual Design | Concept Design | 5 Scheme Design +/-10% Cost Certainty |
| D Scheme Design                 | D                | 6. Coordinated Design | D               | 6 Detail Design |
| E Detail Design                 | E Final Proposals | Hard Gate         | Hard Gate       | Hard Gate |
| Benchmark for Architectural design |                      | Soft gates are suggested between each phase to provide flexibility | An in house process model that has influenced others with its success | An in house process model typical of many developed to meet specific company needs |

Figure 2.18: Process Model Comparisons

Figure 2.18 illustrates the differing process models discussed in the following sections and identifies the conceptual and schematic stages of design encompassed by this research with alternate diagonal shading to identify each stage.
Chapter Two

2.9.2 RIBA Plan Of Work
The Royal Institute of British Architects plan of work (RIBA 1974) had been introduced to this research when discussing the stages of design in section 2.2.1. The plan of work has been used to plan and arrange the contractual process of design for more than 25 years. However, in recent years it has come under increasing criticism for its lack of flexibility both from within (Lawson 1980), (Lord 1996) amongst others and outside the RIBA (Jenks & Dawson 1981) (Pilling 1994). It was found that the RIBA Plan of Work stages no longer met the needs of multi-disciplinary collaborative design organisation and their clients. In response to this criticism the RIBA has reviewed, the scope of its long serving advisory document and provided a revised plan of work titled '99 Work Stages (RIBA 1999). The work stages have new titles and definitions that now state the outputs required. Figure 2.18 illustrates the revised work stages against the original plan of work.

It can be seen in Figure 2.18 that not only have some of the headings changed they no longer align with the previous sages. Clearly influenced by the Construction Industry Board (CIB), the B+ stage contains in its description a reference to the Strategic Brief 'as in the CIB guide' (C I B 1997). The revised plan of work covers all stages of construction in sections F to L and now includes in its recommendations a section titled 'After Practical Completion' to address the whole project cycle and administration of the building contract after practical completion.

The whole issue with the Plan of Work is that it is an advisory document forming part of the Standard Form of Agreement (SFA99) for architects, which has also been revised. Overall, it sets out a prescriptive route for the architect to follow. It determines the deliverables and payment stages that form a contractual arrangement between the architect and his client. In loose terms, it models the RIBA's ideal process for the architect to follow and now takes into account other procurement methods such as Design and Build. It is still designed from an architectural perspective, it is not a prescriptive tool for modelling the flow of information during early stage design. It prescribes what has to be done in a simple descriptive way, it does not make any allowance for the iterative nature of design nor does it take in to account the planning required to do it.

2.9.3 Process Protocol
The Generic Design and Construction Process Protocol (GDCPP) has been developed at the University of Salford (Sheath et al 1996) and is known as the Process Protocol.
Recognising that current protocols such as the plan of work (RIBA 1974) adopted by the architectural profession did not meet with the requirements of current designers and their clients. Kagioglou et al (1998) adopted six broad principles for their Process Protocol aiming to provide:

1. A whole project view
2. Progressive design fixity
3. A consistent process
4. Stakeholder involvement/teamwork
5. Co-ordination
6. Feedback

Taking a whole project view, they provided their own framework for the Process Protocol that breaks down the design and construction process into ten distinct phases identifying four broad stages. The phases identify process deliverables for the whole project separated by either soft or hard gates representing decision gates or phase review meetings.

Soft gates provide opportunity for phase review and illustrate the flexibility of the process whereby the activities that are not finished in time are noted and their significance to the project assessed. The project is not halted enabling the concurrent undertaking of the activities.

Hard gates illustrate the need for completing all the activities described by the Process Protocol before the phase review meeting.

Designed to provide a basis for both company and industry knowledge database the Process Protocol has now entered a second phase in its development where the objectives are to develop the sub-processes using proven methods and technology. The overall aim is to produce a ‘Process Toolkit’ to help in the adoption of the Process Protocol for design and construction. The Process Protocol currently deals with the broad picture framework and its collaborators are currently evaluating techniques that may be adopted to systematically capture the product and processes at the various stages of conceptual and full design, pre-construction planning, and construction. The collaborators have identified that the implementation of the Process Protocol will greatly depend on its ability to translate the strategic to the operational level. Currently the sub-processes, which they have termed, Activity Zone is sadly missing in what promises to become the new standard bearer for the UK construction industry.
Chapter Two

The Process Protocol suggests that throughout the pre-project phases (RIBA stages A to D) the client's need should be progressively defined and assessed with the aim of determining the need for a construction project solution, and securing outline financial authority to proceed to the pre-construction phases (RIBA stages E – J). Additionally, as the design translates through its logical sequence into the pre-construction phase, the Process Protocol suggests it desirable to achieve progressive fixity for the design with the aim of improving communication and co-ordination between the projects participants. Brief definition with progressive fixity as the project evolves has been identified (Latham 1994) (Egan 1998) as providing the greatest opportunity during design stages to achieve improved design efficiency.

2.9.4 The BAA Project Process

The British Airports Authority owns and operates seven UK airports and spends more than £1 million a day providing new and improved facilities to meet the demands of its customers. BAA Plc came to the decision that current project processes were not able to accommodate an overall reduction in construction cost of 50% required by its chairman Sir John Egan. Consequently, the BAA Project Process was developed and introduced in 1995 as their vehicle for continuously improving the quality and efficiency of its capital investment programme. Their decision was to go for a programme of small improvements coupled with a number of high impact innovations. Details were issued in a handbook that has become a mandatory instrument for all BAA projects over the capital value of £250,000 (BAA Plc. 1995).

Key policies addressed by the Project Process are:

- Safe Projects to ensure the safety of customers, employees and contractors.
- A Consistent Process that standardises best practice at BAA.
- Design Standards that meet with BAA requirements.
- Standard Components to reduce construction risk and enhance quality.
- Framework Agreements used with selected suppliers to reduce costs and improve performance.
Chapter Two

- Concurrent Engineering to enhance engineering standards by integrating design, fabrication and construction.

- Pre-planning by completing design work before construction commences.

Structured around a series of formal gateways used to either evaluate the four principal design stages or seek approval via BAA's capital projects committee, the Project Process covers seven major stages from which eight processes are outlined. The stages comprise a simple checklist of all the actions required for each project and the processes will provide a prescriptive guide for all BAA staff. In principle, the BAA process at the higher level is similar to the Process Protocol but because the Project Process has been designed to meet the specific requirements of the BAA, its suitability for wider construction industry application is questionable.

2.9.5 AMEC Construction Project Process

By way of comparison to other design process models, our industrial collaborator to this research project provided an example of the AMEC Construction Project Process. The AMEC Construction Project Process has recently undergone a complete revision to align it with current industry requirements and the latest research being conducted at Loughborough University. The part of the model relevant to the research covers early stage design in four stages followed by a deliverables gateway:

Feasibility Stage, part of the Pre-Project Phase in which the business options are studied and evaluated and a project is defined which would meet the client need, main deliverables being scope of service, scope of work, fee proposal, a +/-50% cost plan and a programme.

Concept Design Stage, the period of the Pre-Construction Phase for the production and evaluation of options culminating in a preferred recommendation, in addition to the pre-project stage the main deliverables being schedule of documents, +/-20% cost plan, outline specification by function and element, project plan, value management requirements and the initial definition brief.

Scheme Design Stage, the period during which the selected option is evaluated to established a preferred engineering solution. Deliverables at this gateway include completed definition brief, layouts signed off by client, +/-10% cost plan by element, programmes, updated project plan, value management plan, work package breakdown, method statement, health and safety plan.
Chapter Two

Detailed Design Stage, the period when the key components are detailed and the rules for the geometric coordination of the design are established. Deliverables include work package specification, work package drawings, bills with target costs, contract documents, cost plan, scope of service, construction programmes, contract documents and risk analysis.

A Project Activity Framework describes the activities that each functional group in the multidisciplinary team will complete to reach the deliverables required at each stage. The framework is designed as a company specific model for the multidisciplinary design-teams to follow. It provides a variety of options in both its prescriptive form and in the expectation of deliverables allowing for differing client types and procurement routes. As with all the models investigated so far it provides a simple prescriptive model but does not address the source of information for the described activities that the research has identified to constrain the management of design.

2.9.6 Building Research Establishments Building 16

When the BRE decided to design and build a new building for their own use they took what must be the unique opportunity for a research organisation and employed the many sections within their organisation to test and monitor all construction related work. Starting at inception stage, through design, construction and into handover and occupancy they used this opportunity to create an activity model of the process (Guardamino & Amor 1996). The BRE model was produced to form a reference point from which to compare other process modelling techniques. The intention was to develop a more generic model to describe the design and construction process. The activity model of Building 16 represents the complete complex building process for that project and captures the activities and information requirements but not the flows of the project using IDEF0 as a modelling tool. The use of IDEF0 is of particular interest to this research. In this case, IDEF0 has been used to record the flow of documentation between management activities and it demonstrates the power of IDEF0 to graphically model a process. The model produced does not identify the information flow between interdisciplinary designers at specific stages of design but it clearly demonstrates the process integration for this particular project and demonstrates IDEF0 as a suitable tool for depicting the building process.

2.9.7 The ADePT Detail Design Process Model

Recognising that an effective and workable design programme is essential for dealing with the complexity of modern buildings and the clients desire for swift occupation provided the
inspiration for the ADePT methodology (Austin et al 1996). The Analytical Design Planning Technique (ADePT) was originally created (Newton 1995) as a data flow model of the building design process that is subsequently analysed in a design structure matrix to produce a powerful but easily understood tool to assist in the planning and management of complex multi disciplinary building design problems. Since then it has formed part of a research project entitled Design Information Methodology and Tools for the Management of Detailed Building Design (Austin et al 1999a) where a design process model (DPM) for detail design was developed and tested by practicing designers on live projects. After analysing many modelling techniques, Austin et al (1999a) observed recent trends and opted to use IDEF0 to create their process model. Acknowledging the differences between DFD and IDEF0 notation Austin et al (1999) chose to adapt the IDEF0 notation to represent information requirements for completing the tasks.

Austin et al (1999b) produced a model of the detail design process that identified the functional primitive tasks (FPT) and the information flows required to execute those tasks forming the first stage of ADePT. The complete ADePT process is given in Figure 2.19.

As part of the later research (Austin et al 1999b) computer software was developed by Dr Baizhan Li and used to produce information dependency tables that would allow the information flows identified in the DPM to be classified and introduced into a design structure matrix (DSM) (Austin et al 1996). The DPM is not able to determine the order in which the information should be delivered to the design task or which design task should be completed before another. Sometimes design tasks may need to be completed simultaneously and on other occasions before the appropriate information is made available.
available. This can create iterations that make progressive sequencing of tasks impossible so a DSM (Section 2.9.8) is used to identify and help break the iterations. The DSM will then re-order the tasks in accordance with the availability of the information required to complete them. This is done by first partitioning the matrix so iterations (shown as red blocks in Figure 2.19) may be identified and then torn or broken down through a process of reclassification information importance. After the DSM has reordered the design tasks into an optimal sequence, a programme of design operation may then be produced using a project programming software tool.

2.9.8 Design Structure Matrix Analysis

Design structure matrix (DSM) analysis was developed in the 1960’s. Steward (1962) introduced the concept of information flow for studying systems of equations. This form of analysis was initially applied to a method of partitioning systems of equations and then further used to study iteration in order to provide faster computer processing solutions. In a later paper, Steward (1981) applied this method for managing the design of complex systems to engineering design. Eppinger et al (1990) used variations of Stewards (1981) DSM to represent both the sequence and technical relationships among design activities and Kusiak & Wang (1993) described the algorithm that is used for organising design activities in order to produce an acceptable design. DSM allows the engineer to organise the design of a system, resolve simultaneous relations and identify design iteration. It is used to analyse the flow of information that occurs during design work and suggests the appropriate point to make estimates where iterative problems arise. The process may be executed by hand but when dealing with multiple design tasks computers are employed. Steward (1981) introduced the first software program called TERABL developed to assist processes that are more complex. Newton (1995) described it as an ideal piece of software when conducting a review of DSM analysis. However, TERABL has since been superseded by Problem Solving Matrix (PSM) designed to deal with much large matrices and interface with current computing requirements. During the course of this research, colleagues at Loughborough University have also developed their own DSM program called the Algorithmic Matrix Manipulation Program (AMMP).

The flow of information within a design process determines the order in which decisions can be made. Some decisions can be made in parallel, some should be made in sequence, and some sets of decisions are so interrelated that one must begin by using assumptions or
Chapter Two

estimates to untangle them. Eppinger et al (1994) explained the rationale behind sequencing design tasks (Figure 2.20). Where dependent tasks may be actionable individually, independent tasks simultaneously, interdependent, or coupled tasks are much more challenging to organise.

![Diagram of task sequences]

**Figure 2.20: Possible Sequences for Design Tasks**

In the case of coupled tasks that are typical of the tasks of design the solution for breaking the dependence is through evaluating the importance of the tasks being considered and deciding on which tasks must be estimated. Unlike conventional network analysis the DSM allows us to perform this operation by advising which tasks hold the key to the iterative sequence.

Therefore whereas IDEF0 diagrams are made to help understand the process (Section 2.8.10) the information they contain can be very complex and difficult to interpret. When the information is represented through a DSM, it can help analysts understand the iterative nature of the process and decide how best to make a programme of work.

2.10 CONCLUSION TO EARLY STAGE BUILDING DESIGN

This chapter has reviewed briefing and developing the client brief during the early stage of building design it has placed in context the current process of design during this critical stage and explored some of the complexities and perceived difficulties in providing accurate and timely responses to the client. There is a clear distinction between the negotiated conceptual stage and the schematic identifying of deliverables stage. The concept design evolves over a period with many adjustments/revisions resulting from the continuing dialogue between client, designers and cost consultants (Aston et al 1989). Scheme design has the specific purpose of determining the design solution and cost
framework (Swinburne 1980) that the detail design will rely on during the next stage of the project.

The literature research has revealed that most problems continue to develop during the interpretative period between the client and the design team when the client relies on accurate information in order to make corporate decisions and sanction the work. As most decisions have cost implications, it will be important to show the relationship between design information and the cost advice given to the client, if improvements are to be made. Poor communication and lack of shared understanding during the process are seen as a major issue during early stage design (Ministry of Public Building and Works 1967), (O’Reilly 1987), (Latham 1994) (Egan 1998) and closer collaboration between the design professions was identified as one solution to this problem. Lack of co-operation and mutual trust (Parsloe 1990) between designers was also seen as much of a problem as adversarial relationships between designer and client. Making statements like: “clients new to the construction industry often fail to understand the challenging nature of building projects” (Newman, Jenks and Dawson 1981) (O’Reilly & Brewer 1986) (Murray 1990) is testament to the designer’s inadequacies not to those of the client.

Other problems emerging from the literature review being the choice of the appropriate team, capturing user requirements, establishing an effective process of communication, defining standards of performance, agreeing a programme of work and agreeing the appropriate fee for the design (Barrett & Stanley 1996).

Brief definition with progressive fixity as the project evolves was identified (Latham 1994) (Egan 1998) as providing the greatest opportunity during design stages to achieve improved design efficiency.

The research also addresses some of the issues encountered by the multi-disciplinary design team.

Again, communication is a major issue and the standardising the terminology used by the different design disciplines to describe the same element is an essential requirement. Encouraging a consolidated approach will strengthen dialogue and facilitate a better understanding of requirement within multi-disciplinary design teams. It is proposed for this research that improved techniques be generated within the Design, Manage and Construct
Chapter Two

route that allow systematic reviews to be shared by professional and lay advisors to help with their understanding of the design process.

Coles (1990) claimed the management of time and resources emerged as an important area of concern. Programming design using traditional project planning techniques and network analysis to represent design does not adequately handle the iterative nature of building design (Newton 1995). Austin et al (1995) claimed that poor information management and design planning are inextricably linked and argued that an improvement in design planning would facilitate the management of information.

In order to meet the objectives of this research and to model design and cost information as an integrated process, we must then address the issue of structure using a representation that will show the flow of the data and the deliverables required to provide an accurate order of cost (Bowen-James 1995).

With improved information exchange, the client may be prepared to commit further resources and support at the front end of projects to help avoid inadequate design solutions and disappointment with the finished product (Barren and Stanley 1996). Additionally, through better understanding the roles and needs of all project participants a smoother transition between the concept and detail stages of design is anticipated. An improvement in programming during early stage design together with the use of techniques like those that Quality Function Deployment (Ishimaru & Kodama 1994) use and the implementation of integrated Risk Analysis are seen (Edwards & Bowen 1998) as ways to facilitate this.

Different types of model have been reviewed, first a normative model should be developed which allows us to explore what is the ideal situation because the development of descriptive models is actually quite difficult. It would initially seem easy to just describe what is current practice but current practice is requisite in nature i.e. each organisation has developed a slightly different model which has been shaped by their own experiences. Requisite models have no place when constructing a generic process or information-flow model but they do allow individuals to express their own needs and requirements and can form part of the investigative research. After investigating the normative model we should then develop a prescriptive model that can be implemented in practice. Prescriptive models suggest guidelines for improving practice, essentially taming down the normative models.
Chapter Two

The research so far has indicated that the early stage design is further separated within the concept and the schematic processes and that it will be important to treat each separately. It was also established that planning design, as part of process planning is a front-end activity performed during the initial briefing stages. It remains separate from the planning or programming of the intra-disciplinary responsibilities of the designers. Although the two are intrinsically linked, a separate methodology is required for each.

Lawson (1994) argued that the study of the design process remains a methodological minefield resulting in a lack of realism in the recommendations of theorisers and researchers.

Platt (1996) argued that because a design engineer's work involves interaction, coordination and decision making with others, a data model focuses on data requirements and the product produced. Thus, it concentrates on a data centric paradigm and a more balanced view is required to model the management of dynamic design organisations. Their research into process modelling claimed that the weakness with a data model alone is its inadequacy to deal with the rich semantics that civil engineering in particular uses to describe the ambitions or the roles people play in managing a design project. They showed that combining a variety of research techniques is required to deliver appropriate solutions when conducting researching into design. The use of qualitative methods to gather information on the tasks and information flow requirements during early stage design will need to be refined to meet the specific requirements of this research.

Activity and information flow models combined with matrix analysis methods (Austin et al 1996) may prove beneficial in identifying deliverables and help to improve the efficiency in delivering design solutions and the order of magnitude estimates provided by cost planers at the scheme design stage. By ordering the information dependencies diagrammatically, a systematic approach may then be developed. The ADePT model of detail design has successfully demonstrated that a combination of techniques, DPM, DSM can deliver multi-disciplinary design teams with a prescriptive and generic process to follow.

Modelling of design stages may also improve communication and understanding of process responsibilities within design teams. The ordering of design task requirements will improve understanding between designers because their responsibilities to each other will have been
Chapter Two

identified and this can help reduce project risk, both of which will help achieve the objectives of this research.

Combining the techniques described to deliver an appropriate solution for improving information exchange and the provision of robust and timely cost advice at early stage design is described in the following chapters.
Chapter 3
Research Objectives and Methodologies
3.1 INTRODUCTION TO RESEARCH OBJECTIVES AND METHODOLOGY

This chapter sets out the original objectives and aligns the research with the chosen methodology aimed at delivering robust solutions from the investigative methods applied. These methods include Literature Review, Case Study, Research Interviews, Archival Research and Action Research, which were applied in two stages first the Problem Formulation and then The Improvements to Concept and Schematic Design Stage.

3.2 RESEARCH OBJECTIVES

3.2.1 The Aim of the Research

The principal aim of this research is:

To improve the management of the concept and schematic design stages with particular reference to developing the brief, the subsequent exchange of design and cost information between the client and designers, and the impact of early design decisions on construction.

There were four specific objectives set at the outset of the research:

1. To investigate current briefing methods in engineering industries (including construction, manufacturing, aero/auto-motive and product design) in order to identify techniques that could improve best practice in the construction industry.

2. To examine how process modelling and matrix analysis techniques might assist in planning/management of the information flow (particularly the effects of changes), and to develop additional strategies.

3. To investigate how designers can provide information of appropriate detail and quality for the purpose of making cost estimates for both the client and the design team.

4. To identify how improved early design strategies could reduce constraints and conflicts during the construction process.

The research methodologies applied to satisfy these objectives are discussed by section in the following chapter and are annotated in Table: 3.1.
Chapter Three

Two stages were planned for the research to satisfy the objectives, the first being the problem formulation and the second being improvements to concept and schematic design:

The Problem Formulation Stage
Stage One was an investigative study to provide the research with an understanding of early stage design and the problems encountered. The study explores the process, the techniques, and the people negotiating design within a multi-disciplinary arena. Strategies employed to gather the needed information include the following:

- A review of relevant literature including journal articles, thesis, reports and conference proceedings aimed at establishing the clearest possible picture of current concerns and problems.

- Discussions with the research collaborator AMEC Construction and their clients to gather information from experts on the issues during early stage design.

- Information gathering visits to obtain a real world sense of the context including observations from a live project, from where the design problems that emerged during the literature search were investigated to establish their real extent.

- Individual interviews with practicing designers actively involved with the process of design. Interviews conducted with design team members provided a clear response to their requirements during early stage design and this was used to formulate the further requirements on the research.

The Improvements to Concept and Schematic Design Stage
Following the thorough examination of the early stage design process and an investigation into the current tools and techniques used by designers in stage one, stage two synthesised and developed tools and techniques for improving early stage design.

Table 3.1: Summary of Research Methodology

<table>
<thead>
<tr>
<th>Section</th>
<th>Methodology</th>
<th>Objectives (Ch.1.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3.3</td>
<td>Literature Review</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>3.3.5</td>
<td>Case Study Research</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>3.3.6</td>
<td>Research Interviews</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>3.3.8</td>
<td>Archival Analysis</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>3.3.9</td>
<td>Action Research</td>
<td>✓✓✓</td>
</tr>
</tbody>
</table>

76
Chapter Three

These two stages are discussed further together with the research methodology applied to meet the given objectives in the following sections:

Sections 3.3.2 - 3.3.6 for Stage One

Sections 3.3.7-3.3.9 for Stage Two

3.3 METHODOLOGY

3.3.1 The Methods of Research

Essential to a well-presented piece of research is the development of the research methodology. The research methodology may be regarded as a decision making process that forms a set of background assumptions or paradigms that are proposed in order to organise the researchers view of reality (Birley & Moreland 1998). These may be constructed individually (ethnomethodological), as an objective phenomenon (positivism) or a mixture of both (realism).

Choosing a methodology for this research into early stage design necessitated a review of appropriate methods and these are listed below:

- Literature Review

- Qualitative Research:
  - Case studies
  - Ethnography
  - Policy research
  - Evaluations
  - Archival and historical research

- Action Research

An outline of the methods applied to the two stages of the research is provided in the following sections where their applicability to the research is discussed.

3.3.2 Stage One: Problem Formulation

Literature review, case study research and archival analysis were used to understand the early stage design process. Early stage design covers many stages of design and each stage delivers specific deliverables to clients when they commission a building design. Concept and Scheme design stages that are covered by this research deal with the development of the client brief and the definition brief that will be relied on by designers and used as a reference by all parties before, during and after the building project is commissioned. By
definition, briefing is about the communication of information. Concept design provides the options and scheme design delivers design solutions. It also delivers robust cost advice that both clients and designers rely on to guide the many decisions required during the remainder of the design process. The conclusion of scheme design is generally considered to represent the culmination of the early stage design process.

It is reasonable to expect that where there are problems with building design they will develop from these early interpretive stages. A detail examination of the way concept solutions guide the schematic design process was required and an investigation into the tools used by the designers meet the requirements of their clients was needed in order to meet the first part of the research objectives.

3.3.3 The Literature Review
Research should follow an established procedure of investigation and normally starts with a thorough literature review to uncover background and content for the work that is to follow. The aim of the literature review is to introduce and develop an overview of the main source of knowledge with examples of a range of techniques that can be used to understand the topic and what has already been done on it to help avoid duplication of previous work. It not only justifies a particular approach to the topics covered by the research but also helps; to identify the gaps in knowledge, to critically analyse ideas, to find relationships between different ideas and to understand the nature of the arguments upon which the research is to be based (Hart 1998).

The literature review into early stage design was conducted during the formative months of the research project when books, journals and conference papers were examined to provide an understanding of the topic area. The gathered data was filed and referenced using bibliographic software this formed a current library of knowledge on briefing and the stages of design relevant to the research. The currency of the data was maintained during the remaining period of the research by accessing Internet newsgroups, media, journal reviews and new publications.

The findings emerging from the literature review provided direction for the case study stage of the research the findings are summarised as follows:
Chapter Three

- Poor communication and a lack of shared understanding is a major problem faced by design teams, this also leads to poor planning during the early stages of design.

- Designers require accurate information from their clients if the process is to be efficiently planned.

- Clients along with other stakeholders look to their designers to provide good design solutions with robust cost advice at the scheme design stage before signing off and agreeing to the commencement of the detail design stage and making the further financial commitment required.

- The real problem faced by designers is one of allowing sufficient design time to complete unqualified iterative problems.

- Evaluating design cost and making a programme of work during the early stage design is an imponderable task.

The literature review also revealed a clear distinction between the conceptual and the schematic stages of design. It is believed that for this research sufficient difference exists between these two stages to preclude further work that aims to combine the two stages with shared solutions.

3.3.4 Qualitative v Quantitative Research Methods

Before embarking on the case study research the question of which data collection method was addressed.

Identifying the problems at early stage design formed the first part of the research. The historical information gathered allowed the author to develop a picture of the issues during the briefing process affecting the production of accurate design and cost information for clients from a broad perspective. In order to examine these perceived problems within the context of a multidisciplinary design arena a strategy was required whereby these perceptions could be tested in real world situations. The industrial collaborator provided the opportunity to observe the design of a new drug development building that formed part of a strategic consolidation process for an international pharmaceutical company. During the conceptual design process and later during scheme design opportunity was also provided to interview designers and other stakeholders in the project.
Exploring the real world issues required a methodology to rigorously deliver a response to the findings generated through the literature review. The question posed for the research was which of the investigative methods of study would be most appropriate to deliver a robust response to the inquiry. Enter the debate quantitative enquiry versus qualitative enquiry. Ackroyd & Hughes (1992) qualified the argument; 'it is not about antimony requiring choice within the context of social research, it is the nature of the research problem' or as in the case of this research the conditions under which the research is to be conducted that should dictate the appropriate research method. Denzin & Lincoln (1998) qualified qualitative research methods by claiming them to involve the studied use and collection of a variety of empirical materials through case study, personal experience, introspective, life story, interview, observational, historical, interactional and visual texts that describe routine and problematic moments and meanings in individuals’ lives. Most of these were applied at some point during this research.

It was clear from the literature review that the problems faced by designers and their clients primarily relate to human issues, communication, understanding, inadequacies, etc. Exploring these issues with a questionnaire aimed at positivistic confirmation of the findings with mathematical data that could be taken and analysed was considered and rejected because meaning could be lost through interpretation.

Building design is an intimate process of negotiation between individuals; it is believed by the author that in order to extract a meaningful response from stakeholders they first need to express themselves in their own terms using familiar vocabulary before analysis and interpretation are made. The conclusion drawn was to adopt a qualitative approach in two stages for the second phase of the information gathering process.

3.3.5 Case Study Research
The first stage would be a case study of a live project. Yin (1981) defined a case study as an empirical enquiry that investigates contemporary phenomenon within its real life context in which multiple sources of evidence are used. In his analysis of relevant situations for different strategies in research, Yin (1981) observed that a case study does not require control over behavioural events. He maintained that the case study’s unique strength is its ability to deal with a full variety of evidence such as documents, artefacts, interviews and observations and stated that in situations such as participant observation some informal manipulation can occur.
Chapter Three

A case study was considered an appropriate method for testing the research objectives, whereas surveys struggle to limit the number of variables to be analysed. This research required a broad practical understanding in order to make realistic appraisal of the context based assumed problems. Thus, a research design for the case study programme was prepared. For a case study, there are four major types of design following a 2 x 2 matrix (Figure 3.1).

The first pair of categories consists of single case and multiple case designs. The second pair, which can occur in combination with either of the first pair, is based on the unit or units of analysis to be covered, and distinguishes between holistic and embedded designs. In addition to this, four aspects validity in the design must be considered (Bickman & Rog 1998):

- **Construct validity**: the extent to which the constructs in the conceptual framework are measured.
- **Internal Validity**: the extent to which casual conclusions can be drawn.
- **External validity**: the extent to which it is possible to generalise from the data and context of the research study to broader populations and settings.
Chapter Three

- **Reliability**: The extent to which the study has used appropriate methods so that an auditor could reasonably repeat the procedure and arrive at the same results.

The initial case study was designed as a revelatory single case study (Liebow 1967) supported as in Type 2 (Figure 3.1) by archival records and interviewing designers and key stakeholders from the project.

The construct validity was confirmed through testing the chain of evidence established from the literature review with the case study of an early stage building design in relation to the objectives. The internal validity of the case study was supported by the interviews. The external validity was satisfied by asking the question; are the study's findings generalizable beyond the immediate case study so that the results can be applied to a broader theory. An affirmative response was supported by the overwhelming confirmation that the problems tested continue to surface within the multidisciplinary design arena and answered the fourth test.

Robson (1993) claimed that observation seems to be pre-eminently the appropriate technique for getting at 'real life' in the real world and described two fundamentally different types of observation; participant observation and structured observation. The former being a qualitative style originally rooted in the work of anthropologists and particularly associated with the Chicago school of sociology, the later being a quantitative style. Quantitative methods have already been discussed and ruled out for this research so the remainder of this section will concentrate on qualitative analysis of a participant observation.

Ackroyd & Hughes (1992) described the four roles open to the participant observer and these are given in Table 3.2 on the following page.
Chapter Three

<table>
<thead>
<tr>
<th>Role</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Complete Participant</td>
<td>The role in which the observer becomes a fully fledged member of the group under study, any research purpose being concealed</td>
</tr>
<tr>
<td>2. Participant as Observer</td>
<td>Both researcher and subjects are aware of the fact that theirs is a fieldwork relationship.</td>
</tr>
<tr>
<td>3. Observer as Participant</td>
<td>Involvement with the subjects is deliberately, or for a number of practical reasons, kept to a minimum.</td>
</tr>
<tr>
<td>4. Complete Observer</td>
<td>Requires investigators to insulate themselves from any social contact whatsoever with the subjects.</td>
</tr>
</tbody>
</table>

Table 3.2: Participant Observation Roles

The choice of role for the participant observation was assisted by AMEC Construction who were able to negotiate with their client for permission for the author to attend the study group meetings for the design of the new building. The author's established record of accomplishment in construction management assisted becoming a participant as observer moreover; it helped promote a seamless integration of the ethnographic research contract with the stakeholders for the design. The approach helped overcome professional language problems, avoid extended explanation of meaning when discussing points of issue and allowed interpretive questions to be fielded during the concept study and later when conducting interviews.

Information gathering during participant observation can be dichotomised as either formal or informal, the structured formal approach imposing a discipline on the amount of information gathered, the informal approach lending itself to note taking or recording the whole process on tape for later dissemination. The latter may be considered unstructured and complex but has the added advantage of gathering large amounts of data. Sometimes, information considered irrelevant at the time of collection can prove crucial to generating a full understanding the process. In the case study an example surfaced when an underlying issue of resentment between the user group and the client management developed. The data allowed the author to look back over the many meetings, observe its gradual evolution and helped develop the concluding recommendations provided in chapter seven.
Chapter Three

3.3.6 Interviews

Interviews are considered one of the most important sources of case study information (Yin 1981). Interviews explain or put into context what the ethnographer sees and experiences (Fetterman 1998). Interviews may be structured, semi-structured, informal or retrospective. A series of informal interviews were conducted as part of the case study. They were chosen to discover from designers and stakeholders, their reaction and feelings about early stage design within a multidisciplinary design arena, and how one person’s meaning compared with that of another. Inevitably, some retrospective data was included as the respondent sought to explain their involvement with design and the problems they currently encounter during the course of their work. Open-ended questions were used to help discover and confirm the participant’s experiences and perceptions. Cohen & Manion (1989) suggested that open-ended questions allow the interviewer to probe and go into more depth, or clear up any misunderstanding as the knowledge of the respondent is tested. They also suggest that open-ended questions encourage better cooperation and support, these suggestions were confirmed during the interview process as it provided the respondent space to reflect on their observations. Each interview was conducted on a one to one basis using a tape recorder over a period of one to one and one half hours. Gordon (1987) identified the values of using a tape recorder and situations when a tape recorder provides the only reasonable method of recording an interview as:

- The more complex the information the less the method should depend upon the interviewer’s memory.

- The more rapid the flow of relevant information, the less we should depend on taking longhand notes.

- The more we wish to explore for unanticipated types of responses, the less sure we are of what categories of information are relevant to the problem.

Asking permission to use a tape recorder brought into question the ethics of recording interviews. Tape recorders are generally accepted where steps are taken in advance to calm fears of misuse. Permission to conduct interviews was first cleared with our industrial collaborator and undertakings given so that when parts of the research transcripts are reproduced or shared, commercial sensitivity and confidentiality can be maintained by first examining the content. In addition, during the interviews, respondents were allowed the
discretion of pausing the recording when they chose to explain a sensitive issue relevant to a probe or prompt.

The notes and tape-recorded data were collected from the participant study and transcribed for analysis. Choosing a method of analysis required a review of the outcomes. It was decided that the context generated from the literature review should guide a system of coding that identified the problems during early stage design and provide empirical support for developing techniques and strategies to improve the process (Brown & Canter 1985). The problem issues identified from the project shadowing were coded in relation to those requirements.

The informal interviews contained many hours of tape-recorded data and controlling the large amounts of complex material was a key issue (Kvale 1996) for the research. In contrast to the problems that surfaced during the case study, the material was largely unstructured and a method was sought to interpret the information. Kvale (1996) claimed that the theoretical basis of an investigation provides the context for making decisions about how interviews will be analysed and that the analyst's theoretical conceptions of the subject matter may be part of generating and testing theories. The grounded theory approach developed by Glaser & Strauss (1967) provided a method of coding and recoding of the observations as the researchers insight grows, working toward an empirically grounded theory. In qualitative research, the goal of coding is not to produce counts of things but to 'fracture' the data and rearrange it into categories that facilitate comparison between things in the same category and between categories (Maxwell 1998). These categories may be derived from existing theory, inductively generated during the research and is the basis for what Glaser & Strauss (1967) termed grounded theory.

Grounded theory was used to uncover and purify the meanings more or less buried in the interviews; it is discussed in more detail in chapter four. The interpreted data was able to provide a base understanding of the major problems during early stage design and provide a platform for stage two of the research.

3.3.7 Stage Two: Improvements to Concept and Schematic Design

The empirical research conducted during stage one revealed that two phases to stage two of the research were required to meet the research objectives. Phase One focused on the modelling of scheme design and Phase Two will focus on value analysis and QFD.
Chapter Three

Additionally stage two of the research would be required to test the questions that emerged during stage one:

- Can Scheme design be modelled using the same ADePT modelling techniques used to model detail design?

- Can Scheme design be modelled to facilitate improvements in risk analysis and cost planning when programming the design process?

- When producing a Scheme Design Process Model (SDPM), is it possible to integrate with the Detail Design Process Model (DDPM) to improve the design-modelling database for planning design?

- Can the accountability of the decision making process be improved using QFD techniques applied at various stages of early stage design?

Phase One: Modelling Scheme Design

Improving the exchange of information was seen as a way to help designers meet the needs of their clients. Modelling the flow of information at the scheme design stage after a design option is chosen should enable designers to consolidate their needs and assist multi-disciplinary design teams to improve the planning of the design process. Designing a modelling methodology was assisted when the ADePT technique (Chapter 2.9.7) was identified as a suitable process for further investigation. A design process model for scheme design that could assist the planning of early stage design and improve the efficiency in delivering design solutions and corresponding cost advice was considered as a suitable focus for the first phase.

Phase Two: Value Analysis and QFD

Delivering a solution to assist communication between designers and stakeholders that might help reach agreement over design options requires a separate tool that is able to audit design requirements and track the decision making process. A study of the tools available to designers from other design arenas indicated that value analysis with Quality Function Deployment (QFD) might provide a secondary solution that could meet the research requirements of the second phase.
Chapter Three

A plan for these two phases of the developmental part of the research was generated (Figure 3.2). The research plan helped to choose the methodology for investigating the objectives for both phases in this second stage of the research. First, a Design Process Model (DSM) would be constructed with IDEF0 from which the information would input into a Design Structure Matrix (DSM) to produce accurate Design Programme Information (DPInf). Secondly, a series of QFD proposals would be tested against current design problems to provide solutions that might combine with the output from one or more stages of the modelling process. The Methods chosen to facilitate the two phases were Action Research supported by Archival Analysis.

![Diagram](image)

3.3.8 Archival Analysis

Archival analysis was conducted when starting the modelling process to develop an understanding of process modelling before deciding the model type. It was also required to understand the elements and deliverables of scheme design and later to verify the adopted procedures when developing the prototype Scheme Design Process Model (SDPM).

Existing models of concept and scheme design (Hassan 1995) produced by using Data Flow Diagrams were examined and reproduced using modified IDEF0 techniques. This part of the work is described in chapter five. The diagrams were examined to assess their suitability to accept the inclusion of risk and cost elements required by the current research. Checks were made against current information requirements during early stage design and
it was established that these had moved on such that the sophistication of current requirements within a multi disciplinary design environment necessitated the construction of a new hierarchy of design activities.

Developing a new hierarchy of activities required close cooperation with the designers. The process of participant interaction described in section 3.3.9 provided the major input into developing the SDPM and was assisted by information generated from the initial case study activities. However considerable archival analysis was employed to cross check the information provided by designers. This took the form of the information exchanged and the deliverables at both concept and scheme stages from a selection of projects. Corporate handbooks, departmental procedures and implementation policy were also investigated to ensure the research observed a broad perspective and avoided the pitfall of becoming case specific. This information was fed back through the action research and provided a constant comparison and benchmark for the developmental of the SDPM.

3.3.9 Action Research

Conventional case study research seeks to minimise the degree of involvement between the researcher and the researched in the interest of objectivity. The role of conventional case study research is to describe, understand and explain (Robson 1993). Delivering a dual understanding and promoting change requires a different perspective. The perspective provided by action research owes much to the work of Kurt Lewin who first introduced the term (Lewin 1946). In his formulation, this involves a spiral of cycles of planning, acting, observing and reflecting involving the researched in the development of solutions. Stringer (1996) called this spiral Look, Act and Think choosing to discuss the planning as part of the acting process required of the participants (Figure 3.3).

![Action Research Interacting Spiral](image-url)
Chapter Three

The basic action research routine being to:

**Look**
- Gather relevant information (Gather data).
- Build a picture and describe the situation (Define and describe).

**Think**
- Explore and analyse what is happening (Hypothesise).
- Interpret and explain how and why things happen as they are.

**Act**
- Plan (Report)
- Implement
- Evaluate

Constructing a model of the scheme design process and developing the QFD techniques followed the principles of action research by working with the designers at AMEC Construction to form a participant research team.

Interaction with the designers in a multidisciplinary environment overcame planning problems that may otherwise been faced when endeavouring to reach agreement when gathering appropriate data through separate organisations. Collaboration with the designers allowed each discipline to define their requirements for the design process model and workshops helped develop a shared understanding when evaluating the robustness of the model design. During each part of the model development and later as the information-dependencies were agreed for the design structure matrix (DSM) a process of negotiation was conducted that met with the think requirements of the research methodology. Presentations were made to departmental heads and corporate stakeholders during the model development to help define requirements and evaluate the results.

Developing the techniques to apply QFD in a construction design environment followed the same procedure. Defining the problems encountered in early stage design that might be solved with QFD involved workshops where the technique was explained and information gathered so that the research could go away and synthesis solutions to real world examples. Meetings were held with architects, value managers and cost planners to evaluate the developed techniques.

The development work for each phase is described separately stage by stage in chapters five and six respectively.
3.4 CONCLUSIONS TO RESEARCH OBJECTIVES AND METHODOLOGY

Choosing the methodology for early stage design was complicated by the many differing elements and stages within the overall research focus. Essentially the methodology adopted a case study approach that involved the researcher as a participant and later the researched subjects as participants to the research.

- The case study methodology examined the reliability and relevance of the major problems uncovered by the literature review.
- The research response to the problems investigated by the case study, employed the evidence gathered during interviews and from archival research to assist the problem formulation.
- The action research methodology employed data generated from case study methods, and archival analysis to assist the improvements for the concept and schematic design.
- Testing of the results was achieved through consistent communication and continuous evaluation of the developed solutions with the research participants.

Whilst endeavouring to maintain the academic rigour required for validating the research design, it was observed that criticism might be levelled at the use of a single case study with only one major contributing industrial collaborator. This criticism can be addressed with the following response:

1. AMEC Construction were able to provide continuity and consistency of approach on a mutually familiar topic

2. AMEC Construction were also able to contribute with the level of detail required together with access to a pharmaceutical building design that demands a certain type expertise and organisational depth of knowledge from their personnel.

3. Building on previous research relationships also provided industry supervision from senior executives that the research could depend on for frank responses and robust feedback to the developed proposals.
Chapter Four

SHADOWING EARLY STAGE DESIGN

4.1 THE CONCEPT STUDY

4.1.1 Introduction to the Concept Study

The literature review in chapter two presented the research with a range of issues faced by designers and their clients during early stage design. The issues emerged as far-reaching and encompassed both the concept and schematic stages of design. To uncover the true meaning of the problems emerging and how they effect the management of multidisciplinary design further investigative research was planned to evaluate the current practice in context with this research.

The investigative research would shadow a concept study and observe the designers as they developed options, delivered the cost advice, and prepared for the scheme design stage that would follow. Specifically it would observe:

- The generation of information and the management of information designed to deliver the options (Austin et al 1995) (Barrett & Stanley 1996).
- Group dynamics and the communication of needs and requirements (Latham 1994), (Egan 1998).
- The interaction between design team members and client stakeholders (Platt 1996).
- The iterative process of negotiation especially the negotiation of project risks (Edwards & Bowen 1998).
- The methods employed to sign off decisions (Latham 1994), (Egan 1998).
- The techniques and activities evolved to deliver the design (Bowen-James 1995).

The investigative research in chapter four contributed to both the Scheme Design Process Model in chapter five and the QFD techniques described in chapter six by allowing the real world problems to emerge and consolidate the findings from chapter two.

AMEC Construction’s Stratford upon Avon office formally AMEC Design and Managementspecialises amongst other design projects in the design of highly engineered buildings such as pharmaceutical plants, laboratories and hospitals. AMEC Construction
are the industrial collaborator for this research and it was from their offices that the opportunity to observe a concept study was created when they were commissioned to carry out a study that would eventually lead to the design manage and construction of a new drug development facility for a leading pharmaceutical company. Scheduled to be conducted over a period of ten weeks the concept study provided a platform from which this research would record the processes currently employed between a leading design and management company and a professional client as the client brief was being taken. It would allow the research to satisfy the stated aim of carrying out a critical review of current practice as designers develop the brief and to identify precisely where the process is both at its most and least effective.

Designing any building is a complex process involving many iterative tasks. Designing buildings incorporating controlled environments that contain a large amount of sophisticated plant for servicing the building can make the process even more complex. Highly serviced buildings of the type required to house chemistry and biology laboratories that have many specialised elements dictated by the nature of the research and the culture of a long established pharmaceutical company will add further complexity.

When the design of a building involves the re-structuring of a division of a company the design process is not just about the design of the building. It is about creating the environment that will accommodate the people and equipment necessary to carry out the science that will enable that organisation to realise its strategies and provide the profits necessary to satisfy the expectations of its stakeholders. With all these elements to consider, it is necessary to remember that the key issues for the design process are highlighted by the negotiations at the forefront of the process. There are also dynamics that strongly influence direction at this crucial early stage of the process that sometimes remain shrouded in the background throughout. An example of this is the strategic decision process when principle stakeholders exercise their executive authority to sanction or censor.

An agreement to proceed with the design came following the extensive marketing process that is employed by AMEC Construction to promote their capability to this particular client. The stakeholders representing the two organisations (Table 4.1) negotiated the fees for the initial study and the client’s engineering department provided several scenarios for the design team to consider based on using an existing working site. The scenarios provided options offering to incorporate some of the existing buildings at the site. A basic schedule
of accommodation was also provided. A programme was prepared to indicate a seven-week period was required to produce the concept study report. During this period five user group and two value management meetings were planned. Additional meetings were arranged between design leaders and the client management to review the project and further internal design team coordination meeting were arranged at AMEC Construction's offices. The author was provided an open invitation to attend any meeting considered beneficial to the research; the client also extended this openness. Consequently, the research was able to probe and question members of both the design team and client user group where ambiguities surfaced or further clarification was required.

The study group for the design comprised the principal members from the AMEC Construction design team, client representatives and client user group. The intention was to use the user group meetings to confirm the stakeholder requirements for the project. Eventually, the user group would be required to sign off their agreement to the design as the new building was being created for their specific use.

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>DESIGN MANAGEMENT COMPANY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Stakeholders</td>
<td>Design Team</td>
</tr>
<tr>
<td>Head of T. A. Respiratory Diseases</td>
<td>Project Director</td>
</tr>
<tr>
<td>Head of Engineering</td>
<td>Design Manager</td>
</tr>
<tr>
<td>Project Manager</td>
<td>Lead Architect</td>
</tr>
<tr>
<td>Project Engineering Manager</td>
<td>Architect</td>
</tr>
<tr>
<td>User Group (Stakeholders)</td>
<td>Building Services Engineer</td>
</tr>
<tr>
<td>Head of Biology</td>
<td>Marketing Manager (first day only)</td>
</tr>
<tr>
<td>Principal Scientist – Biology</td>
<td>Design Strategist (not first day)</td>
</tr>
<tr>
<td>Head of Molecular &amp; Cell Biology</td>
<td>Value Management Facilitator (VM only)</td>
</tr>
<tr>
<td>Head of Chemistry</td>
<td>Cost Planner (VM only)</td>
</tr>
<tr>
<td>Head of Research Services</td>
<td>Economist (detail design start meeting)</td>
</tr>
<tr>
<td>Head of Drug Discovery Support</td>
<td>Civil\Structural Engineer</td>
</tr>
</tbody>
</table>

Table 4.1: Study Group Members

The principal stakeholders from client management provided a strong guiding presence at these meetings as they acknowledged that the users, who are primarily scientists, would require assistance in understanding the design process.
Chapter Four

The design team made use of the initial meetings for general fact finding and gathering. The concept study investigated:

- **The Client Brief** - to determine the extent of the project requirements and available budget later confirmed by the designers in the form of a definition brief and commercial strategy.

- **Functional Requirements** - to include the project overview, essential interaction of disciplines, therapeutic research area, support service requirements, supported by value management exercises and user interviews.

- **Site Evaluation and Analysis** - to capture master planning considerations presented by the chosen location. The retention of existing buildings, external site influences, character and landscaping opportunities, site security and access considerations, topography, geology, consents and site services infrastructure.

- **Description of Selected Options** - to include both rational replacement and pragmatic consideration of the existing buildings in order to best meet the client’s objectives.

- **Schedule of Accommodation** - to interrogate the stated needs and requirements presented in the initial client brief.

- **Key Discipline Design Philosophies** - to develop a set of criteria and consider both practical responses to the functional requirements and esoteric responses to the aspirations of the stakeholders.

- **Design and Construction Programme** - to indicate the key stages of the project from client instructions to proceed through initial design stage, frozen layout signed off, detailed design, procurement, local authority approvals, construction and completion.

- **Health & Safety** - to establish general and specific requirements, site issues, safety reviews and Hazop.

Figure 4.1 provides an outline of the iterative process followed by the concept study as the brief was investigated and potential options tested.
4.1.2 The Meetings

Appendix A provides an outline of the concept study and the other meetings attended as part of the project shadowing. The full transcripts have not been included with this thesis but descriptions of the salient points are provided to assist the reader understand the process and its participants.

Appendix A describes in detail the 23 issues uncovered during the research. These were summarised individually (italics) in the appendix and are listed as bullet points in section 4.1.3. These points form the core issues that emerged. The research then compared these issues with the core categories that emerged from the individual interviews conducted with the design team members in section 4.2.

4.1.3 Summary of the Project Shadowing

Twenty issues had been raised and where similarities were noticed, these are crashed into the following bullet points:

- There was no project coordinator or clear leader for the client user group.

- The perspective of less assertive stakeholders could be overshadowed when investigating the brief.
Chapter Four

- User stakeholders lack coordination and failed to buy into their responsibilities.
- No coherent corporate strategy from the client.
- No client based project manager to drive issues and develop solutions.
- Too many closed relationships leading to rivalry and mistrust.
- Specialists and technology help understanding for stakeholders.
- No central coordination of collected information.
- Risks exist at briefing so a risk register should be started.
- Study group liaison was good on need driven issues.
- Decisions should always be signed off (procedure recommendation).

These points are discussed in section 4.2.4 as part of the outcomes from this chapter where their impact on the design process and implication for the research is consolidated.

4.2 INTERVIEWING THE DESIGN DISCIPLINES

4.2.1 Introduction to the Interviews

A series of interviews were conducted at AMEC Construction's offices to examine the roles and responsibilities of design professionals within a multi-disciplinary design team. Each participant was asked to focus on their role within the organisation and their particular role on the shadowed design project (Section 4.1). Grounded Theory (Section 4.2.2) was used to analyse the data contained within the many hours of taped interviews. The interviews (Appendix B) were analysed (Section 4.2.4) to reveal issues that could be compared with the research findings from the shadowing exercise. Section 4.3 compares the outcomes from both the shadowing exercise and the interviews to develop theory and recommendations for the research.

Because of the fluid nature of the design process, the interviews were conducted after the initial brief taking process and the concept study report. The design team continued to work on the definition brief (Appendix F) after the concept study report had been submitted. The definition brief should have formed a major part of the concept design report but its production was delayed. This was because the stakeholders were not content to sign off the
design options without a project manager to advise them on the technical issues. Following the signing off process for the design options time had allowed the definition brief to encroach on the scheme design. Consequently scheme design was truncated as the principle stakeholders agreed that the project would go straight to detail design on the agreed option. The cost advice (appendix B) had also jumped straight to lump sum from the order of cost agreed for the concept study. This demonstrated the complexity of the early stage design process for the research.

The lead architect and head of cost planning were asked about the definition brief and its relationship to scheme design a report on the findings is given in Appendix F.

4.2.2 Grounded Theory

Grounded Theory is a general methodology for developing theory that is grounded in the data systematically gathered and analysed (Strauss & Corbin 1998). Grounded Theory is often called "The Constant Comparative Method" since as Glaser & Strauss (1967) stated: the constant comparison forces the analyst or researcher to consider much diversity in the data". The diversity refers to the comparison of one incident with other incidents that then result in the emergence of core categories. This technique links similar incidents that result in categories from which theory may be developed, i.e.

![Diagram](Data → Categories → Theory)

The methodology's chief and almost exclusive feature is in the theoretical coding which is done in conjunction with making constant comparisons. The data emerges from the conducted interviews. Codes emerge as significant statements from the data. The codes will vary from the data as they are consolidated into concise statements that are arranged into categories. Table 4.2 provides an example of the process. The process of consolidation uses Theoretical Sensitivity (Glaser 1978).

Theoretical Sensitivity allows the researcher freedom to place their own interpretation or reading of the data, thus bringing their own background knowledge and experience to the interpretation of their findings.
Chapter Four

<table>
<thead>
<tr>
<th>Interview or Data</th>
<th>Code</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>From an interview with the project economist:</td>
<td>Project economists work along with the client and Importance during their budget to look at various options.</td>
<td>Cost Planners Client Negotiation</td>
</tr>
<tr>
<td>The problems being that there was a budget problem at first because we were going over the clients budget. So we went through a series of different options, different shapes of building were devised as we looked at a dozen different options. I was involved in putting budgets together for those different options. Then we went through a series of meetings with the client to discuss the advantage and disadvantage of each option. From that we then selected an option that the client was happy with, which would be within the budgets that had been set.</td>
<td></td>
<td>(A project economist is a cost planner)</td>
</tr>
</tbody>
</table>

Table 4.2: An example of Grounded Theory Coding

4.2.3 The Interviews

Five separate non-structured interviews (Table 4.3) were conducted with members of a multidisciplinary design team. The interviews were tape recorded and later transcribed. The transcriptions from many hours of taping were extensive and the Grounded Theory Method was chosen to analyse the transcriptions by forming codes/categories from the data.

<table>
<thead>
<tr>
<th>Professional Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Marketing Manager</td>
</tr>
<tr>
<td>2. Head of Cost Planning and Value Engineering</td>
</tr>
<tr>
<td>3. Structural Engineer</td>
</tr>
<tr>
<td>4. Lead Architect</td>
</tr>
<tr>
<td>5. Project Economist</td>
</tr>
</tbody>
</table>

Table 4.3: List of Design Professional Interviewed
Chapter Four

The quantity and diversity of the initial two hundred and eight codes that emerged (see appendix C) from the data were analysed by using the Grounded Theory Constant Comparative Method to assimilate twenty-seven sub-categories (see appendix D). In order to make these more manageable the sub-categories were further rationalised looking for similarities and links so that they may be grouped under headings that formed eight core categories. These eight core categories are as listed below, the numbers in brackets provides a reference to one of the twenty-seven sub-categories:

1. The Multi-Disciplinary Experience
   - Team Cooperation in the Interest of the Client (6)
   - Improved Multi-Disciplinary Understanding of Cost Planning Required (8)
   - Multi-Disciplinary Experience during Brief Development (13)
   - Coordinated Gathering of Information (26)
   - Multi-Disciplinary Teams Understand Client Best (27)

2. No Clear Project Manager/Coordinator/leader
   - Designers are Seeking Improved Methods of Relating to Client’s (1)
   - Designers Sometimes Act on own Initiative (4)
   - No Project Coordinator – Client (11)
   - No Project Coordinator – Designers (12)
   - Some Professions see Themselves Working outside Interdisciplinary Teams (18)

3. No Coordinated Project Information
   - Designers are Concerned about Design Changes (3)
   - Marketing Debriefing may Reveal Valuable Client Intelligence (7)
   - Marketing Networking has Valuable Intelligence on Principle Stakeholders (16)
   - Cost Planners Rely on Information from Others (17)
   - Designers Require Quality Information from the Client (19)
   - Cost planners Importance during Client Negotiation (25)

4. The Importance of Risk Analysis
   - Risk Analysis is Under Employed at Early Stage Design (14)
   - Project Participants prefer Lump Sum Cost Advice (20)
Chapter Four

- Clients prefer Guaranteed Maximum Price Cost Advice (21)
- Order of Cost Advice during Conceptual Design (22)
- Two Stage Tendering Mitigates Risk (23)
- +/-10% Cost Certainty at Scheme Design (24)

5. Company Procedure
   - Designers Rely on Company Standard Procedures (5)
   - Cost Planning Follows a Set Procedure (18)

6. Interdisciplinary Rivalry (9)
7. Corporate Level Decisions (2)
8. New Strategic Business (15)

4.2.4 Outcomes

Eight core categories emerged as major issues within the multi-disciplinary team, many of which were confirmed in the summary to the shadowing of the concept study in section 4.1.3.

Category 1 revealed the multi-disciplinary team to be viewed differently by the different professionals in the team, each having their own interpretation on teamwork. All team members share a common goal both within the design team and within the study group. Methods and techniques to develop the multi disciplinary experience are therefore recommended.

Category 2 highlighted a clear deficiency in project coordination. This issue surfaced many times from both observation and interview. Project coordination was evident but what seemed to be missing was a high profile experienced advocate for both stakeholders and the design team. For this to work and provide the reliable continuity for the teams throughout the design period, such individuals would be required in office before the briefing process commences and remain there until the design is signed off.

Category 3 does not refer to CPI (Snook 1995) but to the manner in which information is collected, assimilated and uncovered by members of the multidisciplinary design team. Information is collected through a variety of means during the course of the early stage design process. Currently the information is recorded separately in the order of collection.
and only referenced on a needs basis, primarily by the design team. If that information were to be reviewed systematically, elements of risk could be registered and form part of an action plan. All project participants may then undersign the action plan to establish a thorough audit of the process.

Category 4 highlighted that risk analysis is under employed during the early stages of design. Clearly there are risks to the designer when preparing cost advice and opportunities to mitigate risk are sought and shared with the client at later stages in the process. If the risk analysis process was integrated into design philosophy and shared with the client from inception, it is believed that improved understanding of roles and responsibilities could be achieved. This may also help focus project participants.

Category 5 demonstrated that company procedures for respective disciplines within the organisation exist but no single coordinated procedure for multi-disciplinary design teams was uncovered. If process and information models proposed by this and other research are to be fully integrated, it will be important to address this issue.

Category 6 uncovered strong feelings of interdisciplinary rivalry both within the design team and within the client team. To some extent, this may be put down to human nature. Architects set themselves apart by wearing bow ties. Multidisciplinary team members were never backward in extolling their own virtue. What everyone seemed to overlook was by how much they rely on other team members and how their own work would suffer without their support. Following the recent introduction of risk analysis techniques into the design process, it was observed that team members started to understand their own responsibilities to their colleagues. Within the client team, the perspective of less assertive stakeholders could be overshadowed when investigating the brief leading to an unbalanced brief that may cause dissatisfaction in the final analysis. The phenomenon of collusion was witnessed between the principle stakeholders and the design team management. The stakeholders had also noticed and consequently refused to sign off the concept study without independent advice causing a three-month delay to the project. Each or all of the aforementioned could be overcome with the judicious use of more team building techniques and the appraisal of design strategies.

Category 7 revealed a lack of coherent corporate strategy within the client organisation as the main issue during the concept study meetings. This related to technical matters that
Chapter Four

should have been resolved in advance of study group meetings by the client representatives. It is felt that designers should be more sensitive to this type of issue and submit in advance a list of points they require clarified. This problem may not be an issue where a client project manager is in office.

Category 8 relates to sales and marketing issues, there is no direct relationship to this research so no recommendations are made.

Finally, it was found during the period of shadowing the concept study that specialists and technology help stakeholders understand some of the more complex spatial and esoteric issues that they are expected to sign-off. Techniques and technology that promote improved communication between client and designers are to be encouraged. Techniques that apportion responsibility and risk to the appropriate team participant also help team members acknowledge they’re and the role of others on the project.

4.3 CONCLUSION TO SHADOWING EARLY STAGE DESIGN

The conclusions drawn from both the project shadowing of the concept study and the interviews conducted in its aftermath provided the following indicators for the research:

- The process is information driven and the quality of the information shared between designers, stakeholders and the study teams could benefit by improving communication and empathy between participants. Providing improved planning techniques to identify requirements might benefit the process by allowing all participants to understand their respective responsibilities to each other. In addition, it is suggested that implementing techniques such as risk analysis at an earlier stage might further enhance this. Risk analysis has been seen to improve the way team members negotiate their responsibility towards each other. It has also improved understanding of roles within the team.

- Developing techniques designed to help progressively sign off decisions during the process may be done through risk analysis methods or be part of the value analysis suite of techniques.

- Improvements to multi-disciplinary team management are suggested and this might be achieved through developing clear a QA methodology to encompass the design team as a unit rather than by discipline.
Chapter Four

- It was demonstrated that the concept design stage must remain fluid in its approach to account for the many areas of negotiation, type and sophistication of client, type of cost advice required, location, building etc. It is therefore impossible to recommend using a single process model to help achieve a concept design solution. Instead, the iterative nature of negotiation between designers and the stakeholders might be improved with further integration of CAD and other forms of visual representation to help stakeholders understand what is being proposed.

The case study has reinforced the requirement by designers for improved design strategies by uncovering real world inadequacies initially identified from the literature review. It has further reinforced the finding that the conceptual design process is significantly different from the later scheme design to preclude combining the two stages in a single process model. Observing the later stage as the definition brief was completed and the scheme design proposals prepared clearly identified for the research, the methodical process that designers follow. Providing a process model based on ADePT techniques emerged as a viable proposal for setting out and managing requirements during scheme design. Providing a structured programme for designers to follow and other project participants to share might improve communication and understanding which continues as the principle problem when designing increasingly complex and highly engineered buildings. The author believes that introducing risk analysis into this process can satisfy the secondary requirement of identifying high risk areas and reinforcing the awareness between client and design team allowing cost planners to better qualify the important cost advice mutually expected by both camps.
Chapter 5
Modelling Scheme
Design
5.1 INTRODUCTION TO MODELLING SCHEME DESIGN

Developing a model that could eventually determine the project programme for the whole of early stage design was considered and rejected due to the differing nature of the conceptual and schematic stages investigated for this research. It was decided (Chapter 3) to split the research and concentrate on producing a model of scheme design.

The model developed in this chapter will follow the principles of the ADePT prototype created by Newton (1995) and be known as the Scheme Design Process Model (SDPM).

The SDPM will uniquely model and interlink the cost planning activities of design and introduce the concept of risk assessment. It was reasoned that both cost and risk carry a major influence on project outcomes and that previous models of the design process failed to acknowledge these requirements. A model of the scheme design stage would be flawed if it did not acknowledge the risks involved in producing both the design and the cost advice. Additionally, if the ADePT methodology (Section 2.9.7) is to be followed, questions posed by Newton (1995) should be examined and tested; he outlined a set of parameters for scheme design by asking the following:

- Can scheme design be modelled to the degree of accuracy required to plan it?
- Can the same ADePT modelling techniques be used to model scheme design?
- Is it possible to use parts of the Detail Design Process Model (DDPM) to represent scheme design?
- If so, can the same model be used with differing information classifications?

To provide a suitable foundation a case study of the briefing process for the design of a new pharmaceutical building was conducted (Chapter 4). Monitoring the negotiation and information gathering as the concept study was produced provided an understanding of multi-disciplinary design techniques for the research. It also assisted the model development by creating an empathy with the principals and designers within AMEC Construction who were later relied on to help develop the SDPM.
Additional information was gathered by sitting in on both design management and design team meetings as the design process was negotiated and planned. The communication process between individual designers to report their activities was investigated and recorded. Discussions were held with designers responsible for the separate elements of the design. Deliverables in terms of schedules, drawings presentation items and commercial strategy for the scheme design were identified from the reports provided by the design team. The principle activities and the information flows in the model were generated and verified by the design team. The iterations forced on the multi-disciplinary designers as they determined the information that would be needed to complete the design were also recorded for later use in testing the built model.

5.2 MODEL TYPE

5.2.1 Prototype Or Generic

Initially the desire was to produce a generic SDPM but this desire had to be evaluated due to the time taken to develop the model and the availability of suitable projects on which to test it. The process of producing a generic model was considered.

The design of a new building may be considered as the production of a prototype due in no other way than the location and purpose for which it is conceived. Some clients may wish to follow a corporate image as with supermarket chains but even they are forced to recognise that the location and specific requirements surrounding their facility can dictate alteration to an established pattern. Others who identify with state-of-the-art buildings will use benchmarking techniques to adapt or modify facilities for their own purpose in order to focus on their specific needs and provide a competitive edge for their products. It may be argued that for any given building or facility there can be a generic content but in the case of highly engineered buildings designed for individual clients, it is unlikely that generic continuity will be maintained.

The generic question for this research focuses on the process model used to guide the client and designer during the design process. The design process at its higher levels does follow a generic structure as indicated by the Plan of Work (RIBA 1973). It is in the detailed negotiation between client and designer where continuity can be lost. Newton (1995) posed the further question as to how generic a DPM can be. At the outset of this research, an ideal could have been to test the validity of this question over a series of projects but time
constraints and available projects have precluded this option. It may be noted that when applying a DPM for detail design Austin et al (1999) proved over a variety of different projects that a generic content in excess of 90% could be achieved.

5.2.2 Generic Content

What is generic and what is not generic? Colquhoun & Baines (1991) claimed that a generic model is one that provides an 'as is' means of examining relationships between activities in a process compared to the non-generic 'as should be' model which defines strategy for change or a goal in company-specific terminology. The desire for a generic model is as simple as 'one size fits all'. In practice, it is more likely that once a model of sufficient detail has been produced, elements of the model in the form of activities and information flows between those activities will be dropped where not specifically required. It is expected that for scheme design the tasks or activities will be more stable than at the detail design stage because the activities are fewer and address fundamental issues. The final analysis will discuss this topic in more detail. However, it must be noted that although specific activities for producing a highly engineered building have been covered, mechanical handling and production plant activities have not been included in this model. It is claimed therefore that the SDPM is a prototype of a proposed generic model.

5.3 THE MODELLING PROCESS

5.3.1 A Prototype Scheme Design Process Model

The development of the prototype SDPM commenced after first agreeing on a modelling technique. Chapter two reviewed design process models and the IDEF0 technique was chosen. The five elements of IDEF0, function, input, control, output and mechanism were considered to offer the most flexibility for modelling the diverse information required during scheme design.

A computer aided software engineering (CASE) tool was chosen to assist in building the model. The CASE tool provides an automated engineering discipline for software development, maintenance and management. It includes structured methodologies and tools that automate a process and it has assisted the development of a structured IDEF0 methodology where diagrams can be automatically checked for consistency. It also produced a data dictionary that allowed the extraction of appropriate information to automatically input into the DSM element of the ADePT methodology.
Chapter Five

The IDEF0 model was produced over six consecutive phases (Table 5.1). At each phase, the SDPM was assessed and further refined until a final version could be produced and validated. The first three phases were used to develop the modelling methodology, the main part of the SDPM was constructed in phases four and five and the final phase delivered a model hierarchy under the three principal activities of design, risk and cost.

<table>
<thead>
<tr>
<th>Phase</th>
<th>IDEF0 Model</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concept/Scheme</td>
<td>Identify concept deliverables and links produced by Data Flow Diagram techniques in a previous research</td>
</tr>
<tr>
<td>2</td>
<td>Scheme</td>
<td>Outline of previous modelling findings produced by Data Flow Diagram techniques in a previous research</td>
</tr>
<tr>
<td>3</td>
<td>Scheme</td>
<td>Introduce redefined modelling context and add cost estimate branch to existing model</td>
</tr>
<tr>
<td>4</td>
<td>Scheme</td>
<td>Start new hierarchy and introduce further activities to represent information uncovered in the current research</td>
</tr>
<tr>
<td>5</td>
<td>Scheme</td>
<td>Develop new hierarchy and introduce information flows between activities uncovered by this research and introduce additional risk/value activities</td>
</tr>
<tr>
<td>6</td>
<td>Scheme</td>
<td>Change layout to show scheme design model with three principal top-level activities, design, risk/value and cost. Verify model accuracy with designers and cost planners.</td>
</tr>
</tbody>
</table>

Hassan’s (1996) model of scheme design used to develop simulation techniques with DFDs was recreated in IDEF0 to test the modelling theory. This model for scheme design had a flat initial hierarchy (Figure 5.1) and expanded the structural and architectural activities under the building design process.
Chapter Five

Figure 5.1: Hierarchy for Scheme Design (Hassan 1996)

There was an indication of cost activities with the task A8 Revise Cost Estimate but no provision for linking the detailed production of cost advice to the design activities. At phase two of the model; adding two further hierarchical levels expanded structural design and architectural design was expanded by one further level.

The information flows within the DFD for scheme design were recreated using IDEF0 (Figure 5.2).

Figure 5.2: Stage 2 Model of Scheme Design

The diagrams produced provided clear identification of the activities and the information flows between them but the model was considered constrained by the previous research. It identified the information input from the end of the concept study and some of the deliverables at the end of the process. While this model identified the information requirements, it failed to clarify the source of the information and link the determining
Chapter Five

factors of cost and risk to their respected activities. This was considered a critical omission as, by identifying information source, production strategies can be assessed and understood. The model was evaluated against current practice and rejected in favour changing the context of the model and for building a new hierarchy based on current practice within the multi-disciplinary design organisation.

5.3.2 Revising the IDEF0 Modelling Context

The new model would need to identify the source of the information; to achieve this, the IDEF0 modelling context would require revising. The literature review (Section 2.8.10) had highlighted the flexibility of IDEF0 in terms of the different inputs available to each activity and a decision was made to use a modified ICOM context.

Originally developed to describe manufacturing organisation in a structured graphical form and currently used as a tool for business process re-engineering, the IDEF0 standard convention for its data flow arrows was considered inappropriate for modelling the multi-disciplinary design process. Gibson (1995) used the terms ‘decision’ and ‘decision makers’ but the scheme design process is not about decisions alone. The SDPM must display the source of the information required by the respected disciplines in order to identify responsibilities and establish an accurate programme of work. It was decided that as the process being modelled is information based and the model should be used to describe the information based process (Figure 5.3) thus:

![IDEFO and IDEFOv Diagram](image)

Figure 5.3: Restatement of IDEF0 Context for Scheme Design

The model of detail design being developed in a parallel research project (Austin et al 1999a) was termed IDEF0v to describe the variant context. It was considered appropriate
Chapter Five

that if model integration was to be achieved (Section 5.7.6) the modelling context for both scheme and detail design should be complementary. IDEF0v context can now be described as:

- Arrows denoting inputs would now denote information flow within disciplines i.e. architect to architect.

- Arrows denoting control inputs would now denote information flow across disciplines i.e. architect to engineer.

- Arrows denoting mechanism inputs would now denote information flow from external sources i.e. from client, supplier or regulating authority.

5.4 THE MODEL HIERARCHY

5.4.1 Developing a New Hierarchy

Through the offices of AMEC Construction, designers were interviewed individually. They were provided examples from the model at phase 3 (Table 5.1) and asked to comment on its validity. The comments from that meeting had been kept and were used as a benchmark with which to compare the new hierarchy of activities. There was concern about a bias being introduced when adopting this methodology but that concern was outweighed by the need to brief the designers and differentiate between tasks relating to managing the design process and tasks that rely on information that will result in the deliverables expected at the end of the scheme design process.

To establish the new hierarchy of activities from which phase four of the model would be based, a multi-disciplinary meeting was arranged. A blank hierarchy was given to the principal designer from each design discipline and they were asked to identify the activities they perform during scheme design. There was concern that the list of activities generated from these interviews may result in a project specific model and the designers were asked to consider requirements from previous projects as they determined the principle activities they perform.

The results were used to construct a new hierarchy for the SDPM that was validated in further one to one meetings with each designer. An AMEC Construction estimation plan was used during these meetings to coordinate activities with deliverables and this together with the activities prepared by other designers was used to question the validity of their
responses. A few examples of the many problems uncovered whilst developing the new hierarchy are provided in the following sections.

5.4.2 Architectural Design

Architectural design was the most difficult process to map because the coordinating role expected of architects clouded their response when developing the hierarchy of activities used to produce the scheme design deliverables. An initial compromise was reached where the activity A116 Design Review was allowed to be included in their hierarchy. The architects insisted that this is used to develop the project and feedback results to the team from the presentations and sketch development with the client. It was argued that decisions made following such iterative discussion could affect more than one discipline and thus affect the design process. This was to later prove to be an iterative problem in itself when the finished model was analysed in the DSM (Section 5.7.4).

The hierarchy of core activities produced was reviewed at verification meetings with the lead architect. Refinements such as A117 Presentation Items originally included within architectural drawings was moved to a separate activity (Figure 5.4) when the architect realised that the continuing verification of client requirements was fundamental to other activities and needed to be shown separately.

![Figure 5.4: The Architectural Scheme Design Hierarchy](image)

This same process of discussion, development, review was repeated with each of the design disciplines until the hierarchy portrayed a true representation of the core activities required to deliver the scheme design.

5.4.3 Structural Design

The civil and structural design was produced by a single engineering discipline; the research will refer to the product of both disciplines as from structural design. Structural designers had a clearer view of their contribution to the design process than their
architectural colleagues did and it took three meetings to agree the structural hierarchy in Figure 5.5.

Principles issues for the research became the identification of who initiated the surveys. It was concluded that although structural engineers considered it their responsibility, initiation of some surveys very often started as an architectural response to their own initial enquiries. Multi-disciplinary design team members then share the information collected from surveys equally. Sharing raised the issue of drainage design as this too was split between disciplines. Eventually it was agreed that architects were responsible for layouts, mechanical engineers for the pipe work and structural engineers for means of disposal.

5.4.4 Mechanical Design
Mechanical scheme design (Figure 5.6) became a benchmark for the services design and initiated an agreed response between mechanical and electrical services. It introduced a third category to the services section of the hierarchy that they termed A133 M & E Co-ordination to reflect the mutual reliance between mechanical and electrical engineers for layouts, loads etc.

5.4.5 Electrical Design
The research questioned the response from the electrical engineer due to the similarity between its hierarchy and that of the mechanical scheme design. The only difference in the
Chapter Five

Hierarchies was that of the addition of A1325 First Stage Co-ordination. Using examples from previous designs, the electrical engineer demonstrated the process and satisfied the scrutiny (Figure 5.7).

![Figure 5.7: Electrical Scheme Design Hierarchy](image)

5.4.6 Risk Management

In recent years, emphasis has been placed on restructuring organisations to become more horizontally structured with the aim of creating flexible organisations able to effectively adapt to change. Risk management has helped design teams in other industries understand their colleagues' roles and needs. Chapter four identified that more emphasis needs to be placed on developing an appropriate level of knowledge of various qualitative risk analysis techniques. Cultural issues and the building of interpersonal relationships based on respect, trust and openness are seen as essential elements to encourage the development of group synergy. Discussing these issues with management members of AMEC Construction confirmed that the use of risk analysis within their organisation:

- Made the search for risks and risk resolution a more objective and less subjective affair.
- Enables the respective design disciplines to identify risks, grade elements of risk, record them in a risk register and allocate the risk to the risk owner.
- Facilitate the production of action plans designed to mitigate risk at the earliest opportunity.
- Assists the cost planners negotiate design and project costs.
- Identified to clients responsibilities extraordinary to the design.
- Helped cross-disciplinary team members to understand their responsibilities to colleagues when developing the design concepts.
AMEC Construction currently use proprietary software to register and assess project risk as it enabled them to monitor and manage the many entries made to the risk register and predict likely outcomes as the design progressed. Some points listed above already form part of their risk management process but risk management during the earlier stage design was still being assessed to provide a workable mechanism as the client brief is investigated.

The mechanisms employed during the later stages of design were investigated and checked against the corporate QA procedures, the proprietary software program was also reviewed to establish a common process and set out the activities for the model. The risk analysis section of the model (Figure 5.8) was negotiated and verified by the design economist, as he was responsible for these elements in the AMEC Construction design office.

The value analysis process was placed under the heading of risk evaluation because it forms part of the information gathering that precedes the establishment of design risk. Designers collect project information from inception and if a process of risk identification and mitigation is started at the earliest possible opportunity, the information collected will form an audit of understanding for the design team. It is reasoned that better understanding of whole project risk will help focus the project participants leading to earlier clarification of major issues. It may be argued that the VM₁ and possibly the VM₂ will have been completed before the commencement of scheme design but designers claimed that where the concept stages have been undertaken by others or proved inconclusive a definition brief may benefit further VM investigation at the outset of the scheme design.

Figure 5.8: The Risk Evaluation Hierarchy
Chapter Five

The Construction (Design and Management) Regulations (CDM 1994) imposed clear duties upon the designer to carry out risk assessment procedures on a design. The A25 CDM Assessment activity was created to process project information during scheme design to help designers select design options that entail fewer foreseeable risks at the earliest possible stage.

5.4.7 Cost Planning

The cost plan hierarchy became the largest part of the SDPM with potential to be further developed later to include corporate and management issues. This is where decisions are taken on the tactical procedure for a specific client and the build up of overhead cost and profit is negotiated and agreed. To complete the cost section of the SDPM in its working version these activities (shown on the model hierarchy) will have to be extended. For this research, the requirement was to provide links to the design and risk sections of the model and show the interaction with cost planning in determining the outcomes from early stage design. The initial hierarchy is given in Figure 5.9 and this is further developed through the A7231 Prime Cost Estimate branch. This branch consists of eleven sections that each contain between two and fifteen activities at the bottom level of the hierarchy.

![Cost Plan Hierarchy Diagram](image)

Cost planners assisted in developing the hierarchy by providing a breakdown of their requirements at two levels of estimate preparation +/-20% and +/-10% cost certainty. As the later is the norm at scheme design, the cost hierarchy was prepared to process the design information required for this level of price sophistication.

115
Chapter Five

5.5 INFORMATION FLOW MODELLING

5.5.1 IDEF0 and Information Modelling

The model hierarchy was completed and verified by the designers and cost planners. The next part or phase five in building the scheme design model was to uncover the information required to link the activities and develop the model using IDEF0v. This process used five criteria to help verify the accuracy of the information:

1. Ask the designers to identify the information they require to complete the activities they have verified.
2. Check this against information available to designers from earlier design stages.
3. Examine the deliverables required at the completion of scheme design.
4. Check against the estimating plan for information required by the cost planners.
5. Submit completed diagrams to designers and cost planners for verification.

The first was achieved by producing a list of available bottom level activities/tasks from the hierarchy and providing each design discipline with this together with forms listing the tasks they perform and space to note on the form, the information they require. An example of a completed form is given in Table 5.2. The information flows in terms of cross disciplinary, intra disciplinary and external requirements were plotted on the IDEF0v diagrams created from the new hierarchy in phase four of the modelling process. An example IDEF0v diagram is given in Figure 5.10.

<table>
<thead>
<tr>
<th>Name</th>
<th>Design Activity</th>
<th>Information Required</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1221</td>
<td>Foundation Options</td>
<td>Soil investigation report A121, Architects floor plan, Elevations, Sections, Foundation load calcs A1222</td>
<td>Civil, Arch, Ditto, Do</td>
</tr>
<tr>
<td>A1222</td>
<td>Foundation Load Cals</td>
<td>Architects floor plans, Elevations, Sections, Mechanical plant loads, Electrical plant loads</td>
<td>Arch, Ditto, Do, Mech, Elec</td>
</tr>
<tr>
<td>A1223</td>
<td>Foundation Type Decision</td>
<td>Foundation load calcs A1222, Soil investigation report A121</td>
<td>Civil, Ditto</td>
</tr>
<tr>
<td>A1224</td>
<td>Foundation Scheme Doc.</td>
<td>A121, A1221, A1222, A1223</td>
<td>Civil, Ditto, Do</td>
</tr>
</tbody>
</table>

Table 5.2: Information Requirement Form
Chapter Five

Each IDEF0 diagram was then checked against the information available from the concept study and the deliverables at the end of scheme design. Further information was added from both intra and cross-disciplinary disciplines where a requirement was indicated on another diagram or from the cost plan. This information requirement was first investigated to establish if it could be obtained elsewhere and then the respective discipline asked to sign off the amendment. For instance in Figure 5.10 the Borehole location drawing output from A1221 Foundation Options was required for the A121 Site Investigation activity. This information was an intra-disciplinary requirement and was therefore easily signed off when the model was shown to the structural engineer. On some occasions, further negotiation was required between the disciplines especially when the information uncovered did not relate to the current project. The cost planners provided a more generic requirement that needed information on Piling layouts and details from A1223 Foundation type decision. The structural engineer initially questioned this because it was not relevant to the current project but eventually realised it was information he would provide on other occasions.

This form of interrogation helped the research, as it required designers to demonstrate their particular knowledge and promoted further discussion about the model content.

The final phase (six) in building the model was to ensure the integrity of the model and develop the links between the design risk and cost elements. The design economist verified the flow of information between the design activities, cost activities and the risk evaluation activities. It was during these discussions that the author suggested the iterative problems
identified by the SDPM might be sent to the risk register to identify where estimates have
been made as the design is planned and that further connections to the risk register should
be made when design iteration was unresolved by reference to the DSM (Section 5.7.4).

Each part of the model hierarchy was examined and rigorously tested against the criteria at
the start of this section.

The complete SDPM is not provided in the thesis to protect intellectual property rights. The
final version of the model is only produced in the table form described in section 5.6.
During the validation process and as further information became available it was decided
not to update the IDEF0 diagrams for the prototype SDPM, the information dependency
table (Table 5.3) was found to be more adaptable and easier to update. Although this
decision provided a practical solution for research time management, designers preferred to
have a graphic representation (Section 5.5.1) as it made it easier for them to follow the flow
of information between activities.

5.6 INFORMATION DEPENDENCY TABLES
5.6.1 Producing an Information Dependency Table
Before the information from the IDEF0 model can be input into the Design Structure
Matrix (DSM) as required in the ADePT methodology (Section 2.9.7) an information
dependency table is produced. The information dependency table is used to classify the
importance of the information required by the activities. This is necessary because the
many pieces of information can then be grouped into categories that enable the designer to
understand where to make an estimate or where a piece of information must be fully
worked out before proceeding with the design. For example, the foundation loads cannot be
calculated until the total load from the building has been established. The total load of the
building will not be established until much later in the process when all the relevant
information has been collected. Often this is after work on site has commenced. Therefore,
an estimate of the foundation loads must be made so that the foundation design may be
completed in time.

5.6.2 Classifying the Information
The process of classifying the information helps to reduce the amount of design iteration to
be dealt with by the DSM.
The information extracted from the IDEF0 CASE modelling software allowed the information classification table to be produced (Table 5.3). This was achieved with the assistance of bespoke software designed in a parallel IDAC 100 research project by Baizhan Li (Austin et al. 1999a). Both the design activity and the information source activity are provided with their respective numeric activity address. The software is able to identify each of the bottom-level design activities or Functional Primitive Tasks (FPT) within the model and describe the information inputs in terms of its ICOM source. Each FPT from the IDEF0 model is dependent on information from other FPT’s in the model; through constructing a dependency table an ordered programme of work may be produced.

<table>
<thead>
<tr>
<th>Design Activity</th>
<th>Information Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Name</td>
</tr>
<tr>
<td>Number</td>
<td>Information Name</td>
</tr>
<tr>
<td>A 1 2 2 2</td>
<td>Foundation Load Calks</td>
</tr>
<tr>
<td>Elevated</td>
<td>Elevation Drawings</td>
</tr>
<tr>
<td>External walls</td>
<td>Elevation Drawings</td>
</tr>
<tr>
<td>Floor layout</td>
<td>Floor Layout Drawings</td>
</tr>
<tr>
<td>Roof and plate</td>
<td>Floor Layout Drawings</td>
</tr>
<tr>
<td>Foundation</td>
<td>Foundation Options</td>
</tr>
<tr>
<td>Foundation type</td>
<td>Foundation Type Decision</td>
</tr>
<tr>
<td>Frame design</td>
<td>Frame Scheme Design Doc.</td>
</tr>
<tr>
<td>Plant weights</td>
<td>M &amp; E Co-ordination</td>
</tr>
<tr>
<td>Details of rules</td>
<td>Sections &amp; Details</td>
</tr>
<tr>
<td>Sections typical</td>
<td>Sections &amp; Details</td>
</tr>
<tr>
<td>Site layout plan</td>
<td>Block Plan &amp; Survey Drgs.</td>
</tr>
<tr>
<td>Commercial strategy</td>
<td>Budget Control</td>
</tr>
<tr>
<td>Concept study</td>
<td>Concept Study Report</td>
</tr>
<tr>
<td>Floor layouts</td>
<td>Floor Layout Drawings</td>
</tr>
<tr>
<td>Foundation load cals</td>
<td>Foundation Load Calks</td>
</tr>
<tr>
<td>Soil investigation report</td>
<td>Topographical Analysis</td>
</tr>
<tr>
<td>Design recommendations</td>
<td>Value Engineering</td>
</tr>
<tr>
<td>CDM recommendations</td>
<td>CDM Risk Assessment</td>
</tr>
<tr>
<td>Risk action plan</td>
<td>Risk Register</td>
</tr>
<tr>
<td>Project objectives</td>
<td>Value Management One</td>
</tr>
<tr>
<td>Estimating plan</td>
<td>Total Project Cost Estimate</td>
</tr>
<tr>
<td>Commercial strategy</td>
<td>Budget Control</td>
</tr>
<tr>
<td>Foundation load cals</td>
<td>Foundation Load Calks</td>
</tr>
<tr>
<td>Foundation option</td>
<td>Foundation Options</td>
</tr>
<tr>
<td>Foundation type</td>
<td>Foundation Type Decision</td>
</tr>
<tr>
<td>Soil investigation report</td>
<td>Topographical Analysis</td>
</tr>
<tr>
<td>Commercial strategy</td>
<td>Budget Control</td>
</tr>
<tr>
<td>Foundation load cals</td>
<td>Foundation Load Calks</td>
</tr>
<tr>
<td>Foundation option</td>
<td>Foundation Options</td>
</tr>
<tr>
<td>CDM requirements</td>
<td>Health &amp; Safety Executive</td>
</tr>
<tr>
<td>Soil investigation report</td>
<td>Topographical Analysis</td>
</tr>
<tr>
<td>Piling cost information</td>
<td>Piling Cost Estimate</td>
</tr>
<tr>
<td>Basements cost info</td>
<td>Basements Cost Estimate</td>
</tr>
<tr>
<td>CDM beam &amp; strip</td>
<td>CDM Beam &amp; Strip Foundation Cost Est</td>
</tr>
<tr>
<td>Retaining walls cost info</td>
<td>Retaining Walls Cost Estimate</td>
</tr>
<tr>
<td>CDM floor slab cost info</td>
<td>CDM Floor Slab Cost Estimate</td>
</tr>
<tr>
<td>Suspended slab cost info</td>
<td>Suspended Slab Cost Estimate</td>
</tr>
<tr>
<td>Machine bases &amp; piles cost info</td>
<td>Machine Bases &amp; Piles Cost Estimate</td>
</tr>
</tbody>
</table>

Table 5.3 Information Dependency Table
Chapter Five

The tables with space in the right hand column for the classifications together with a copy of the IDEF0 diagrams were given to each of the design disciplines for them to provide classification letters for each piece of information that they require. The ADePT methodology (Newton 1995) required that the information classification should follow the format outlined in Table 5.4.

<table>
<thead>
<tr>
<th>Information Type</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A Information</td>
<td>It is absolutely essential to a task that class A information be made available prior to its commencement.</td>
</tr>
<tr>
<td>Class B Information</td>
<td>It is not essential to a task that class B information be made available prior to its commencement but it would be preferable</td>
</tr>
<tr>
<td>Class C Information</td>
<td>It is not essential to a task that class C information be made available prior to its commencement</td>
</tr>
</tbody>
</table>

Table 5.4 Classification Criteria.

To assist the designers they were provided with a flow chart to help guide their decision-making during the verification process (Figure 5.13).

5.6.3 Information Dependency Tables

It was found during the research that whereas the information dependency tables provided a suitable medium for representing and modifying the model information, designers could not relate to the tables alone. They required the support of the model diagrams to relate to the flow of information between activities. This was reinforced when the model was prepared for validation (Section 5.8).

For clarity, Table 5.3 shows the same activities and information flows from IDEF0 diagram in Figure 5.10. It will be observed that there is more information in the table than on the drawing. The CASE software is able to group information under a single heading. Typically, information from the child activities under Architectural GA’s has been grouped before being input into A1221 Foundation Options and A1222 Foundation Load Calcs. In the table, these may be identified as coming from the architectural activities in the IDEF0 model by their numbering starting with A11xx (Figure 5.4).
Classifying the data provided designers with further opportunity to scrutinise the IDEF0 model and dependency tables as they evaluated the priorities of their information requirements.

5.6.4 Verification and Validation of the SDPM

Verification was provided throughout the modelling process. A CASE tool was used in the construction of the graphic model to check for consistency of terminology and avoid repetition. AMEC Construction was consulted at each stage of the model production to establish appropriate structure and content. The information received was separately tested against both current project and archival information to establish conformity to the quality processes maintained by the organisation.

Validation necessitated a holistic approach due to the shortage of projects at the scheme design stage and was limited to the appraisal of the project information produced through the DSM. This is discussed in section 5.7.
5.7 DESIGN STRUCTURE MATRIX ANALYSIS

5.7.1 DSM Analysis of the SDPM

Design structure matrix analysis captures both the sequence of and the technical relationships among the many design tasks to be performed (Eppinger et al 1994). It has been shown that this form of matrix analysis helps designers structure design activities so that practical programmes of work may be produced. When the table of dependencies had been completed, further manipulation of data was required to prepare it for Design Structure Matrix (DSM) analysis. A combination of MS Excel and MS Access spreadsheet and database was used to manipulate the data and prepare the information dependencies, converting the data into a comma separated CSV format.

Two types of software, PSM32 (Steward 1994) and AMMP (Austin et al 1999) have been used by the research to present the many tasks or activities and dependent information in a matrix. The computer software developed to manipulate the matrices use sophisticated algorithms to refine and reorganise the design tasks. It allows designers to predict which tasks are dependants on which piece of information they or their colleagues produce. Thus by reordering the matrix all the iterative tasks that cause designers to rework previously prepared solutions may be uncovered and understood. Both PSM32 and AMMP were reviewed before choosing the former as the analysis tool for this project. Currently AMMP is being developed as part of a suite of tools designed as part of the IDAC 100 design research programme at Loughborough University. Whereas AMMP was used initially to display the DSM for the SDPM, it did not offer at that time the tearing analysis tools that PSM32 incorporate. The ability of AMMP to graphically represent and print was considered better consequently, AMMP was used to view and demonstrate the DSM to our industrial collaborator. Feedback from this project provided helped with the ongoing development programme for AMMP both of which were conducted over the same period.

5.7.2 Building a Design Structure Matrix

From the modified dependency tables a design structure matrix (DSM) is produced where tasks in rows are dependent on information from tasks in columns (Figure 5.14). The matrix example in Figure 5.14 from the PSM32 program displays the A, B and C classifications as 0, 3 and 9 respectively. The full matrix (Figure 5.16) displayed the one hundred and fifty three bottom level activities or functional primitive tasks that were identified in the SDPM. Before partitioning, the marks that represent the design tasks are
Chapter Five

scattered and do not display an ordered sequence. After partitioning the tasks are reordered into their optimal order of progression, the example in Figure 5.14 from PSM32 shows the recommended tear that will break the iterative loop of activities indicated in the red box.

The PSM program provides a facility called tearing advice that offers the various alternatives for performing this task. Figure 5.15 shows an example of the tearing advice for the example problem in Figure 5.14.
The process of tearing or declassifying dependencies may be conducted from the tearing advice or from individual analysis. Remembering that tasks in rows are dependent on tasks in columns, the process will declassify predecessor or successor tasks respectively.

### 5.7.3 Partitioning the Matrix

Figure 5.16 displays the DSM for scheme design. This initial matrix illustrates the nature of the scheme design process with the large red (A class) and green (B class) iterative blocks. Before a project programme is produced, these iterations will require analysis and breaking down into manageable parts.

It can be observed that the A class iterative block represents approximately twenty-five percent of the problem displayed in the matrix and the B class iterative block represents seventy-five percent of the problem. This was compared with the initial results uncovered from a parallel research into detail design that displayed an initial area of approximately sixty eight percent of activities that were in a loop after the first partition of the matrix. It was reasoned that these findings are not incongruous; as by the time detail design is performed, many of the client-centred negotiations still in process at scheme design will have been completed.

### 5.7.4 Solving the Iterative Problems

Some design iteration could be observed in the IDEF0 diagrams but it is not until all the dependent information is gathered and passed through the DSM that the true nature of dependency is revealed. The impact of a single piece of information that is required by several task activities can be enormous.
It is clear from Figure 5.16 that the design iterations were too complex to allow the production of a design programme so the PSM procedure for tearing the DSM was followed and the iterative blocks analysed before being broken down. This process was complex as it involved reviewing the sequence of tasks recommended by PSM to see if further reclassification of information required by the tasks was possible. The designers had already provided their opinion of which tasks could be estimated so justification would be required before classifications are changed.

The PSM tearing advice only works on a single class of information so the large red block of A class information in Figure 5.16 was analysed first. The problems were considered and the following tears were made:

- It was revealed that A1311 Mech Design Parameters required A class information from A131 M&E Co-ordination and a decision was made to declassify this to B or estimative as it is an advisory process that would be further developed during detail design.
Chapter Five

- A21 Value Management One and B114 Client Information were declassified to B as both activities would normally be concluded as part of the A1 Concept Study Report thus these may be considered a duplication of information.

- A116 Architectural Design Review - Review information supports the design process by providing esoteric information to the disciplines. The hard information required by the design disciplines having already been delivered with plans, elevations and sections. A decision was taken to declassify successor information to C. Selectively the output from the Cross-disciplinary information activity was assessed and adjusted where the same information was provided elsewhere. The information Schedule of internal alteration was considered to be of weak dependence and insensitive. If and where changes are made to the design a procedure of Design Change Control would be employed to report and estimate cost to the client all occasions for this information were declassified to C.

- A1121 Block Plan & Survey Drawings required information from A1122 Floor Layout Drawings and vice versa. It was reasoned that where the former would naturally be completed first and the latter would follow thus the interdependence may be broken and the required information declassified to B or estimative.

The preceding changes left three small A class blocks (Figure 5.17) reading from the top left of the DSM:

1. This small block identified a loop between project specific data and the topographical analysis and in reality, that condition may be expected.

2. This iterative block represents the intra-disciplinary decisions that the structural engineer would negotiate when considering frame loads, layouts and foundation types.

3. This iterative block contained two processes of iteration. First, the interrelationship of Finishes and materials requiring information about External walls and cladding from the Elevation drawings and the Elevation drawings requiring a Finishes and materials specification. This was considered an intra-disciplinary issue that would be resolved by the architects. The other was again intra-disciplinary and involved the mechanical designers decision process.

The risk identified by these iterations may now be added to the risk register maintained by the designers.
Chapter Five

The changes to the A class blocks still left the SDPM with a large B class or estimative iterative block that indicated to the research that too broad an estimate of the design issues would be required. This was considered an inadequate result as the research was seeking techniques to improve both the delivery of design solutions and the accuracy of the accompanying cost advice at the end of scheme design.

![Figure 5.17: The DSM after Tearing](image)

The DSM in Figure 5.16 was reviewed again to try to uncover grouped problems that may help break the iteration. It was found that the SDPM had incorporated a cost feedback to advise designers on the development of the cost advice to help guide design choice. Each discipline was also provided with an Estimating plan, so this feedback was reconsidered. It was reasoned that if designers strayed from the commercial strategy then and only then would the cost planners intervene to investigate. If the design process remained within budget, no purpose would be served by the cost feedback. This analysis allowed the B class cost information to be declassified to a C classification significantly reducing the B class
Chapter Five

estimative block from eighty percent of the matrix to thirty six percent (Figure 5.17). The model was now considered suitable for building a project programme and testing.

5.7.5 Testing and Verification
Testing and application of the ADePT methodology to Scheme Design on a real project was not possible during the research period. The process of evaluating the results from the DSM and reviewing the information required by the activities in the model allowed sufficient virtual testing of the generic information requirements to prove the validity of the methodology for scheme design. This work is described in the previous section 5.7.4 where the research uncovered instances of design disciplines exercise a 'wish list' for requirements without considering alternative information sources. In the real world, this leads to the iterative problems that cause delays while priorities are agreed making it even more important to test the validity of the information used in the model.

Designers and principals from AMEC Construction confirmed their approval of the amendments to the information dependencies following DSM analysis. The amendments made to the mechanical and value management issues were accepted. The issues relating to A116 Architectural Design Review required further discussion as architects consider the review process as an essential part of their work on a project. It was argued that the review process might be considered part of the management of design and not essential to providing information to satisfy activities. That information was delivered from elsewhere. It was agreed that the order of work programme facilitated by the DSM did not preclude a review process but in order to provide a solution concentrated on the ideal of unchallenged requirements. The other architectural issues were accepted unchallenged.

Concern was expressed that the DSM might allocate cost planning to a higher order in the design process than the design activity. After checking the model, it was found that only three activities, External Other, Office Furniture and Finishes Cost Estimate featured in this way. When these were investigated on the DSM, it was found that because the information flows were all of C classification PSM32 had conveniently located these activities away from the problematic iterative blocks, as they would have no significant effect on the design. Elsewhere the DSM adequately demonstrated that the costing activities follow the design activities, as would be the case in practice. The argument for declassification of the B class cost information to reduce the large iterative block caused by the cost feedback was accepted.
Chapter Five

It was agreed that the direct link between remaining iterative problems and the risk register promoted an awareness of issues. It was suggested that similar connections between high-risk activities and the risk register for specific projects might improve the project timing or frequency of the risk review process and this should be tested on a real project.

Suggestions were made that further improvements might be possible if the process of simultaneously cost planning with the design activities was conducted where there may be a high risk of exceeding the budget. It was agreed that a project would be sought where the SDPM would be employed to identify the activities of high-risk value requiring early estimates.

5.7.6 Interface between the SDPM and Detail Design

One of the objectives set at the outset of the modelling process was to examine the relationship between the tasks at scheme design and those at detail design. Design is an extremely fluid process; the nature and content will vary with the type of cost advice required and the overall time allowed within the programme of work to achieve fixity. Variables such as whether or not the design process will continue on to the construction stage or the overall complexity of the project can determine at what point scheme design will end and detail design will begin. For this reason suitable interfaces may be required in the models of both scheme and detail design. Discussions were held to establish which components of the respective design models could cross over between the stages and how this may be achieved in information modelling terms. Comparisons were made with the detail design model produced in a parallel research project to find where scheme design and detail design overlap. The first impression from the IDEFO diagrams describing the respective models was that the activities could not be transferred between the models. The diagramming technique did not lend itself to sharing information between the two models and it was not until the respective tables were consulted that a solution became clear.

Initially a table was produced from the detail design model to establish the inputs required from scheme design. It was found that only 6% of the detail design model called for information from scheme design. This was then compared to the activities and deliverables established for scheme design (Table 5.6).

The incompatibility was attributed to the detail design model not having been designed to interface with the earlier scheme design process. The other information inputs into the
Chapter Five

detail design model were either; generated during the detail design process, identified as a client requirement, a regulation or standards, or were to be found in manufacturers data or design guides. These became a given requirement of the process accepting the few cases that were identified as coming from scheme design. An alternative solution to making a direct comparison was therefore required.

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Information Required from</th>
<th>Identified Scheme Design Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 174</td>
<td>Ceilings Finishes</td>
<td>Arch scheme design</td>
<td>A 113 Finishes and Materials</td>
</tr>
<tr>
<td>A 181</td>
<td>Stairs &amp; Ramps Layouts</td>
<td>Arch scheme design</td>
<td>A 1122 Floor Layout Drawings 122</td>
</tr>
<tr>
<td>A 182</td>
<td>Stairs &amp; Ramps Details</td>
<td>Arch scheme design</td>
<td>A 1124 Sections &amp; Details</td>
</tr>
<tr>
<td>A 191</td>
<td>Door Components</td>
<td>Arch scheme design</td>
<td>A 1142 Int Doors &amp; Partitions</td>
</tr>
<tr>
<td>A 192</td>
<td>Screen Components</td>
<td>Arch scheme design</td>
<td>A 1142 Int Doors &amp; Partitions</td>
</tr>
<tr>
<td>A 3 3 111</td>
<td>Primary Structure Frame Analysis</td>
<td>Frame scheme design</td>
<td>A 1243 Skeleton Layout Production</td>
</tr>
<tr>
<td>A 2 2 13</td>
<td>Ground Investigation Reports</td>
<td>Loads from scheme design</td>
<td>A 1222 Foundation Load Cals</td>
</tr>
<tr>
<td>A 4 1 322</td>
<td>Prel Spec Duct Sys Equip Select</td>
<td>Services scheme design</td>
<td>A 1313 Mech Block Layouts</td>
</tr>
<tr>
<td>A 4 2 22</td>
<td>Prel AC / Vent Ductwork Routing</td>
<td>Services scheme design</td>
<td>A 1314 Mech Riser Routes</td>
</tr>
<tr>
<td>A 1 3 11</td>
<td>Basements GA</td>
<td>Struct scheme des: grid</td>
<td>A 125 Floor Design</td>
</tr>
<tr>
<td>A 1 3 12</td>
<td>Ground Floor GA</td>
<td>Struct scheme des: grid</td>
<td>A 125 Floor Design</td>
</tr>
<tr>
<td>A 1 3 13</td>
<td>Upper Floors GA</td>
<td>Struct scheme des: grid</td>
<td>A 125 Floor Design</td>
</tr>
</tbody>
</table>

Table 5.6: Examples of Information Similarities at Scheme & Detail Design

The purpose of IDEF0 modelling is to identify information flow between activities that in turn generates output from the activity; the diagrams are not used beyond that in the ADePT methodology. It is the information contained in the diagram that is used for the DSM when translated into data tables and it is this numeric tabular information that may also be transferred between the models. By examining each activity in the table model, it can be seen that each has a unique name and number, for each piece of information there is a unique name and number. Typically, the activity A1122 Floor Layout Drawings (highlighted in Table: 5.6) consists of twenty-nine unique pieces of information from nineteen different activities. The software developed to prepare the IDEF0 data for the DSM makes use of the unique number and links the unique name to that number. By referring to the number for any information incomplete at the scheme design stage, designers during detail design can identify that information, include it in the DSM analysis, and programme the respective activity as part of the detail design programme. This may also be conducted in reverse when required. Thus in Table 5.6 detail design activities in column two require information from the source in column three so by locating the activity at scheme design shown for example in column five the designer can add to the detail design data all the information required to complete the activity. The only criterion required
to allow this information to be processed through the DSM is to close the loop by providing an activity source for the source of the information required.

At this stage, the incompatibility in the data does not allow both models to be run simultaneously. For practical purposes, the numerical data allows information that is incomplete at either stage to be identified and aligned together with its predecessor activities until the missing information for that stage is made complete. This may be all that is required, as there remains a clear gate between scheme design and detail design (Kagioglou et al 1998) requiring for the time being only that information incomplete at the end of scheme design or the start of detail design be adequately programmed into either model.

5.7.7 Project Outcomes
Trials were made inputting the data into MS Project where it was found that by allocating task predecessors (Figure 5.18) to the tasks order determined by the DSM a project outcome could be determined. The MS Project program is typical of the many project-planning tools available to designers and programming specialists. It was not considered necessary to evaluate programs from other software suppliers as the method of direct pasting the information within a Windows™ environment has become an accepted norm and similar results may be expected from any of the many commercially available programs. Most programming tools are able to allocate a variety of resources and their respective cost to employ. Together with the facility for the design organisation to apply their own estimation of duration in terms of the time designers require producing the design deliverables associated with the design tasks, an accurate programme of work may now be produced for a project at the scheme design stage. An example is provided in Figure 5.19 on the following page.
For the trials a duration of one day was allowed for each of the one hundred and fifty-three tasks, resulting in a scheme design that would last five weeks (Figure 5.19).
5.8 CONCLUSIONS ON MODELLING SCHEME DESIGN

The ADePT techniques provided the procedure that the research was able to follow and adapt when producing the SDPM. This research drew together both conceptual and the recent IDAC 100 (Austin et al 1999) detail design developmental work on ADePT before preparing the model. Identifying the new developments made by this research and acknowledging existing work on which it is based is important if the reader is to differentiate between the two.

The ADePT methodology pioneered by Newton (1995) provided the basic modelling technique that was followed. The methodology used data flow diagrams to describe the flow of information during the detail design process and logic networks to identify the exact interfaces and coordination required between different disciplines.

Austin et al (1999) identified the need to describe cross disciplinary and intra disciplinary information flows and to produce the information dependency table. Their research provided the proprietary software to extract IDEFO data and prepare the inputs into the design structure matrix (DSM) and outputs from both PSM32 and their own AMMP matrix analysis tools into programming software.

This research applied the modified IDEFO notation and showed how external inputs can be used to represent the information required from the client, suppliers and regulatory bodies at early stage design. Working with the IDAC 100 team, modifications were made to the proprietary software to allow these to be input into the design structure matrix.

The modified IDEFOv methodology applied in the SDPM demonstrated the flexibility of IDEFO over DFDs to represent the many types of information employed during early stage design to satisfy design activity requirements and produce design deliverables.

The introduction of cost and risk analysis for the first time with ADePT has shown the potential for the techniques to absorb and analyse the many complex procedures that form part of the design process. It was considered paramount at the beginning of this research to identify how best to improve the quality of information for making cost estimates. This has been achieved by linking the design deliverable to the generation of cost advice such that it is now possible to determine the accuracy of the cost advice by cross referencing the progress on the information dependant deliverables at any point in the process. The SDPM
provides the added benefit of allowing cost planners to better plan their time in relation to the project deliverables.

Where information dependent deliverables either are incomplete through the iterative nature of the design or due to the point in time that the process is put under review an assessment of the project risk can now be made by reference to the SDPM and DSM generated programme information. Risk analysis can now be done accurately in the first case by registering the specific risk to design and cost certainty caused by the identified iteration then secondly by entering the incomplete design deliverables into risk analysis software. Most design organisations maintain risk analysis software that is able to predict the likely outcomes from either or both cases simultaneously. Only now, it is possible to identify precisely which information is in an iterative loop and more accurately identify costs associated to a point in time.

The successful portrayal of the SDPM in a DSM has demonstrated the reorganisation of the design activities into a structured format and answered two of the questions posed at the start of this chapter. Can scheme design be modelled to the degree of accuracy required to plan it? Can the same ADePT modelling techniques be used to model scheme design? The modified ADePT techniques that have been presented in this chapter can accurately model and help to plan the scheme design process.

When preparing the SDPM a key question was whether a model of sufficient generic content for scheme design was possible.

Because early stage building design focuses on the initial development of a design option that has already met with the client requirements the elemental detail required at scheme design requires only that the chosen option prove viable for further development. It is not about the underlying concepts generated to fulfill the objectives of an individual client. That will have been completed during the concept design.

Identifying the key elements for the design option requires designers to examine the developed brief and this is done in a structured manner generally starting with the site conditions and progressing through all the functional and esoteric constituents but at a fairly low level of detail. The level of detail is such that when confirmed to the client they may be sure that it will meet their requirements (BSI 1996). If scheme design follows a set
procedure then it is a generic process and the scheme design model will also be generic? Not quite but nearly.

By theorising over what constitutes a generic model it is possible to conclude that:

- In the case of this particular modelling process and where nothing is added or subtracted either by the SDPM or the DSM from the information input into the model the information is conserved and therefore the modelling process does not affect the question of what is or what is not generic.

- What does affect that question is the quality and completeness of the information that is collected and used to build the SDPM. For the model developed in this research the quality and completeness of the information it contains has been verified as meeting the current requirements at AMEC Construction for a scheme design model considering the design of highly engineered buildings. This still does not make the SDPM generic.

- The research has identified that a generic modelling technique based on the SDPM can be produced but it will require two additional factors. First it must contain all the activities and information flows between activities necessary to produce the design and cost accuracy required for all types of building design. Secondly it must be flexible enough to be implemented by other organisations.

- When a model that meets these requirements is produced it can then be considered to be generic.

The ideal test for the ADePT SDPM would have been on a real project but this was not achieved during the course of the research, because of a shortage of available projects. Instead, a process of virtual testing was conducted by first examining and verifying each stage of the model and the results from the DSM and to uncover any working faults. AMEC designers provided invaluable help and assistance cross-examining the findings before approving the output. Thus, the information and dependencies contained within the activities covered by the model was tested and retested before a generic process pertaining to AMEC Construction could be claimed. The research has demonstrated by attending to the requirements of the disciplines that the ADePT methodology when applied to Scheme Design can produce structured programmes for designers, cost planners and managers. Currently a live project is being sought by AMEC Construction on which to test and apply the revised ADePT methodology for Scheme Design.
Chapter Five

The investigation of the interface between a Detail Design Process Model and the SDPM has demonstrated the possibility of integrating the two stages at their crossover point. The method suggested is able to provide the flexibility desired by designers when differing project requirements need to be addressed. Thus the second two questions presented at the beginning of this chapter may also be answered. It is possible to use parts of the Detail Design Process Model (DDPM) but not to represent the whole of scheme design. The same model cannot be used with differing information classifications. A stage specific model is required because although some similar information is applicable the information will have different levels of detail and different classifications. For instance, smaller scales are applied to drawings and more detail is provided in schedules during detail design.
Chapter Six

VALUE ANALYSIS AND QFD

6.1 INTRODUCTION TO VALUE ANALYSIS AND QFD

During the course of this research, it was established that process models are able to assist the planning of early stage design and improve the management of design information, the deliverables and corresponding cost advice during scheme design. It was argued that the research into developing a SDPM could also help improve understanding and cooperation between designers and stakeholder by setting out the requirements of each party to the design. The process of communication uncovered during the investigative stage of the research between designer and stakeholders presented a major problem to solve. The problem is one of how to assist designers reach agreement with stakeholders when attempting to fix the developed project options.

The initial evaluation of QFD techniques had looked at the potential for using QFD in early stage building design. It was anticipated that outcomes could be directly linked to the activities within the Scheme Design Process Model (SDPM) described in chapter five. During discussions held with AMEC Construction designers, it was agreed that customer requirements originate with a Value Management One (VM₁) value tree and the research might concentrate on the possibility of applying QFD to help evaluate selected parts of the design.

Value Analysis (VA) methods (Section 2.5) were investigated before observing the VM techniques applied by designers to establish stakeholder requirements during the concept study for a new drug development facility for a leading pharmaceutical company. The VM facilitator set out to establish project values by applying VM₁ during the start up meetings where the customer requirements were recorded in terms of objectives. In order to provide additional support to these objectives a brainstorming session was arranged at the end of the VM₁ to identify additional values for consideration. The whole process was recorded and later used to support decisions made by the designers as they prepared several options for presentation to the stakeholders.

The designers and stakeholder study group committed to further investigative meetings to establish spatial arrangements and develop a mutual understanding of requirements but they did not interrogate the original VM₁ values any further. The importance of applying the
second Value Management (VM₂) was also considered by the designers to be secondary to developing options and for this particular design became so delayed as to render the process impractical. It was consequently abandoned in favour of negotiating the final option based on the practicalities of the site. The observation drawn from this experience was that the design was not conducted in a clearly auditable manner and relied on the autocracy of the senior client representative and his relationship with the designers to drive the design solution. Later in the design problems evolved where stakeholders refused to sign off the developed option as meeting their requirements after observing the collusion at the project management level. This caused several months delay to the project as an independent advisor was sought to confront the many unresolved issues.

It was reasoned that a more systematic approach was required to help improve the communication of project deliverables in relation to stakeholder requirements as the design evolves.

The first of the original research objectives was to investigate current briefing methods in other engineering industries in order to identify techniques that could improve best practice in the construction industry. Quality Function Deployment (QFD) (Section 2.5.3) was identified as an underdeveloped technique in the construction industry. It may be considered as a part of a suite of VA tools because QFD questions the impact of the voice of the customer on the process of design and delivers a measurable response to qualitative requirements. This chapter describes QFD and how a variety of QFD proposals were developed with the cooperation of AMEC Construction designers to help resolve some of the problems experienced.

6.2 QFD AND THE HOUSE OF QUALITY

6.2.1 The House of Quality in Detail

Hauser and Clausing (1988) described the QFD as the House of Quality, a conceptual map that provides the means of inter-functional planning and communications. They showed how people with problems and responsibilities could prioritise them while referring to patterns of evidence on the house's grid. They used the design of a car door to demonstrate this process. Clausing (1994) and Cohen (1995) expanded on these principles. In Figure 6.1, the House of Quality schematic describes the functionality of the House of Quality.
Chapter Six

Each of the numbered elements is described as rooms. Room 1 contains the voice of the customer in terms of attributes or needs and desires in the customer’s own language. This section may also be split into primary secondary and tertiary elements to further refine the attributes. The attributes in Room 1 are classified as the *Whats*. Room 2 contains the *Hows*, these are in the organisation’s technical language and are normally generated from the needs and desires in Room 1.

In order to overcome any translation difficulties from the customer language to the design organisation’s technical language the House of Quality has a relationship matrix in Room 3. Both *Whats* and *Hows* are then benchmarked in Rooms 4 and 5 respectively. Room 4 is used to compare the customer’s own product with that of a competitor and may include computations for rank ordering of the customer needs and desires. In Room 5 the design team may plot their technical response in terms of targets or priorities. Both sets of benchmarks are then compared and adjusted for consistency.

![Figure 6.1: The House of Quality Schematic (Clausing 1994)](image)

The attic of the house may be used to isolate any conflict of interest within the *Hows* (Room 2) and it allows the design team to inspect their specifications for interference or
reinforcement. This interaction analysis is best described (Bicknell & Bicknell 1995) if the following question is asked: "If I try to improve this parameter or operation will it have a positive or negative effect on something else I am trying to control?"

In Room 7, at the bottom of the House of Quality all the data is collated. Weightings from each technical expectation in the relationship matrix are joined with the values derived from within Room 4. Finally, in Room 8 these values are quantified in relation to the benchmarks given in Room 5.

6.2.2 The Four Phases of QFD

The "Four Phase" model (Section 2.5.4) is a process for driving the customer voice through an organisation while simultaneously facilitating improvements at four distinct phases.

Each of the phases assembles critical information that forms the basis for the next phase. This act of bringing key information from one phase's chart to the next phase's chart is called "Phase Progression" (Figure 6.2).

![Figure 6.2: An Example of Phase Progression](image)

The most important *Hows* or, those most difficult to accomplish are selected from the chart and brought into the next chart as the *Whats* for that phase. This continues until each objective is refined to an actionable level.

According to Cohen (1995) the four phases of QFD are described as follows:
Chapter Six

Phase I - Planning
This initial phase uses the chart that is often referred to as the House of Quality because of its appearance to capture the "Voice of the Customer". To translate that "Voice" into measures (Design Requirements) that reflect, in a technical language, the customer's needs and desires.

This phase can also be used to help teams make decisions about what the focus for their project will be. Essential outcomes of a Phase I study include:

- Identification of Customer Requirements.
- Determination of Competitive Opportunities.
- Determining Design Requirements.
- Determining Target Values.
- Determine Requirements for Further Study.

Phase II - Design Deployment
Phase II can be used to establish the optimum materials and design. This is accomplished by taking selected Design Requirements from Phase I and incorporating them onto the Phase II chart as What's. The Hows of Design Deployment are Part Characteristics. Key outcomes of a Phase II study include:

- Identification of the best design concept.
- Determination of critical parts.
- Determination of critical part characteristics.
- Determination of items for further development.

Phase III - Process Planning
Phase III is used to establish the optimum process set-up to produce the design determined in Phase II. This is accomplished by transferring the Part Characteristics of Phase II onto the Phase III chart as What's. Process Parameters are established as the Hows of this phase to assist the team in optimising the best process. Key outcomes of a Phase III study include:
Chapter Six

- Determination of the best process/design combination.
- Determination of the critical process parameters.
- Establishment of process parameters and target values.
- Determination of items for further development.

Phase IV - Production Planning

Phase IV is used to establish the systems that need to be implemented to support the processes selected in Phase III. The Phase IV chart is created the same way the previous charts were. Selected Process Parameters are transferred from the Process Planning chart onto the Phase IV chart as the Whats. The Hows of Production Planning is established for areas such as quality control, maintenance, and training. Key outcomes of a Phase IV study include:

- Evaluation of process operations to be for achieved.
- Establishment of production planning requirements.

6.3 QFD METHODOLOGY

6.3.1 Developing Concepts for Building Design

The purpose of this part of the research was to use Quality Function Deployment concepts and generate techniques in the form of solutions that designers could apply during early stage building design to improve interaction with their customers. The research combined three stages of previous QFD application from both construction related and other industries and applied them to specific problems.

After first reviewing QFD as applied in engineering for the evaluation of customer requirements (Clausing 1994) a methodology emerged that would allow similar techniques to be deployed during the early stages of building design. Huovila et al (1995) had shown how they assessed the customer requirements and Kamara et al (1997) had described a method for translating the voice of the client into solution neutral design specifications. By employing these three QFD techniques combined with the four phases of QFD (Section 6.2.2), outcomes to enable designers to quantify and qualify customer requirements and design characteristics were examined by AMEC Construction designers and evaluated for use on future projects.
Chapter Six

Table 6.1 outlines the stages used to develop appropriate QFD tools for early stage design.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Task</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>To synthesise QFD methods and to explore their applicability to early stage design.</td>
<td>A QFD technique to analyse customer requirements against the design.</td>
</tr>
<tr>
<td>2.</td>
<td>Discuss developed QFD technique with AMEC Construction designers.</td>
<td>Uncover the requirement for a case specific model.</td>
</tr>
<tr>
<td>3.</td>
<td>Prepare a case specific model for a roof light and present to AMEC Construction designers.</td>
<td>A developed method for identifying key design philosophy.</td>
</tr>
<tr>
<td>4.</td>
<td>Strip out numeric elements and reduce the QFD diagrams and test with AMEC Construction value engineers.</td>
<td>A QFD solution for value engineers.</td>
</tr>
</tbody>
</table>

Table 6.1: Development Stages for the QFD tools

The series of QFD variants proposed during stages 1 - 4 (Table: 6.1) were each refined in the light of comments made by AMEC Construction. Each of the variants has a number of phases and these are described in sections 6.3.2 to 6.3.5.

6.3.2 Stage 1 Development of Basic QFD Techniques

The initial development of QFD techniques reviewed how the basic House of Quality might assist designers to reach agreement over problems where no particular consensus was achieved during the brief consultation period at concept design stage. A QFD exercise was conducted using workstation design as an example. During the concept study for the new pharmaceutical research complex (Chapter 4) workstation issues discussed included:

- Location of workstations in relation to laboratories.
- Accessibility of workstations in relation to conducting experiments in sterile areas.
Chapter Six

- Whether they should be open plan or closed to provide privacy when writing up experiments.
- Whether or not they should be shared across the different science disciplines using the facility.

The procedure explored by the research and results from stage one, which provided a basis for further discussion, are outlined below.

**Stage 1 QFD Procedure**

Prepare a House of Quality *Whats* table based on an adaptation of the example and formulae developed by Kamara et al (1997) for the customer requirements using the tertiary levels of a VM1 value tree to highlight specific requirements (Table 6.2).

<table>
<thead>
<tr>
<th>Customer Requirements (What's)</th>
<th>Absolute Weight (AW)</th>
<th>Relative Weights (RW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Provide for Flexibility</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>B Allow Future Expansion</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>C Provide for Personal Flexibility</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>D Comfortable Working Area</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>E Maximise Daylight</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>F Improve Reception</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>G Reliable</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>H Maintainable</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>I Convenient Services</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>J Provide for Working out of Hours</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>K Facilities for Exchange of Ideas</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>L Increase Interpersonal Interaction</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>M Adjacencies of Facilities</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>N Efficient Functional Interaction</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>O Optimise Three Disciplines Interaction</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>P Ensure Visibility of Interaction</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Q Perceived Openness</td>
<td>16</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 6.2: Evaluations of Customer Requirements

In the absence of customer attributed values the research employed the pairwise comparison technique from the Analytical Hierarchy Process (AHP) developed by Thomas L Saaty (Cohen 1995). The AHP provides a fundamental scale that reflects the relative strengths and feelings and provides a multi-criteria decision making process for planning and resource allocation (Saaty 1988). This technique provided the absolute (AW) and relative (RW) weights for the requirements (Table 6.2). The pairwise comparison technique is shown in Table 6.3, the score of the absolute weights (AW) for each
requirement is given based on its scored importance to a series of paired requirements. This is calculated by adding together the importance \( i \)th from the pairwise table thus:

\[
H = 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 = 8
\]

The relative weights \((RW_i)\) are calculated by:

\[
RW_i = \left(\frac{AW_i}{AW_{\text{max}}} \right) \times 10.
\]

The voice of the designer can now be considered. A list of design attributes (Table 6.4), the quality characteristics used to express the voice of the designer were generated from generic design terms (Kamara et al 1997) using BS7643 parts 1.2 & 3 (BSI 1993). They provide the design \emph{hows} in the House of Quality (Figure 6.3). Some designers may wish to use other terms to define these attributes but wherever possible standard terminology that can be understood by all members of their multidisciplinary design team is recommended.

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>P</th>
<th>Q</th>
<th>Absolute Relative Weight</th>
<th>Weight (AWi) (RWi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>C-3</td>
<td>D-3</td>
<td>E-B</td>
<td>B-F</td>
<td>G-B</td>
<td>H-3</td>
<td>D-K</td>
<td>L-3</td>
<td>B-M</td>
<td>N-2</td>
<td>O-3</td>
<td>P-2</td>
<td>Q-2</td>
<td>11</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>D-C</td>
<td>C-2</td>
<td>C-3</td>
<td>C-4</td>
<td>L-2</td>
<td>J-3</td>
<td>C-KC-2</td>
<td>C-2</td>
<td>C-NO-2</td>
<td>B-P</td>
<td>Q-2</td>
<td>21</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>E-D-3</td>
<td>D-GH-1</td>
<td>D-JK</td>
<td>L-1</td>
<td>D-3</td>
<td>D-NO</td>
<td>L-1</td>
<td>D-DO</td>
<td>Q-2</td>
<td>22</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>F-E-3</td>
<td>G-E-3</td>
<td>E-J-4</td>
<td>K-3</td>
<td>L-3</td>
<td>M-1</td>
<td>N-2</td>
<td>O-4</td>
<td>P-1</td>
<td>E-Q</td>
<td>16</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>G-F-2</td>
<td>F-J-3</td>
<td>K-2</td>
<td>F-MM-2</td>
<td>F-N</td>
<td>O-3</td>
<td>P-1</td>
<td>Q-2</td>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>H-12</td>
<td>O-JK</td>
<td>L-2</td>
<td>G-MG-NO-2</td>
<td>G-PG</td>
<td>Q-2</td>
<td>10</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>I-2</td>
<td>K-2</td>
<td>L-2</td>
<td>H-MH-NO-2</td>
<td>H-PH</td>
<td>Q-2</td>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>J-L</td>
<td>K-1</td>
<td>2-1</td>
<td>L-3</td>
<td>L-N</td>
<td>O-1</td>
<td>I-3</td>
<td>J-2</td>
<td>1-1</td>
<td>13</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Importance</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Strong</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Strong</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak or Equal</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.3: The Pairwise Table

<table>
<thead>
<tr>
<th>Quality of Finish to External Envelope</th>
<th>Supply of Fresh Air for Occupants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Architectural Expression</td>
<td>Dry-bulb Air Temperature</td>
</tr>
<tr>
<td>Number of Access Points</td>
<td>Wet-bulb Air Temperature</td>
</tr>
<tr>
<td>Control &amp; Operation of Lighting &amp; HVAC</td>
<td>Mean Radiant Temperatures</td>
</tr>
<tr>
<td>Function of Spaces</td>
<td>Air Velocity</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>Operative Temperature</td>
</tr>
<tr>
<td>Indoor Lighting</td>
<td>Sound Pressure Levels</td>
</tr>
<tr>
<td>Definition of Spaces</td>
<td>Airborne Sound Transmission</td>
</tr>
<tr>
<td>Relationship Between Spaces</td>
<td>Impact Sound Transmission</td>
</tr>
<tr>
<td>Reverberation Time Within Spaces</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.4: The List of Design Attributes (adapted from Kamara et al 1997)
Chapter Six

The relationship matrix in House of Quality (Figure 6.3) is used to formulate the how importance using 9, 3 and 1 to denote strong, medium and weak relationships respectively for the design attributes (d). The absolute weight (AW_di) is given by:

\[ AW_{di} = \sum (RW_n \times S_{nd}) \]

RW_n is the relative weight of each customer requirement.

S_{nd} represents the strength of the value relationship between the customer requirement and the design attribute.

Thus for the Absolute Weight of No. 19 Impact of Sound Transmission:

\[ AW_{di} = [(7 \times 1) + (8 \times 9) + (3 \times 3) + (10 \times 1) + (8 \times 1) + (3 \times 3) + (7 \times 9) + (10 \times 1)] \]

\[ AW_{di} = 188 \]

This is repeated for each of the design attributes until all their absolute weights have been calculated.
To determine the relative weight of each design attribute \( (RW_{di}) \) the highest absolute value is given a grade of 10 and the others are calculated proportionally.

For the Relative Weight of No. 19 Impact of Sound Transmission where the absolute weight is 188:

\[
RW_{di} = \frac{AW_{di}}{AW_{di, sum}} \times 100
\]

\[
RW_{di} = \frac{188}{4092} \times 100 = 4.6
\]

A prioritised table can now be produced (Table 6.5) that may be used to guide the design process to provide design effort into areas likely to provide enhanced customer satisfaction.
Chapter Six

<table>
<thead>
<tr>
<th>Design Attribute</th>
<th>RW&lt;sub&gt;d&lt;/sub&gt;</th>
<th>Design Attribute</th>
<th>RW&lt;sub&gt;d&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship Between Spaces</td>
<td>11.7</td>
<td>Mean Radiant Temperatures</td>
<td>4.0</td>
</tr>
<tr>
<td>Function of Spaces</td>
<td>11.2</td>
<td>Reverberation Time etc.</td>
<td>3.9</td>
</tr>
<tr>
<td>Definition of Spaces</td>
<td>10</td>
<td>Number of Access Points</td>
<td>3.7</td>
</tr>
<tr>
<td>Indoor Lighting</td>
<td>9.1</td>
<td>Dry-bulb Air Temperature</td>
<td>3.6</td>
</tr>
<tr>
<td>Ctrl &amp; Op of Lighting &amp; HVAC</td>
<td>8.9</td>
<td>Wet-bulb Air Temperature</td>
<td>3.6</td>
</tr>
<tr>
<td>Supply of Air for Occupants</td>
<td>5.1</td>
<td>Strong Architectural Expression</td>
<td>2.9</td>
</tr>
<tr>
<td>Sound Pressure Levels</td>
<td>4.9</td>
<td>Energy Consumption</td>
<td>2.1</td>
</tr>
<tr>
<td>Airborne Sound Transmission</td>
<td>4.6</td>
<td>Air Velocity</td>
<td>1.2</td>
</tr>
<tr>
<td>Impact Sound Transmission</td>
<td>4.6</td>
<td>Quality Finish to Ext Envelope</td>
<td>1.0</td>
</tr>
<tr>
<td>Operative Temperature</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.5: Prioritised Relative Weights for Design Attributes

The next part of the procedure is to use a second phase QFD (Figure 6.4) to identify the activities from the SDPM most appropriate for dealing with the specific design attributes highlighted in the first stage analysis.

The analysed design attributes are transposed and rounded up to become the prioritised what's and a second matrix for analysing design activities is prepared. Only the higher value design attributes are used for this example.

A wide range of information can now be generated from the Scheme Design Process Model (SDPM) described in chapter five. Prioritising activities (Table 6.6) according to the discipline most affected during workstation design may help concentrate design effort.

<table>
<thead>
<tr>
<th>Design Activity</th>
<th>RW&lt;sub&gt;a&lt;/sub&gt;</th>
<th>Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Doors &amp; Partitions Design</td>
<td>19.7</td>
<td>Architectural</td>
</tr>
<tr>
<td>Mechanical System Design</td>
<td>13.6</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Superstructure Int. Cost Estimate</td>
<td>12.2</td>
<td>Cost Planner</td>
</tr>
<tr>
<td>Electrical Systems Design</td>
<td>12.2</td>
<td>Electrical</td>
</tr>
<tr>
<td>Finishes and Materials Design</td>
<td>10.2</td>
<td>Architectural</td>
</tr>
</tbody>
</table>

Table 6.6: Workstation Design Activities and Relative Weightings
Figure 6.4: The QFD of Design Activity Relationships for Workstations

Design deliverables generated by design activities can now be identified from the SDPM (Table 6.7) this may help with understanding how for instance decisions about the design of the workstation will affect other parts of the project.

<table>
<thead>
<tr>
<th>Design Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal door schedule</td>
</tr>
<tr>
<td>Quotes for plant</td>
</tr>
<tr>
<td>Mechanical scheme design</td>
</tr>
<tr>
<td>Mechanical plant weights</td>
</tr>
<tr>
<td>Mechanical system information</td>
</tr>
<tr>
<td>Internal walls &amp; partition cost information</td>
</tr>
<tr>
<td>Electrical scheme design</td>
</tr>
<tr>
<td>Electrical system information</td>
</tr>
<tr>
<td>Wall floor &amp; ceiling finishes schedule</td>
</tr>
<tr>
<td>Finishes and material specification</td>
</tr>
</tbody>
</table>

Table 6.7: Design Deliverables for the Workstation Analysis
Chapter Six

Stage 1 Outcomes

The research example has demonstrated how the processing of clients requirements can assist the design team relate to the voice of the client on their terms. The information is generated in a clear and auditable form and may be presented back to the client or to the intra-disciplinary design team at design review meetings to underwrite design philosophy.

The application of the QFD technique has prioritised the design attributes (Table 6.5). It identifies a requirement to reach agreement in order of that priority. The information is directly linked to the customer requirements from the value tree created during VM1. From Table 6.5 it was clear that relationship, function, and definition of spaces together with environmental issues formed a priority for designers to address when making decisions on workstation location.

The QFD identifies the principal design activities associated with a particular element of the design (Table 6.6). These activities will be affected until decisions are made and an order of priority is generated to help with the decision-making process.

The AHP pairwise table was found to be a suitable solution for manipulating the data for the House of Quality in this example. Where it is intended to implement this or similar processes on a live project numerical data will have been kept from the VM1 and form part of a data archive for the project.

From the Scheme Design Process Model a list of the design deliverables likely to be affected have been identified (Table 6.7). In addition, a list of information flows may be generated to display information that is both constrained and determined by the affected activities. Information from the SDPM will indicate the potential impact workstation decision-making has on other elements of the design within the project.

Why does this information help the design process?

- An audit of intra-disciplinary requirements for workstations has been made.
- The technique provides a visual prioritisation of issues for meeting agenda.
- Team members including client representatives get to share ownership of the problem solving analysis.
Can these responses be achieved elsewhere?

- Whenever difficult decision need to be made that involve many factors, applying QFD provides a single process tool to numerically advise design thinking.

- QFD may be considered as a part of a suite of Value Analysis (VA) techniques. Where VA and in particular Value Engineering (VE) uses relationship matrices to analyse functional requirements in terms of client value criteria and design value criteria, QFD questions the impact of the voice of the customer on the process of design.

6.3.3 Stage 2 of the QFD Development

A meeting was arranged with AMEC Construction designers to present the first stage of the QFD development. The director of design and a director of architecture attended the meeting. The process was explained stage by stage and a critical response sought. It was agreed that the QFD proposal demonstrated its applicability during early stage design but that it would need further development if it were to be applied in a way that would add value to existing VA techniques.

Significant issues uncovered during the meeting:

- Concern was raised over mixing up the natural design process with having achieved a solution and then testing it with QFD.

- Once you have undertaken the design you need a technique to check the design impact against customer needs.

- Key design philosophy statements help to define for architects the softer elements in architecture as those are the ones that are attacked when they are not seen as objectives.

- In addition to issues of functionality, designers need a method of confirming design vision and the key design philosophies that make the whole thing work.

- It was claimed that the current VM process is inadequate because the process stops at VM2 after the client chooses his preferred options. Leaving too many non-negotiated decisions that project managers, scope cutting or cost cutting specialists feel able to attack because they fall out of the remit of the negotiated values. A process to record the development of significant design decisions and explain their significance at a
further VM meeting was desired. The QFD methodology was seen as a potential aid to this process.

- A roof light (Section 6.3.4) issue that AMEC Construction experienced on the pharmaceutical building design presented designers with a problem they intend to resolve in the future within a VM process. The research was asked to investigate to see if QFD could help with this type of issue and a proposal was made to test the methodology using the roof light case as an example.

6.3.4 Stage 3 QFD: Using the Roof Light Case Study

During the second QFD meeting with AMEC Construction designers and the head of cost planning, two interrelated design management problems were given:

1. “At design review meetings you may ask the architect to justify why they have made a particular decision and you get this ‘well it just feels right’ type of answer. You may have a way of identifying why they have come up with that conclusion that is not the issue. Providing justification that the solution is correct so that it may be supported to the client by others design professionals is the problem”.

2. “At a client review meeting you do not call the value engineer in because it is we that are cutting scope; roof light comes up in a big long list of items. When going through the list the client states ‘we do not want a roof light really I will have that £20,000 saving, next. Then what happens when this is explained to the designers, you find that the roof light is fundamental to the quality of the space and environment in that central atria/entrance”.

The roof light in question was part of the roof system in a full height polygonal adjacency that was designed as an entrance to the research building. It is glazed on two sides with a rear shear wall clad in brickwork to match the main structure. In addition to the light qualities provided by the glass walls, a roof-light was added on one side to provide borrowed light to the workstations and write-up areas in the adjoining main building. The whole provided light to the architectural qualities of tubular steel columns, glass enclosed open tread steel stair well, with surrounding meeting areas. The building addressed corporate image and the light airy feel required by the stakeholders for their building entrance. It transpired that the way the natural light washes down the wall etc was essential to the design. The commercial managers were not aware of the aesthetic implication that
their decision would have on the design. Nor that it would incur further issues for the designers to resolve negating the commercial saving.

As a decision tracking mechanism, QFD can assist in identifying how solutions are achieved. Pugh (1990) and Clausing (1994) suggest that benchmarking within the QFD methodology is able to deliver this function. The research so far has reviewed only a small part of the QFD methodology. The second QFD exercise would explore the full House of Quality. A QFD of the roof light element was prepared to support key design philosophy statements at design review meetings that might better inform project participants and improve communication of design solutions. It addresses customer requirements and provides:

- A quantitative response to a qualitative requirement at each of the four phases of QFD.
- QFD diagrams that generate data support for the design requirements.
- Qualification and evaluates the validity for the requirement of a roof light within the design.

Stage 3 QFD Procedure

The methodology provides a series QFD diagrams adopting the full House of Quality Schematic (Clausing 1994) so that a supportive case may be built up for the design. Four QFD analyses were made each taking established and weighted arguments from the previous. This analysis followed the four phases of QFD (Section 6.2.1) the content in terms of whats and hows is listed in Table 6.5.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Figure</th>
<th>Whats</th>
<th>Hows</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>6.5:</td>
<td>Customer Requirements</td>
<td>Quality Characteristics</td>
</tr>
<tr>
<td>Two</td>
<td>6.6:</td>
<td>Quality Characteristics</td>
<td>Design Concept One</td>
</tr>
<tr>
<td>Three</td>
<td>6.7:</td>
<td>Design Concept One</td>
<td>Design Characteristics</td>
</tr>
<tr>
<td>Four</td>
<td>6.8:</td>
<td>Design Characteristics</td>
<td>Design Process</td>
</tr>
</tbody>
</table>

Table 6.5: The Four Phases of QFD Analysis for the Roof Light
Chapter Six

Customer Requirements - Quality Characteristics

The customer requirements or 'whats' (Figure 6.5) were taken directly from the secondary level of the VM₁ value tree generated by stakeholders for the project instead of using the pairwise table from the previous example. During VM₁, these values are given a weighting by the stakeholders as part of the concept study and are used to provide the values for the client importance rating. (Italics in the text highlight the QFD component headings in the Figures 6.5 - 6.8).

The voice of the customer for the new building was further assessed on a scale of 1-5 where five is best against the current status of the client’s existing facility. For the exercise the author has estimated this and the facilities of the client’s immediate competitors, competitor x and competitor y. In practice, these values will be discussed with the high level stakeholders. Following this assessment a proposal is made in terms of a plan. The plan is based on the competitor rating (benchmarking) or on what is considered a reasonable compromise in order to meet the stakeholder expectations. Dividing the plan by the current status provides a ratio of improvement. To this is added a sales point, which is a simple factor i.e. high, medium or low used to represent value in terms of competitive advantage. This would also be applied by the high level stakeholders and may represent value in terms of attracting staff or as providing product prestige, corporate image etc.

The client importance, the ratio of improvement and the sales point are multiplied together to determine an absolute weight for the customer requirement. This process is common to each of the phases of QFD used in this analysis. To help the reader a legend is provided with each diagram (Figures 6.5 – 6.8).
Next part of the QFD process is to determine the quality characteristics or design hows. Bicknell and Bicknell (1995) suggested that these technical requirements could be developed through a brainstorming session with a multifunctional team to create a hierarchy diagram; this may then be transferred to a relationship matrix. The design how's were prepared by looking through a brainstormed list of attributes and selecting those characteristics most applicable to a roof light over a full height entrance foyer. Both designers and stakeholders in the study group created the list at the time of the VM. The idea being that if the designers can control the delivery of these quality characteristics then it should also allow them to meet the customer objectives. The level of control is assessed with the relationship matrix where the matrix weights are multiplied with the absolute weights from the voice of the customer and summed for each of the quality characteristics.
Chapter Six

to provide a measure of *how importance*. The *relative importance* values from these summaries are carried forward as the *design importance* when the quality characteristics are assessed against the design concept in the next House of Quality.

The roof of the House of Quality is a simple matrix that allows the designer to assess the *how's* for their technical interactions with each other and may be used as an aid to establish where an improvement to one *target value* can impact on another. This can also assist designers in multi-disciplinary teams to identify features that need to be addressed collaterally. The roof may for instance identify a particular feature that has an impact on so many of the others that it promotes a decision to leave it unaltered. Using the term's strong positive through to weak negative to qualify relationships can also identify where negative relationships can be traded off to find the best compromise and strong positive relationships may be studied to prevent duplication of effort.

Beneath the relative importance values at the bottom of the House of Quality is space to assign the specific *target values* for as many requirements as possible. These values have been abbreviated in the examples given; in practice, a range of goals may be defined for the designers and engineers or targets established for further studies and analysis. Clearly there may be a list of targets and these can be formulated on additional tables with reference to the respective *how* characteristic. Below the target values is a competitive rating on a scale of 1-5 where 5 is best, to identify how well the designer or the competition are capable of meeting the technical requirements. The competitive rating may also be carried forward to the next House of Quality where it will help determine the importance or relative weights in the same way as the *client importance* in Figure 6.5. The final element in the House of Quality is a *concept evaluation*, which provides a visual indication of how well the concept being evaluated meets the technical requirement.

**Phase One Analysis**

**Figure 6.5** - Indicates that the *quality characteristics* (*hows*) in columns 1, 9, 8, 11, 4 and 12 in that order of scoring that could best satisfy the *customer requirements*.

The quality characteristics from columns 2, 3 and 13 form the main aesthetic criteria supporting the roof light architecturally. A review of the *concept evaluation* supports this.
Further information on the quality characteristics is given with the technical interactions in the roof of the House of Quality. For example, an open plan culture will have a strong positive effect on easy access through the building. Some target values have been given for the quality characteristics and these may be enlarged upon separately to detail how the quality characteristics can best fulfil the customer requirements.

In our capability and competitor x and y analysis the data was estimated by the author. These parts of the House of Quality allow the designer to estimate their capability to meet the target values or deliver an appropriate solution. It may also indicate where they expect to outsource a particular design solution.

Design reports could to make reference the QFD diagrams and the diagrams can be marked to reference where further qualification is required.

**Phase Two Analysis**

Figure 6.6 – Demonstrates how the concept of a roof light may be evaluated against the quality characteristics developed in phase one (Figure 6.5). An evaluation could have been made against not having a roof light but that would be contrary to the purpose of making this evaluation. It is not to test the designer but to qualify and then quantify the designer’s solution by using a systematic review process that is accessible to non-designers.

The quality characteristics (hows) from phase one (Figure 6.5) are introduced as the what’s in the rows of Figure 6.6 and given a design importance from the relative importance values from phase one.

The quality characteristics do not necessarily describe how the designer has determined they can best deliver the customer requirements when detailing the roof light for the entrance area. Instead, this is a reflection of the strength of technical requirements needed to satisfy customer requirements.
Chapter Six

What is significant is the cluster of connections in the correlation matrix for the quality characteristics in rows 1, 2, 3 and 13. These relate directly to the aesthetic qualities that a roof light was conceived to provide for the design.

The design hows in Figure 6.6 describe the qualities of the entrance and for this exercise they are taken from the authors observations of a presentation perspective provided by the designers of the building. They represent the aesthetic and practical detail of the building.

The how importance of columns 3, 5, 8, 9 and 10 score highest as elements chosen for the building entrance, with the other design hows scoring significantly lower. The target values from this study provide starting points that can later be revised following detailed analysis.
Chapter Six

The *our capability* section, provides an illustration of how QFD could show whether designers have confidence that the elements can be detailed ‘in-house’ or given to another design studio for detailing.

**Phase Three Analysis**

Figure 6.7 takes the design concept *hows* from Figure 6.6 and expresses them as *whats* so that the design concept may be analysed against specific, quantified design characteristic targets from BS7643 (BSI 1993) or other appropriate standards (Section 6.3.1).

![Figure 6.7: House of Quality Design Characteristics Evaluation](image)

The relationship matrix is completed as before and the *how importance* in this QFD phase identifies the design characteristics that may benefit from further development. The QFD
has moved on from direct evaluation of customer values, phase three evaluates the concept functions developed from the quality characteristics with the design characteristics that qualify the standards to be deployed. It allows designers to set targets that directly relate to the concept.

As the QFD is now dealing with design characteristics it may be argued that Figure 6.7 neither supports nor rejects the roof light concept, instead it takes the conceptual elements and provides quantifiable qualities for the designers to address. The target values have changed from ideals to statutory or regulatory standards. The technical interactions in the roof of the House of Quality start to identify potential iterative design problems.

It may be seen in Figure 6.7 where the now clearly identifiable design disciplines impact upon one another. For instance the strong negative interaction of number of access points and the control and operation of lighting and HVAC could indicate that the engineers require information from architects before they qualify the design parameters.

Additional information is provided by the concept evaluation which suggests in this phase how well the design characteristics meet the concept requirements and the sales point in the voice of the designer may help focus the designers and managers on element of higher stakeholder requirement.

**Phase Four Analysis**

In Figure 6.8, the design characteristics from phase three are transposed as whats and can now be viewed in relation to the process operations from the Scheme Design Process Model (SDPM activities). These activities determine the deliverables at scheme design and the how importance values can provide an indication of how these deliverables may be affected when designing the roof light. When the SDPM activities are correlated in the relationship matrix against the design characteristics a pattern emerges. This pattern indicates the importance of the deliverables listed in the target values and in the example also indicates that the higher relative importance activities relate to architectural issues.
Figure 6.8: House of Quality Evaluation of Design Activities.

The technical interaction in the roof of the House of Quality provides early recognition where change to one target deliverable may affect another. It may be possible to correlate the strength of the technical interaction and identify where design iteration is to be expected.

**Stage 3 Outcomes**

The QFD in this exercise provided a clearer picture of the component decisions used by the designer. Systematically it looks at customer requirements, quality characteristics, a design concept, the design characteristics and the design processes involved in order to present a measurable response for the roof light solution.
Chapter Six

It has attempted to neither vindicate nor deny the merit of using this building component instead it has put values to what may otherwise have remained feelings. The method employed will require further refinement and validation by the design team but in broad principle, it has demonstrated that the process of QFD primarily used in the manufacturing domain can be applied to the building design process.

Initial Assessment

A further meeting was arranged with AMEC Construction designers and value engineers to review the QFD proposal. Designers and specialists involved in value analysis and cost planning were invited to comment and discuss the outcome of the research.

It was established that the QFD roof light proposal provided data that helped designers prepare design statements but that its format would not translate to stakeholders at review meetings due to its complex numerical content. However, designers were satisfied that it was able to provide an audit of the process that might be used in support of design statements that could be presented to the client.

If QFD were to be employed to identify the key characteristics of a design to the stakeholders, a simplified version that non-designers could understand was needed. The following parameters were suggested:

- Existing VA methods were considered suitable during the earlier brief taking stage but value managers required a tool such as QFD that could be used after VM and before the VE process.

- Designers were considering a further value management exercise to address the problem in agreeing clear targets from the options determined during the VM2 this could employ QFD techniques.

- The tool should assess the customer values agreed during the VM2 against the systems developed for and within the new building.

- One of the QFD stages should address the conflicts between design elements using the roof of the House of Quality.
6.3.5 Stage 4 QFD and Value Management

As part of the VA process, (Section 2.5.2) AMEC Construction conduct value management (VM1) initially to help develop a dialogue between designers and stakeholders as the brief is taken. The process provides a discussion about values and a value tree is developed. The designers will then provide a glossary of terms to the stakeholders to further assist them to understand the information that the designers have established during this process. The designers will constantly refer to the value tree to test their response to the stakeholder requirements as design options are produced.

When the options have been sufficiently developed a second value management is conducted (VM2) this will use a numerical technique as a basis for the discussion when three or four options and a series of criteria are presented to the stakeholders. At this point, the designers are trying to establish if and why an option meets a particular criterion. The designers find that what is missing when discussing these options is a way to explain to everybody why that concept option meets that set of criteria.

The QFD House of Quality was seen as a method for displaying the refined options and a procedure was discussed to facilitate this. An outline based on that discussion was prepared (Figure 6.9). The following terms are used:

Building: - The building contains the systems that have been developed following the VM2 thus the process starts by reviewing the building in terms of the stakeholder perception. From a CAD or physical model, the client is asked whether it meets with their expectations. The targets may be listed separately if required.

System: - The building system contains the elements that may or may not need further discussion. These are listed in the How's of the QFD House of Quality and the relationships to the client values are discussed. Targets here may introduce specific requirements that relate to the developed design.

Elements: - When further refinement is required, individual components can be discussed.

The fourth stage of the QFD development is aimed at dealing with those elements or components of the design where the stakeholders feel uncomfortable or unsure about their
current development. It will provide a further forum to debate the design before fixing and agreeing the overall scheme proposal.

Lists of Building Systems, Building Elements and Building Components have been suggested (Tables 6.6 & 6.7) as examples of typical Hows for the respective houses of quality. It is expected that eventually a standardised classification system such as UNICLASS (RIBA (1997)) will be used to compile the building systems analysis tables.

UNICLASS is a new system of classification for the construction industry published by the RIBA; it includes all the topics covered by CI/SfB, CAWS (Common Arrangement of Work Sections for building works) and EPIC (Electronic Product Information Co-operation) and addresses the weaknesses of existing systems by introducing new tables and expanded listings. It is intended to supersede CI/SfB, which was last revised in 1976.
Chapter Six

<table>
<thead>
<tr>
<th>Roof System</th>
<th>Exterior Wall System</th>
<th>Elements of Vertical Circulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Finish</td>
<td>Exterior Finish</td>
<td>External Finish</td>
</tr>
<tr>
<td>Structure</td>
<td>Structure</td>
<td>Structure</td>
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<tr>
<td>Ceiling</td>
<td>Interior Finish</td>
<td>Interior Finish</td>
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<tr>
<td>Fenestration</td>
<td>Fenestration</td>
<td>Mechanical Properties</td>
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<tr>
<td>Climate Control</td>
<td>Doors</td>
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<td>Drainage</td>
<td>Climate Control</td>
<td>Durability</td>
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<tr>
<td>Fire Systems</td>
<td>Sound Control</td>
<td>Sound Control</td>
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<td>Durability</td>
<td>Fire Systems</td>
<td>Fire Systems</td>
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<td>Services inc. ventilation</td>
<td>Durability</td>
<td>Services</td>
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<tr>
<th>Interior Wall System</th>
<th>Floor System</th>
<th>Foundation System</th>
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<tbody>
<tr>
<td>External Finish</td>
<td>Surface Finish</td>
<td>Ground</td>
</tr>
<tr>
<td>Structure</td>
<td>Structure</td>
<td>Floor Beds</td>
</tr>
<tr>
<td>Doors</td>
<td>Services</td>
<td>Retaining Walls &amp; Foundations</td>
</tr>
<tr>
<td>Sound Control</td>
<td>Ceiling</td>
<td>Pile Foundations</td>
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<tr>
<td>Fire System</td>
<td></td>
<td>Special Elements</td>
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<tr>
<td>Durability</td>
<td></td>
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<td>Services</td>
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</tbody>
</table>

Table 6.6: An Example of Building System Elements

<table>
<thead>
<tr>
<th>Fenestration Elements</th>
<th>Door Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rough Opening</td>
<td>Rough Opening</td>
</tr>
<tr>
<td>Window Frame</td>
<td>Door Frame</td>
</tr>
<tr>
<td>Operable</td>
<td>Operable</td>
</tr>
<tr>
<td>Sash</td>
<td>Appearance</td>
</tr>
<tr>
<td>Glazing</td>
<td>Glazing</td>
</tr>
<tr>
<td>Fire System</td>
<td>Fire System</td>
</tr>
<tr>
<td>Security</td>
<td>Security</td>
</tr>
<tr>
<td>Climate Control</td>
<td>Climate Control</td>
</tr>
<tr>
<td>Sound Control</td>
<td>Sound Control</td>
</tr>
</tbody>
</table>

Table 6.7: An Example of Building Element Components

An example hierarchy was produced (Figure 6.10) to demonstrate how the tables enable the QFD facilitator to drill down through the building system to the elements and individual components of the system. The highlighted boxes follow the examples of how the House of Quality has been used to examine the least satisfactory elements and components in a building system (Figures 6.11 to 6.13).
Chapter Six

Building System Element

Exterior Finish
Structure
Interior Finish
Fenestration
Doors
Climate
Sound Control
Fire Systems
Durability

Figure 6.10: An Example Building System Hierarchy

Figure 6.11: An Example of QFD on the System
The process outlined in stage four does not conduct a full QFD exercise but it demonstrates the effectiveness this simplified version can have in determining the element or component seen by the stakeholders as requiring more design input. If this part of the process was conducted as a value management exercise, the facilitators will have further tested the option against the values and the designers could then choose to develop the process further using the QFD process outlines in stage three (Section 6.3.4).

**Assessment**

Another meeting was facilitated with designers at AMEC Construction to evaluate the QFD developments. The architect and project manager/VM facilitator that instigated this
Chapter Six

response together with the head of value engineering attended it. The process was delivered and the meeting facilitated the following responses:

- Value Management facilitators see the introduction of a VM\textsubscript{3} that would start early in the scheme design stage and be used to resolve remaining issues before VE is undertaken.

- A VM\textsubscript{3} was seen as a way to identify key design characteristics that are fundamental to the success of the design brief.

- It was agreed that the QFD proposal in stage four had been simplified and could be adapted for use during a VM\textsubscript{3} meeting but some participants still saw the process as being difficult to relate to stakeholders not familiar with the concept.

- The matrix and the roof of the House of Quality were liked and it was suggested that the greater number of hits within the matrix could indicate a more complete compliance with the customer values.

- It was also suggested that a system of recording the values associated to a particular relationship might better clarify the customer requirement. It was clear that at this point the QFD process was being considered as a VM tool and not for its own unique qualities.

- Architects that are looking for a process to support design statements, building up a record where the designer stores the statements to provide evidence on the issues that lock the design together and stage three and not stage four of the preceding QFD proposal was seen to have the potential for this.

- Architects believe this type of QFD should also be used later in the scheme design process before the VE stage to translate the client values and design characteristics into a one-dimensional set of criteria rather than the two dimensional value and option that are currently used to compare cost.

6.4 CONCLUSIONS TO VALUE ANALYSIS AND QFD

Designers at AMEC Construction made it clear that the current inadequacies inherent in early stage design need to be resolved before the quality standards currently presented to the customer can be improved. AMEC designers embraced the idea of using a quantifiable
technique such as QFD to help address two specific problems. That of making key design
statements and secondly identifying key design characteristics.

While QFD has previously been viewed as a tool to be used where routine procedures
cannot be applied (Huovila et al (1995). The three variations developed in this chapter
sought to further recent developments by (Mallon & Mulligan 1993), (Serpell & Wagner
1994) and (Kamara et al 1997) in QFD for building design and provide designers with a
tool that could be adopted as part of the culture of a design organisation rather than an
occasional tool.

Using action research methods it was possible to directly involve the AMEC Construction
design professionals in the development of the proposals. At each stage in the development
the QFD techniques were presented to the different teams of designers requiring solutions
in the form of workshop presentations. This research method used computer images and
blank overlays of the House of Quality to elicit suggestions on how the respective
techniques could be best applied. Following each presentation, designers were asked to
produce sketches of how the techniques should be modified to meet their requirements.

The QFD techniques presented here are able to offer early stage building design three
distinctly different approaches to providing measurable solutions to qualitative problems.
The design team members that were asked to validate the proposals viewed each separately
and gave an opinion based on how QFD might be introduced into building design culture to
help overcome the problems they currently experienced within their own discipline:

- Designers more readily relate to the concepts demonstrated in stage three (Section
  6.3.4) rather that stage one (Section 6.3.2) as a tool for delivering design statements.

- Value managers considered QFD for its ability to raise the level of discussion from
  values to concepts as demonstrated in section 6.3.5.

- Value engineers and cost planners were looking for process somewhere between the
two that could help in signing off design solutions.

QFD was demonstrated by this research as a tool offering many possibilities to assist
building designers. Further introductory workshops were seen as the next stage in the
process development.

169
Chapter Six

Finally, where QFD was seen previously as a tool to be used where routine procedures fail or a tool with limited application, design organisations are now able to visualise where QFD techniques can be applied to provide the solutions they require.
Chapter 7
Conclusions and Recommendations
Chapter Seven

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION TO CONCLUSIONS AND RECOMMENDATIONS
This chapter draws together the findings from the research and identifies the contribution to knowledge made in this thesis. The conclusions and recommendations are given in five parts:

1. Overview of the Research Project (Section 7.2.1)
2. General Findings of the Research (Section 7.2.2)
3. The Scheme Design Process Model (Section 7.2.3)
4. Supplemental Tools (Section 7.2.4)
5. Reflections and Recommendations for Further Study (Sections 7.3 and 7.4)

Where the author encountered problems not specifically addressed by the research general observations are made, these form part of the author's reflections and recommendations for further study. The research has involved substantial collaboration from the main industrial collaborator AMEC Construction and worked alongside the research assistants on the EPSRC IMI/LINK IDAC project into detail design (Austin et al 1999). This collaboration has provided the added benefit of synergy and interaction when examining the multidisciplinary design process undertaken by AMEC Construction and other collaborators. The main thrust of the research has been to develop tools to improve strategies and reduce the conflicts during early stage design.

7.2 CONCLUSIONS
7.2.1 Overview of the Research Project
The research project required a thorough examination of the conceptual and schematic stages of the design process to investigate some of the problems encountered during these early stages of design. Closely following the design of a new pharmaceutical research centre provided insight into current methods employed by designers to establish their client's requirements as the brief was investigated. The research examined the process as designers explained the problems they face when undertaking the design of complex highly engineered buildings. Central to delivering design solutions is the role of the cost planner
Chapter Seven

and the risks they negotiate when providing accurate cost advice. Early stage design by nature of the many processes within each stage requires a wide variety of information from many sources. The tools and techniques currently used during early stage building design and from other industrial arenas were examined and evaluated. Conclusions were drawn and a research plan made as the basis for the output from early stage design (Chapter 3.3.7).

7.2.2 General Findings of the Research

Initially the findings of the research into early stage design highlighted a broad range of interrelated problems. These findings have been summarised in Chapter Two (Section 2.10) and Chapter Four (Section 4.3), principal among these being that of poor communication of information.

Finding 1. Poor communication leads to unclear strategies, weak management, rivalry and mistrust.

During early stage design communication between participants:

- Promotes the development of strategies.
- Provides designers with the information they require to design.
- Mutually shares the design issues.
- Allows solutions to be signed-off to prevent unnecessary design iteration.

It was found that unclear strategies and weak management are linked to the investigative process employed during client briefing. Strategies seldom develop until relationships between designers and their client can be established leading to a chicken and egg situation and loss of valuable time. When the underlying reasons were investigated through the participant study and later interviews, project coordination especially the lack of a dedicated client based project manager emerged. This was also linked to rivalry and mistrust that had a detrimental effect on decision-making throughout the early stages of the participant study. All indicating the requirement of clear framework to be in place before the design process commences.

The research also addresses some of the issues encountered by the multi-disciplinary design team where again communication is a major issue. This time poor communication relates to the understanding between designers across the disciplines and between designers and the
cost planners. Improved understanding of their respective needs would enable them to respond better to the requirements of their clients.

The objectives from the outset helped the research deliver an investigative response:

1. To investigate current briefing methods in engineering industries (including construction, manufacturing, aero/auto-motive and product design) in order to identify techniques that could improve best practice in the construction industry.

2. To examine how process modelling and matrix analysis techniques might assist in planning/management of the information flow (particularly the effects of changes), and to develop additional strategies.

3. To investigate how designers can provide information of appropriate detail and quality for the purpose of making cost estimates for both the client and the design team.

4. To identify how improved early design strategies could reduce constraints and conflicts during the construction process.

Primarily after reviewing literature and shadowing a building design from its inception, a clear distinction emerged between the negotiated conceptual stage and the schematic identifying of deliverables stages of design.

Finding 2. The Conceptual and Schematic stage of design are sufficiently distinct from each other to preclude the formulation of a common modelling solution.

This made it impossible to draw together a process solution that would apply equally to both stages. It was decided therefore to concentrate on the scheme design to develop and improve current techniques that would compliment other research being conducted into detail design. Solutions were also sought to answer further the questions formulated in Chapter Three:

- Can scheme design be modelled using the same ADePT modelling techniques used to model detail design?

- Can scheme design be modelled to facilitate improvements in risk analysis and cost planning when programming the design process?
Chapter Seven

- When producing a Scheme Design Process Model (SDPM), is it possible to integrate with the Detail Design Process Model (DDPM) to improve the design-modelling database for planning design?

- Can the accountability of the decision making process be improved using QFD techniques applied at various stages of early stage design?

Work was already in progress developing the ADePT methodology for detail design. As detail design relies heavily on information and product from scheme design, a decision was made to review the processes at scheme design and develop a Scheme Design Process Model (SDPM).

Finding 3. There emerged a clear requirement for a contribution to the design-modelling database in the form of a process model for scheme design.

There was concern that the SDPM based on ADePT may not be considered an original contribution to knowledge. However, it is argued that the design process during this earlier stage is so dissimilar in function to detail design that a new set of parameters would require establishing and testing. This work is explained in Chapter Five.

Discussing design problems with designers also identified their need for additional tools to support some of the difficult decisions that need to be taken both in partnership with their clients and from within their intra-disciplinary environment.

Finding 4. Additional tools are required by designers to help support the decision process during early stage design.

Accurately assessing the requirements of stakeholders is an essential part of the design process. Without a consensus to the design problems the iterative process of redesign, in part mitigated by using process models will continue to cause delay, this also applies equally to formalising the design solutions. Where design solutions cannot be signed-off during the course of the design, designers feel exposed and vulnerable to change. It was therefore decided to investigate methods used in other industries to prepare and audit design solutions.

Finding 5. Quality Function Deployment emerged as a tool used in engineering design but underexposed during building design.
Research uncovered opportunities to apply synthesised techniques to specific problems and evaluate QFD as a multi purpose tool when managing early stage design. Three examples of QFD techniques were applied and tested with designers against current problems. This work is explained in Chapter Six.

7.2.3 The Scheme Design Process Model

The research into early stage design had identified that coordination of information within the multi-disciplinary design teams was found to be a major problem for designers leading to delays in delivering the design and cost advice to their clients. Understanding the requirements of others was only just secondary to this. Risk analysis was seen to improve the way team members negotiate their responsibility towards each other. It also improved understanding of roles within the team. Combining these three elements into a SDPM allows designers to:

- Accurately plan ahead for the work required during the scheme design stage.
- Identify conflicts that lead to iterative problems.
- Mitigate iterative problems by identifying and recording the design risks source.
- Qualify the accuracy of the cost advice based on the progress of the design.
- Ensure closer cross-disciplinary cooperation.
- Reduce overall project timescale.

The preceding bullet points can now be qualified:

**Accurately planning ahead for the work required during the scheme design stage**

The SDPM diagrammatically identified information flows from which information dependencies were determined then through systematically ordering the activities with a design structure matrix, a programme of work was produced. From the programme of work designers are advised which tasks by which discipline should be completed before the next may continue with certainty. An improvement to programming techniques has been demonstrated. The investigation of the interface between a model of detail design and the DPM in Chapter Five (Section 5.7.6) has demonstrated the integration of the two design stages. The method created is able to provide designers the flexibility they desire when differing project requirements need to be addressed. Field tests leading to further
Chapter Seven

development of the SDPM will allow the development of a generic model (Chapter 5.1.1) and from this where the information dependences have been further refined the programme may further identify which part of which design on a specific project poses the higher risk through estimation.

**Identifying conflicts that lead to iterative problems**
Conflicts during early stage design are mainly information based. Not the information we can plan for i.e. "do we have the right information" or "will the information arrive on time" type of information. The design iteration that cannot so easily be planned for is the iteration that causes the conflicts. Typically, when one or more tasks are awaiting information from another task before itself can supply the information that the originating task requires. Looking at the SDPM after it was constructed gave little indication of the highly iterative process created. It was only after passing the model through the Design Structure Matrix (DSM) that the true nature of the iterations created in the model was exposed. Experience may indicate to the design team where potential problems await but often that information is not shared. It was revealed during the research that professional rivalry could lead to the withholding of information and in fairness; human nature may also play its part where issues are missed or overlooked. Through passing the SDPM through a DSM to identify these conflicts at the start of a project the potential to save thousands of pounds worth of costly delay after the design has commenced was demonstrated.

**Mitigating iterative problems by identifying and recording the design risks source**
The desire to inform designers and project stakeholders in advance to create an open understanding of issues that may cause delay or additional cost mitigates potential problems after the scheme design has commenced. The risk section incorporated within the model proved an advantage to this desire as it identified risk source for the risk analysis process. In order to produce a workable programme using the design structure matrix some information dependencies required further declassifying as estimative. Identifying this information by creating an input into the risk registration activity enables designers to make a list of predecessor information requiring special consideration, avoiding potential conflicts with successor tasks. Decisions can thus be taken for a given task for example where special surveys may be required on a particular project before the scheme design process commences or where an estimate has been made it advises designers with a list of tasks that may need rechecking at a later stage.
Chapter Seven

Qualifying the accuracy of the cost advice based on the progress of the design

One of the principal objectives for the research was to improve the quality of information for the purpose of making cost estimates. This was delivered by introducing the cost section to the SDPM. The term quality information was understood in this case to mean accurate, appropriate and timely. Investigating the information required by cost planners enabled the research to identify the type and scale of the drawings, the information contained in schedules and the level of detail required to produce the cost estimate. Matching these requirements to the production of the design information identified at which point in the programme of work the information will become available. Additionally, identifying the requirements of cost planners for a +/-10% cost certainty enabled the research to accurately correlate the design task output to the information required at the scheme design stage. Cost planners are now able to adjust their response in relation to the design programme produced from the DSM. This will save cost planners valuable management time where previously they had seen their role as one of directing designers and chasing cost information to meet their own targets.

Ensuring closer cross-disciplinary cooperation

Closer cross-disciplinary relationships were identified from the research as a requirement. Improving understanding and responsibilities through employing project coordinators emerged from the shadowing exercise. Coordinating information through the SDPM may be considered an initial step in promoting better harmony as it identifies the responsibilities for delivering the information. These responsibilities have been coordinated through the research where the individual disciplines performed a two-stage qualification process. First, they identified individually the information they required as the model was constructed and then by mutually prioritising that information through the dependency tables each discipline bought into the requirements of their colleagues.

The SDPM should also improve communication and understanding of process responsibilities within design teams and help the development of risk analysis processes. The ordering of design task requirements can improve understanding between designers because their responsibilities to each other have been identified. The introducing of risk analysis into the early stage design process has already proved beneficial to communication and understanding across the disciplines at AMEC Construction and risk analysis processes have been revealed during the research to reduce project risk.
Chapter Seven

Reducing Overall Project Timescale

Early stage design relies on the combined experience of the lead designer and that of the design organisation directors during the option forming conceptual stages. It was revealed that this is often carried out in an ad-hoc manner to suit the individual client circumstances. Whereas experience is able to guide the brief investigation process using a variety of differing techniques to develop the options, the focus of the scheme design stage is to develop the chosen option. It is during scheme design that a formula approach can be adopted. Given that for each project a similar process is followed during scheme design, making improvements primarily relate to programming in terms of duration and resources.

The focus for building a SDPM was to understand the activities performed and the information required by those activities. Using a DSM and prioritising the information input into it allowed the research to address the sometimes difficult to unravel iterations that result when dependent tasks simultaneously rely on the same information. The end result being that a deliberate and workable order of tasks emerged from a programme that would otherwise require considerable float built in to accommodate the iterative processes, thus adding time to the project. This in turn demonstrated for the first time that by combining the design process with the cost planning and risk analysis elements of design, a workable programme could be produced. The net result has been to deliver a model that is capable of significantly reducing project timescales by reducing the time allocated for solving iterative problems. It is not that design iteration will be mitigated altogether but that it may be identified and properly planned for in advance so that project participants may fully understand their responsibilities.

7.2.4 Supplemental Tools

In recent years, designers have been exposed to many new processes and techniques; architects in particular have been exposed as relying heavily on past practice and been under increasing pressure to accommodate multi-disciplinary design and build practices. This has led in some cases to them and their colleagues from other disciplines questioning motives and resisting change when clearly that change will increase the amount of administrative work imposed on them. This argument was accepted when the research investigated supplemental tools to assist designers achieve their objectives during early stage design.
Chapter Seven

Investigating the working practices of designers as the SDPM was developed revealed their frustration in fixing design requirements and communicating design solutions. The value analysis process of value management and value engineering is used to overcome the former and a system of documentation that is prepared for signing off at the conclusion of each design stage, the latter. It emerged that neither fulfilled the needs of both designer and client exposing a desire to better capture the client's requirements and a method of delivering design statements that may be progressively fixed as solutions emerge. The research into techniques used in other industries found that Quality Function Deployment (QFD) was able to capture the voice of the client and display a quantitative argument to qualitative requirements. It was reasoned that QFD might hold the answer to both problems. The research found that the QFD process developed for the automotive and manufacturing industry has not easily translated to building design and been previously viewed as a tool to be used where routine procedures cannot be applied. Chapter Six presented three variations of the QFD technique and tested the response of designers to introducing it as part of the culture of design rather than as an occasional tool.

The conclusions drawn provided a favourable but guarded response.

First, the QFD techniques presented had enabled designers to visualise where the type of QFD techniques developed may be applied to provide the solutions they require. The techniques were able to offer early stage building design two distinctly different approaches to providing measurable solutions to qualitative problems. The method chosen demonstrated its value in expressing the client's needs in terms that designers could refer to when questioning and evaluating outcomes and to providing a basis for justifying their design response. However, as a technique for reaching agreement to stakeholder requirements once the initial options had been selected value managers still found QFD to be too numerically based to present to all but the most experienced of clients.

The second requirement, that of providing support to design statements with a QFD technique was better received. Auditing the design response by following a quantitative argument for providing value to client's requirements was also seen as a function that could be employed to support the design statements and form part of a quality assessment procedure. It was revealed that architects within AMEC Construction had already reviewed the functional analysis methods employed during the value engineering process and found them to provide a snap shot of the selection process for specific components. It was
concluded during an evaluation meeting with architects that further discussions were due to be held where the QFD technique demonstrated by the research would be tabled for discussion before choosing the appropriate corporate policy. If QFD was chosen further introductory workshops were seen as the next stage for its development. The designers at AMEC Construction confirmed that the current inadequacies inherent in early stage design still need to be resolved before the quality standards currently presented to the customer can be improved and that it was their intention to pursue that goal.

7.3 REFLECTIONS

It was interesting to reveal that design problems have changed little over the years. Designers and their clients cite similar inadequacies today as they had during the earlier periods examined (Barrett & Stanley 1995). The observations and findings from shadowing the concept study and the interviews conducted in its wake confirm this point. In particular, it cited professional relationships, intra and cross-disciplinary cooperation and the coordination of both to be the main cause of the problems faced by designers and their clients. The research has confirmed that in recent years there has been a significant advancement understanding the traditional problems between contractor and client that manifest itself in the adversarial relationships of the past. There have also been cross-disciplinary improvements particularly where information technology has helped with understanding between the parties (Cockshaw 1995). The current thrust of interest no doubt initiated by Latham (1994) and continued with Egan (1998) has had a positive effect on dealing with the problems encountered by designers and the industry as a whole. It should not stop there as building design can only benefit by this interest; however, initiatives appear to be cyclical in nature in that when confidence in the industry is low measures are taken to bolster confidence. When confidence is high, such problems are often overlooked. It would be of no surprise to find that the thrust of current research into design management issues to wane only to be resurrected again in a few years time when industry believes it timely to convince their clients again that they do actually provide a value for money service. It is a shame that progress has to happen in this manner.

The major part of this research has concentrated on the production of the SDPM. It was seen as the single most practical output from the research that designers could reliably employ to improve the delivery of design objectives and the robust cost advice they desired. Before arriving at this decision many avenues were investigated and most revealed
Chapter Seven

that it was not the shortage of tools or techniques available to assist the designers but the lack of resolve by the participating parties to reach mutual agreement and understanding that was causing the majority of problems for design organisations.

The limitations of this research conducted exclusively using a single case study with one organisation needs to be placed in context. AMEC Construction, who are considered an industry leader in multi disciplinary design management made it possible to conduct the research by providing unrestricted access; firstly to a commercially sensitive process with a high profile client on an highly engineered building and secondly to their specialist designers, engineers and managers. It would have been impractical to generate the information required by the SDPM from other sources on this occasion. It is believed that wider applicability of the model developed will follow naturally when its commercial value is fully appreciated.

Some of the techniques investigated have been in existence for a long time as in the case of IDEFO and DSM. It is through the increased capability of personal computers that research is able to evaluate yesterday's techniques and present them in the form of user-friendly software programs. These are made accessible to modern designers for dealing with today's workplace problems. The work into QFD in chapter six made use of MS Excel to provide an automated spreadsheet that would be easily manipulated by an IT literate professional.

Personal observations, from the authors background as a manager of construction projects and construction organisations, lead him to believe that this research has also helped in this particular instance to bring together the providers of design in a unique way. The ADePT methodology, that has been enhanced and refined by this research for scheme design, has the potential to break the fragmentation between designers because all parties are given an equal say about their information requirements. Culturally, when introduced to new organisations, and this forms part of the recommendations that follow, a similar process to that of the research may be required when introducing the technique in order to promote a user buy-in. The process does not tell designers how to design. That would be presumptuous. It advises what should be designed and when it should be done. By producing a logical sequence of events, the SDPM empowers designers for the first time at the scheme design stage with knowledge that no amount of creative thinking could otherwise accomplish.
Chapter Seven

7.4 RECOMMENDATIONS

When reviewing the SDPM with senior managers at AMEC Construction the Design Economist suggested that the decision to declassify cost feedback in the dependency table (Chapter 5.7.4) appeared to make the cost planning operation piecemeal. Cost feedback was declassified as part of the DSM analysis to reduce unnecessary iteration, as it served no purpose in having cost feedback where the activity involved was within budget. It was generally agreed that cost planning activities naturally follow design for a given design activity but in some instances it appeared that the DSM separated the design from the costing of an activity by an unnecessarily wide margin to improve the sequence of the overall design and cost estimate process. When the DSM was manipulated to move cost planning activities closer to the design activities within the SDPM it increased the size of the iterative blocks. A compromise was suggested where once the overall programme of work had been produced the cost planning process might be run separately to identify further cost plan-programming efficiencies. This would allow cost planners to conduct other work whilst awaiting definitive information such as preparing preliminary cost advice based on available information. It would also allow a programme to be prepared for the production of work packages and other tender documents as the design progressed in preparation for detail design stage.

There are two alternatives to this:

1. Whereas the previous suggestion may yield immediate efficiencies without overcomplicating the SDPM, the research indicated that further work to refine the model into an all-encompassing generic model could deliver the same outcome. The basic reasoning being that when sufficient and accurate information is passed through a quality system that does not change the nature of the information but only acts on that information as in the case of the DSM the information is conserved. Therefore, by inputting the additional parameters required by the cost planners, a mutually reliable programme could be delivered. It would seem that the economist was trying to derive immediate gratification from a thus far prototype model.

2. The preparation of work packages and other tender documents are generally carried out during detail design so manipulation of activities between the scheme and detail stages could also yield the desired results. This procedure has been shown by the research to be viable (Chapter 5.7.6).
Chapter Seven

**Recommendation 1.** Test the Design Economist suggestion for separating the cost planning operation post DSM and evaluate the validity of such an exercise on a live project. (Low cost objective)

**Recommendation 2.** Conduct further work combining elements of the SDPM with a model of detail design on a live project. (Medium cost objective)

**Recommendation 3.** Can the SDPM be made more generic by increasing the scope and range of the existing undeveloped activities and information requirements? (High cost objective)

The tools and technology applied during the creating of the SDPM for the ADePT methodology are currently in various stages of development and an opportunity exists to promote further work to develop an integrated modelling approach for both scheme and detail design. During the testing of the DSM programs, it was found that PSM32 was able to advise where to tear the matrix and declassify information dependencies. The AMMP tool that was initially used to display the DSM will also need to provide this function if complex matrix analysis is to be conducted within an integrated package. Further development and testing of the SDPM is required.

**Recommendation 4.** Consideration should be given to further develop the existing ADePT tools built at Loughborough University; to integrate the detail and scheme design stages, to include risk analysis and cost planning elements and to link to the generic SDPM suggested in recommendation 3. Consideration should also be given to improving the functionality of the AMMP module.

It was found that the multi-disciplinary designers responded enthusiastically to being asked about their information requirements when developing the model. If the ADePT methodology is to work with other companies, a similar method of introduction to that presented when developing the SDPM will be required in order to make the procedures culturally acceptable.
Chapter Seven

Recommendation 5. Cultural issues should be considered when introducing processes that will bring about change rather than allowing the process to be viewed as an administrative access to the designers’ workload.

Findings from the initial shadowing exercise not covered specifically with the tools developed by this research deserve two specific recommendations. Future research into early stage design especially at the conceptual stage will benefit by addressing these findings if a congenial methodology is to be formulated.

Project coordination emerged as a major issue especially during the option selection process towards the end of the concept study. Project delays were caused unnecessarily when stakeholder members of the study group were asked to sign-off options that they felt uneasy with or unqualified to accept. The project was put on hold whilst a client project manager was recruited.

Recommendation 6. Design organisations should ensure that the client has the resources to recruit and maintain adequate professional advisors and make it a condition of engagement that design management issues are conducted through professional advocates acting separately for both the client and designers.

It became clear as the topic of risk analysis was evaluated that opportunities were there from the outset of the concept study to collect and register risk data. Formalising risk responsibility was made a part of the SDPM and forms part of AMEC Construction’s corporate policy to maintain a risk register during the later stages of design. It was identified that where risk analysis policy is employed during the earlier sages of design stronger cross-disciplinary bonds are created among designers. Client stakeholders can also benefit from a risk policy by being given the opportunity to understand their responsibility to the design process. Risk analysis allows risks to remain topical throughout the design process and risks are commensurate with the values placed on them until such time as the risk is mitigated.
Chapter Seven

**Recommendation 7.** Further research is required into creating and maintaining a risk database that both designers and the client can subscribe to starting at project initiation. Consideration should be given to managing and monitoring the mitigation process with an independent authority over both client and design team.

The QFD techniques in chapter six demonstrated solutions to problems uncovered during the research. To unlock the potential advantage that QFD has to offer building design an implementation process has to be undertaken. There was a natural reluctance to change when the developed tools were evaluated but the tools clearly provoked interest especially for the purpose of developing design statements and matching customer requirements to design solutions.

**Recommendation 8.** To test whether QFD can be incorporated into the design statement process being developed at AMEC Construction.

These recommendations conclude the research into techniques and strategies to improve conceptual and schematic design.


Akao, Y (1990) QFD Integrating Customer Requirements into Product Design. Productivity Press, Massachusetts, USA.


References


References


References


References


References


Liebow, E. (1967) *Tally’s Corner: a study of Negro street corner men.* Little, Brown, Boston, USA.


References


References


References


Appendices
## TABLE OF CONTENTS TO APPENDICES

### APPENDIX A

**THE PROJECT SHADOWING MEETINGS - 23 ISSUES UNCOVERED**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Start up Meetings</td>
<td>ii</td>
</tr>
<tr>
<td>Value Management</td>
<td>iv</td>
</tr>
<tr>
<td>The Interdisciplinary Design Ideas Workshop</td>
<td>v</td>
</tr>
<tr>
<td>Meeting with Lead Architect</td>
<td>v</td>
</tr>
<tr>
<td>Collective User Group Meeting in Place of VM2</td>
<td>vi</td>
</tr>
<tr>
<td>Detailed Design Start-up Meeting</td>
<td>vi</td>
</tr>
</tbody>
</table>

### APPENDIX B

**THE INTERVIEWS**

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Economist</td>
<td>viii</td>
</tr>
<tr>
<td>The Project Economist</td>
<td>xi</td>
</tr>
<tr>
<td>The Lead Architect</td>
<td>xi</td>
</tr>
<tr>
<td>The Structural Engineer</td>
<td>xii</td>
</tr>
<tr>
<td>The Marketing Manager</td>
<td>xii</td>
</tr>
</tbody>
</table>

### APPENDIX B

**THE 208 CODES**

<table>
<thead>
<tr>
<th>Interview and Details</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>From the Interview with Head of Cost Planning and Value Engineering</td>
<td>xiii</td>
</tr>
<tr>
<td>Head of Cost Planning discussing Early Stage Design</td>
<td>xvi</td>
</tr>
<tr>
<td>From the Interview with the Project Economist</td>
<td>xvii</td>
</tr>
<tr>
<td>From the Interview with Lead Architect</td>
<td>xix</td>
</tr>
<tr>
<td>From the Interview with the Senior Structural Engineer</td>
<td>xx</td>
</tr>
<tr>
<td>From the Interview with the Marketing Manager</td>
<td>xxii</td>
</tr>
</tbody>
</table>

### APPENDIX C

**THE 208 CODES ARRANGED INTO SUB CATEGORIES**

### APPENDIX D

**THE 27 SUB-CATEGORIES**

### APPENDIX F

**DEFINITION BRIEF OR SCHEME DESIGN?**
8.1 THE PROJECT SHADOWING MEETINGS - 23 ISSUES UNCOVERED

The Start up Meetings

The concept start-up meeting introduced the study group members to one another and familiarised the design team with the site. It was also the start of the interrogation process to test and evaluate the statements within the client brief. During the first meeting, the design manager explained the design teams methodology to the study group and how the project would be defined in the Definition Brief. He also set a series of objectives for the following meetings and provided a programme for the concept study. The identified deliverables at this stage being:

- A Concept Study Report based on the initial client brief and the designer's proposal. This report would consider an expanded research and development facility to provide the client with a new centre of excellence in respiratory diseases. It would use contributions generated through interview, Value Management, brainstorming and review alongside the investigative and developmental process to formulate the projects functional and budgetary requirement.

- A Definition Brief representing the clients statement of requirements for the new permanent research building that would contain general statements covering issues such as engineering requirements, floor and wall finishes etc. on which the designers will agree a contract to undertake the detail design and construction of the building. Contained within the Definition Brief are overall layout drawings, room data sheets, equipment schedules with some of the detail drawings where required for clarification.

- Cost advice providing a +/-20% order of cost and a commercial strategy that would eventually produce a lump sum price for the project.

Issues arising from the First and Second Meetings (Summarised in Italics)

A principle stakeholder had asked for and was provided by the designers a list of issues for the user group (the stakeholders) two weeks in advance of the start up meeting. It is important to note that this was an important procedure yet from the amount of user group co-ordination it would appear that the principle stakeholders failed to explain the
Appendices

requirement or co-ordinate a response to that document in time for the meeting. *(There was no project coordinator or clear leader for the client user group).*

It was clear from the study group discussion with respective heads of department, that each had a different perspective and strength to contribute to the design. It was unfortunate that this was not co-ordinated, as had it been a more cohesive team effort it would have contributed to a more balanced exchange of views. *(There was no project coordinator or clear leader for the client user group).*

The more assertive stakeholders seemed to establish a 'pecking order' as their 'wish list' was presented to the design team. This created a bias that seemed to undervalue the other stakeholder requirements. *(The perspective of less assertive stakeholders could be overshadowed when investigating the brief).*

It was observed that advance preparation for the meetings was unstructured and uncoordinated. It appeared that the initial meeting was the first opportunity for the majority of study group members to discuss the project together. *(There was no project coordinator or clear leader for the client user group).*

Major strategic issues were not resolved and uncertainty was evident. An example being insufficient stakeholder knowledge of a coherent corporate strategy specifying the category that was to be adopted under the statutory regulations for isolation measures in laboratories. *(No coherent corporate strategy from the client)*

Other uncertainties surfaced when a principal stakeholder asked: “Are we working our science teams discipline based or project based? And what is the philosophy in terms of reserve capacity and adaptability between disciplines?” *(No coherent corporate strategy from the client)*

Also identified for the design team when common areas and crossover areas were discussed was that a forum would be required, as issues would not surface from individual discipline based science teams. This demonstrated that there was no principle stakeholder responsible for driving the issues and developing solutions. *(No client based project manager to drive issues and develop solutions).*
Appendices

There was also a sense that there was collusion between principal stakeholders and designers that implied to members of the user group that they were not fully informed. This resurfaced at later meetings. (*Too many closed relationships leading to rivalry and mistrust*).

On the second day, the design team introduced a design strategist to advise on alternative solutions to elements that have received favourable reception on recent projects of a similar nature. This was appreciated by stakeholders as it demonstrated a wealth of understanding by the design team for what they believed sensitive design problems to their particular project. (*Specialists and technology help understanding for stakeholders*).

**Value Management**

The third meeting for the Study Group centred on a Value Management One (VM₁) meeting followed with a brainstorming session in the afternoon. The information that the team gathered and generated during the VM₁ was later used to guide the esoteric and technical response to the client brief. A Mission Statement for this project was generated and agreed to form the focus for the project. This was underpinned by a list of seven secondary and thirty-three tertiary requirements.

**Issues Surfacing from the VM Meeting**

The information generated at significant meetings such as VM₁ and the brainstorming sessions that involve the client will be used as a directing influence during the many differing stages during the design process.

If all the information collected is systematically consolidated and analysed it will have the time saving benefit of delivering reliable information that is consistent with the clients needs from a single source. (*No central coordination of collected information*).

The collection of information from the VM₁ helped this research develop its QFD proposal and the suggestion of a consolidated process of information gathering has directed this research to seek methods to incorporate risk analysis at an earlier point than currently practiced. (*Risks exist at briefing so a risk register should be started*).
Appendices

The Interdisciplinary Design Ideas Workshop
The meeting was called to focus stakeholders on the original options and to try to find solutions that would be robust enough for the principle stakeholders to defend when presented for sanction at corporate level.

Issues from the Interdisciplinary Design Ideas Workshop
During the meeting it emerged that the stakeholders had allowed requirements to exceed the 20 m²/scientist recommended at corporate level by as much as twenty-five percent. (No coherent corporate strategy from the client)

Stakeholders appeared more relaxed when participating in discussions supported by techniques and computer-aided technology. This may relate to the high proportion of scientists within the stakeholder group and may not be precedence for other design projects. (Specialists and technology help understanding for stakeholders)

Meeting with Lead Architect
Following a discussion with the Design Manager when concern for continuity was expressed, he suggested the research should be channelled through the Lead Architect and a meeting was arranged at our industrial collaborator’s corporate offices. Additionally, regular updates on the progress of the design were achieved over the telephone.

Issues Surfacing through Contact with the Lead Architect
A good example of needs driven co-operation within the Study Group was provided when a scientist stakeholder contacted the Home Office for some technical advice and realising its importance, promptly relayed it to the design team who were able to respond by modifying drawing layouts. (Study group liaison was good on need driven issues.)

A stakeholder project coordinator had not been engaged so the most technically competent principle stakeholder had assumed the role. It was not an elected post, and his other responsibilities and particular bias would not allow him to devote the time to, or favour the interests of, the stakeholders. His responsibilities to corporate stakeholders would inevitably conflict with his ability to provide the study group stakeholders with unbiased advice concerning the suitability of the developed design. (There was no project coordinator or clear leader for the client user group.)
The design team felt insufficient time was being allocated by the stakeholders. This was leading to unsupported decisions being taken by designers that could contribute to complications at a later stage in the process particularly when minutes of meetings were not taken to record the project agenda. *(Risks exist at briefing so a risk register should be started) (A procedure recommendation Decisions should always be signed off.)*

**Collective User Group Meeting in Place of VM2**

This meeting was arranged for the express purpose of focusing the study group on delivering a supportable design.

*Issues from the Collective User Group Meeting in Place of VM2*

The stakeholders had now accepted the message that there is a direct relationship between their ‘wish list’ and the project cost. *(Risks exist at briefing so a risk register should be started.)*

It had taken the shock realisation that the principal stakeholder was prepared to come in and cut scientist numbers at a stroke if it appeared that they were contemplating overspending the budget. *(A procedure recommendation Decisions should always be signed off.)*

This author questioned the Design Manager as to why it could not have been clarified at an earlier stage. Their view was that if they had done so it would have given the wrong message to the stakeholders. This could be seen to disregard the specific technical requirements of the science and the people conducting that science, in favour of a commercial solution. *(Too many closed relationships leading to rivalry and mistrust.)*

The client and User Group are finally considering the appointment of a Project Manager it was agreed that it would take time to find and orientate an individual with the appropriate skills so the design was placed on hold for a three-month period. *(No client based project manager to drive issues and develop solutions.)*

**Detailed Design Start-up Meeting**

A draft of the concept study was presented at week twelve, the schedule of accommodation is complete and the general arrangement drawings are finished. The principal negotiators for both client and design team had following sanction from client’s corporate stakeholders agreed a revised programme of work for the design to culminate in a lump sum tender that
Appendices

would eventually lead to construction of the new research facility. This meeting was considered seminal for the research as introductions could be made with the full in house design team being engaged to complete of the scheme design before starting detail design.

Issues from the Detailed Design Start-up Meeting

The meeting would be held in two parts the first of which would be chaired by the Design Manager followed by the Design Economist who would explain the commercial strategy for the project. The Design Manager was asked who would lead the design team as it was made clear that the project was becoming increasingly cost driven. In reply the design manager responded that he would continue to manage the design. *(There was no project coordinator or clear leader for the client user group.)*

The VM2 continues to be postponed and the most likely scenario is that it will be held sometime post Concept Study sign-off. The overriding obstacle is that the User Group is without a co-ordinator. This position was noted earlier in the research and it now seems to becoming an important issue. *(There was no project coordinator or clear leader for the client user group.)*
8.2 THE INTERVIEWS

Five separate interviews were conducted as part of the investigation into working practice within a multidisciplinary design organisation. Although at other occasions discussions were held with all the team members in relation to their responsibilities and roles within the team, these were not recorded as formal interviews. The interviews were non-structured and allowed the interviewee to discuss a range of topics. Each interview started by asking the interviewee to discuss their role in general and then to discuss their role in relation to the project being shadowed by the research. The interviews lasted between forty-five minutes and two hours and were tape recorded for later transcription. The interviewer maintained a passive role with the exception of refocusing the interviewee when required.

The Economist

A non-structured taped interview with head of cost planning and value engineering was conducted where the discussion covered how the department worked in a multi-professional organisation and how they interact with their clients.

The following explanation about cost advice during the design of a building brings a perspective to the research and helps focus the requirement to integrate the cost planning process into any model of the design process.

Cost Advice

Cost advice is used to qualify the clients budget and provide a cost certainty within given parameters. At AMEC Construction a range of cost advice may be given: +/-20%, +/-10% through to Lump Sum. There is also a reimbursable prime cost variation offered called Guaranteed Maximum Price (GMP is an AMEC Construction term used to describe a price capping arrangement that fits somewhere between +/-10% and Lump Sum in the ordering of cost certainty). In a management type contract no guarantee on cost is given.

At +/-20% or order of cost all that is required is a 1:100 scale plan of the building so that approximate floor area may be taken off and the functional spaces of the building assessed. The function area costs are then built up using benchmarking data combined with
individual sums for specialist building components to provide the budget appropriate to this order of cost.

At +/-10% the cost certainty changes from area analysis to quantification of the building elements. This may form the basis of a bill of quantity, the purpose being to identify all elements that may involve risk when providing the cost advice.

At the next stage and depending on the proposed procurement route, a decision is usually made to proceed with more detailed design work. Where the lump sum route is chosen usually following a period of further design work, the design is packaged together and submitted to the market for market support. Each package is reviewed technically and commercially, and the risks are assessed so that a Figure can be given to the client.

After negotiation, a project cost is fixed and the designers proceed with detail design. As an alternative, in a management type contract the design would be progressed and assessed against a cost plan on an ongoing basis. The management contractor or construction manager then lets each package. The cost plan being adjusted after prices are confirmed.

If it is just a design commission then the cost advice will likely stop at the +/-10% stage.

Approximate times taken to prepare cost advice will vary depending on the complexity of the project:

- For +/-20% order of cost about four weeks plus a further four weeks for the front end study if applicable.
- For +/-10% cost certainty about six to eight weeks.
- For GMP it will take two to three month and to put this into perspective, on say a twelve to fourteen month overall design period, a sophisticated GMP may be fixed after five or six months.

Cost Planning
When an enquiry is received, the design office creates a mechanism of recording and tracking the progress of the enquiry. This process is part of the divisional QA manual:
Appendices

The *Estimating Plan* - contains information relative to the cost enquiry. It asks if the client has provided a specification, as the cost advice will depend on standards determined by the client, i.e. the quality of materials used such as gold plate verses chrome plate taps etc. The information contained therein is part of the client brief and it will determine where the risks are.

The *Client Brief* is the information provided at feasibility stage that the client would produce to support their requirements.

Sometimes the *Feasibility* will be commissioned for a fee, other times it may be paid for on an hourly basis. Often the commission will be taken at a loss to provide the future design work and construction elements of the contract.

A *performance specification* will have a requirement whereas a *detailed specification* will list the client’s actual needs a quantifiable manner. The larger ‘professional client’ will very often use the later approach. Alternative less experienced clients may produce something simple like a thumbnail sketch to convey their requirement.

The final outcome or deliverable from the cost planners will be the internal tender approval forms showing analysis, prime cost, overhead allowance and profitability.

This may be further enhanced with analytical information that may be made available to the client in terms of *Cost Comparisons* to explain where the building will stand in the market place. That provides the client a description of the proposed build quality to satisfy strategic conditions made as part of the decision to build.

Clients are driven by capital sanction therefore once they have their cost certainty which may be either +/-20% or +/-10% they can make or ask for decisions to take them into the next stage of the design.

The following lists key people and their duties within the design office during the preparation of cost advice at early stage design:

- The *Head of Department* who is responsible to the stakeholders.
• The Enquiry Manager who is responsible for liaisons with the client and production of the design brochure.

• The Fee Manager that prepares the design management fees. At the +/-20% or order of cost he may expect to charge in the order of 5% or 10% of the project value for the design fee. To obtain more accuracy before commitment to design he may agree a percentage based on previous similar contracts.

• The Project Economist is then responsible for bringing the commercial side of cost advice together and gives a commercial focus to the commercial team.

• The Design Leader is the person who gives focus to the design team.

• The Cost Planning Team are the people who use the square metre of building type as a basis for their work expanding and developing the cost by asking specific questions. i.e. Type of HVAC system to be installed in the building? Thereby defining the scope and content of the building.

• The Cost Planners are quantity surveyors who do the taking off and show how to build up cost.

The Project Economist
This interview was held to establish the working process that cost planners employ to gather the appropriate information required when preparing their cost advice. It was conducted to establish a balance to the corporate views presented by the head of cost planning and revealed more information about the interaction between the cost planner and the designers.

The Lead Architect
This was the first of many meeting that was conducted with the lead architect from the design project shadowed for this research. The meeting was recorded on tape but where the other meetings primarily allowed the interviewee the freedom to explain their role within a multidisciplinary team, this interview had a second agenda that was to:

1. Review how the user brief is being developed

2. Identify any new team members.
Appendices

3. Obtain a record of client/design team communication to identify and record interaction.

4. Book a spot at the VM2 meeting and at one of the forthcoming team design and co-ordination meeting.

The Structural Engineer

The meeting with the principle structural engineer for the design project followed the meeting with the project economist. Interestingly knowing that I had been speaking with the project economist encouraged the structural engineer to describe the interaction between designers and cost planners.

The Marketing Manager

At the meeting, an interview was recorded by tape recorder during a single two-hour session. The interview started with an explanation of how the sales team operates within the AMEC Construction organisation. The following topic areas were carefully explained in order to present an overall picture of the marketing process:

- Philosophy
- Sales and Marketing
- Focus
- Enquiry Management

During the tapped interviews, 208 initial codes or categories emerged.
9.1 THE 208 CODES

From the Interview with Head of Cost Planning and Value Engineering

1. Cost advice will depend on client requirement and the design team/stage.

2. Pricing is crucial to the project, which could mean profit or loss for the company.

3. Cost planners can provide cost certainty and help fix the contract price.

4. Lump sum payment to the company can sometimes work in the company interest and sometimes against the company interest.

5. Risk is mitigated at the lump sum stage to the client.

6. Type of cost advice to the client will depend on the scope of the project.

7. GMP is a type of cost advice used in Design and build procurement projects.

8. Some clients have already decided the procurement route.

9. Sometimes the cost planner will provide robust cost advice that can follow a number of routes.

10. Cost planners receive their enquiries in a number ways.

11. Costing can vary considerably in its accuracy.

12. An enquiry plan is raised for each enquiry as it arrives it will show scope and the client's estimate of costs.

13. The enquiry plan will also identify the level of cost certainty required.

14. Sometimes estimated jobs can lead to further work for the company.

15. Not much precedence is placed on small value cost enquiries.

16. Cost planners say they work to a code of practice and await a signature from a director before starting work.

17. Cost planners establish whether an enquiry is formal or informal.
Appendices

18. Fee managers oversee the enquiry and cost planners prepare the cost advice.

19. Fee managers issue the enquiry plan.

20. At +/-20% order of cost a nominal fee of 5-10% of the contract value may be quoted for the design.

21. Each project is assessed for its potential worth both as a design commission and eventual construction.

22. The enquiry manager will take the enquiry plan and produce a method statement that outlines design cost responsibilities to the client.

23. The liaison between the cost planner and the client depends on the enquiry manager.

24. The project economist will decide with cost planners how they are going to build up the cost.

25. An estimating plan is produced by the cost planners and issued to the design team.

26. Cost planners are only interested and concerned about their particular part in the design process.

27. At +/-20% order of cost, estimates are based on block floor plans that outline the functional area to be designed.

28. At +/-10% cost certainty, the areas are broken down into measured elements and bills and schedules are priced. Documents are prepares for collecting market rates.

29. At +/-20% order of cost it will normally take two days to confirm a price once all the documents have been received form the designers.

30. Cost advice on GMP contracts carry risk to the company as it is undertaking to cap the price.

31. Cost planners ask for market rates at GMP stage to mitigate their exposure to risk.

32. Bills of quantity are produced for a GMP.

33. By the time GMP is finished a large part of the detail design will have been completed.

34. Cost planners refer to their colleagues as doing separate work.
35. Cost planners recognise where the client's brief is not well defined and claim in such cases the process is likely to take much longer.

36. Cost planners feel they are always waiting information from others.

37. Cost planners acknowledge that it is important to know the client and the standard the client requires in order to arrive at an appropriate cost.

38. Risk analysis is only considered important at GMP or at lump sum stages.

39. The risk analysis and knowing where risk resides is considered an intuitive part of a cost planners work.

40. Cost planners concern themselves with company profits.

41. Cost planners present their work to people higher on the decision ladder to seek approval before submitting their price.

42. At +/-20% order of cost, cost planners provide estimates based on general floor area.

43. At +/-20% order of cost, cost planners will have a general specification to help them.

44. Cost planners are often given specifications and drawings without prior knowledge of the project.

45. Cost planners rely on a good client brief to help define the scope of the cost estimates.

46. Cost planners do not feel part of a multi-professional team and refer to their colleagues in the company as other teams.

47. Cost planners hand their work over to quantity surveyors when their work is complete.

48. Cost planners are able to identify areas on paper that require specific treatment.

49. Other disciplines are able to liaise with cost planners to verify specifications. This liaison is done outside the multi-disciplinary meetings.

50. Cost planners rely on other disciplines to see or write to them about specifications in order to provide a cost.

51. Cost planners rely on building up historical rates when providing cost advice to clients.
Appendices

52. Cost planners working on complicated designs will often use provisional sums and rely on negotiating the elements of cost with the client.

53. Cost planners use benchmarking to demonstrate the validity of their pricing to a client.

54. Cost planners acknowledge the market economy and sensitive areas of pricing to the client about his project.

55. At +/-20% order of cost changes to specification can be handled on a pro rate basis.

56. Cost planners use outside companies to verify pricing for specific elements.

57. At GMP stage, cost planners negotiate with contractors to hold their quoted prices.

58. At +/-10% cost certainty the cost advice is usually delivered with the definition brief it is then up to the client on how they wish to proceed.

59. If a GMP is negotiated then it is up to that company to take on the construction work, as other companies would not wish to proceed on the cost advice provided by another company.

Head of Cost Planning discussing Early Stage Design

60. Economists rely on the quality of the information taken from the client by the designers.

61. Economists would prefer to introduce their experience during the brief taking process as they feel it helps to focus the design.

62. Economists believe they can influence good decision taking on strategic matters.

63. The type of contract will depend on the information given to the client about his project.

64. Some clients provide a comprehensive brief with their own feasibility study.

65. Economists sometimes try to win client contract and open themselves to be informed by the client who know what they want.

66. Economist sometimes quotes to the client fixed rates if the client knows what they want.
Appendices

67. Corporate level decisions are made outside the multi-disciplinary teams remit on the type of work undertaken by the company.

68. Economist has to await corporate sanction before starting to process an enquiry.

69. Economist find clients are often enlightened about their needs and wants and already have their own PQS on their team.

70. Value management is undertaken at the start of the brief investigation process as it helps with understanding the client needs.

71. Designers have a standard VM approach meeting to help the client and establish needs.

72. Value management is a standard approach with all clients to help identify opportunities the client may have overlooked.

73. Economists are able to educate their prospective clients about unnecessary buildings.

74. Economists accept there to be a need for further training on how best to prescribe to their clients needs.

From the Interview with the Project Economist

75. Project economist has weekly meetings with designers.

76. Project economist helps the designers to stay focused on the job in hand.

77. Designers can sometimes go down a route that is outside the cost plan.

78. Frequent design changes require a Design Change Control document and a budget costing is applied before the designer starts the new process.

79. The project economist keeps a note of all changes in project cost to get an overall picture of cost and this is fed back to the client.

80. The project economist relies on costing of some items outside the company and overall project costing will depend on the information provided from design colleagues.

81. Cost planners and project costing follow a standard procedure within the company.
Appendices

82. Two-stage tendering is where AMEC Construction chose a partner from a list of contractors who must first tender for the contract then designs the element with a view to carrying out the work as a sub-contractor.

83. Outside contractors participating in two-stage tendering will be expected to work at AMEC Construction's offices and will become part of the multi-disciplinary team.

84. Project economists see a project through to the end.

85. Project economists work along with the client and their budget to look at various options.

86. Project economists work alongside designers to the end of the project and produce packages for the sub-contractors.

87. Project economists rely on drawings submitted by other design colleagues for costing.

88. Project economists negotiate with designers about estimating plans in order to get the pricing correct.

89. The process of detail design will allow accurate pricing that will be acceptable to the client.

90. Project economist work alongside other designers and clients to constantly review design and pricing.

91. Building up a price structure will depend on the expectations of the client and the extras required.

92. Cost planners are divided into specialist teams who deal with specific disciplines.

93. The cost headings used by cost planners are generic and translate to their bills of quantity.

94. Work packages comprise of bills of quantity made up for a particular trade to tender for the works.

95. Project economists will give final lump sum pricing after the work has started on site.

96. Project economists cut off point for lump sum pricing depends on other departments providing their work details and schedules on time.
Appendices

97. Project economists rely on all the various disciplines producing their part of their work on time in order to do the costing.

From the Interview with Lead Architect

98. Architects like to create a building block of the building to better understand the client's requirements.

99. Architects generally collect more information than they will use but feel that necessary to provide sufficient choice.

100. Building design modules will generally follow industry standards.

101. Architects collaborate with other architectural colleagues to develop their designs.

102. User group meeting with various stakeholders provides the basic accommodation requirements.

103. Floor plans emerge after co-ordinating all requirements. These are then arranged to suit the site location.

104. In multi-disciplinary laboratories, relationships between disciplines are taken into account before establishing layouts.

105. There is a danger of developing too many options early in the design of a building.

106. Architects will help the client to understand how best to use the available space within the new building.

107. Computer simulation (CAD) is used to help client visualise the developed designs.

108. When budgets have been set architects worry about variations and additional requirements emerging from the developed options.

109. Architects have employed design strategists to liaise with client specialists and users to negotiate finer details.

110. Design options are tested by using the premise of satisfying the client's needs and then revisiting them in terms of commitment with the user group to test the flexibility of the options.
Once a starter footplate is agreed, the cost planners will be asked to apply money against square area and start developing the cost.

Architects expressed concern that the user wish list would allow the floor plate to expand and the corporate stakeholders forcing further redesign would cap this.

The architect collects all the notes taken at user group meetings and provides them to the other disciplines so that intra-disciplinary problems may be uncovered.

Different professional groups are able to work together linked by the common need to satisfy the client’s requirements.

The lead architect has to wait for information from other disciplines before a clear indication of cost can be established.

No clear project co-ordinator for the client user group has clouded decision-making and started delays in the project.

Currently the user group is using an ad-hoc advisor and elements of mistrust are visible.

No clear client project manager creates long waits for stakeholder decisions.

Client professional advising the user group have been given the responsibility to try to provide solutions to client driven problems.

Cost will eventually drive the architectural design and it is hoped that this will not provide further constraints.

Different structural frame types are assessed before structural engineer makes decisions on the best solution for a given project.

The end solution is chosen by the Structural Engineer for its engineering merit after first receiving the cost advice provided by the cost planners.

Structural engineer would have a professional bias on a particular style of building and would push for this after first observing the project specific requirements.
Appendices

124. Cost planners are provided with floor plans, frame section dimensions and weights from which they prepare their estimates.

125. The structural engineer will assist the cost planner when specialist information is required.

126. Where there is no project co-ordinator the architect will negotiate fire and other regulatory/statutory constraints with the appropriate outside authority and advise the engineer accordingly.

127. In the absence of a project co-ordinator, the structural engineer will take the responsibility when required specialist surveys specific for their profession.

128. Structural engineer sometimes raises extra price costing for further investigation on site soil and the client will pay for all surveys sometimes directly and sometimes indirectly.

129. Structural engineers are required to provide management role in the absence of a project co-ordinator.

130. Sometimes the structural engineer will work on his own initiative when negotiations with colleagues and clients are not possible because of shortage of notice.

131. Structural engineers make professional decisions sometimes on already existing buildings.

132. Overlap of project at different points means different disciplines introduce different elements of risk when stags have not been completely signed off.

133. Certain professional groups indicated that they would continue with the next stage of a project in the absence of a project co-ordinator.

134. Depending on the project one of the factors of delay can be getting the principle stakeholders to undersign what is being proposed and sign off the design.

135. Structural engineers would prefer a more organised structure to that they fully understand their design requirement.

136. Structural engineers believe that their input is more complicated than their interdisciplinary colleagues they would like a bigger voice in the team.
Appendices

137. Structural engineers see their selves taking risk separately to other colleagues and sometimes work on their own.

138. Structural engineers seem pressurised by start dates of a project irrespective of the company decisions about the project.

139. Structural engineers believe AMEC Construction’s marketing department do a good job.

140. Structural engineers see their impact as sometimes reducing pressure on the team.

From the Interview with the Marketing Manager

141. Sales team members can have a varied background.

142. Sales team canvas for company business.

143. Organisational strategies allow the business development manager to tender for opportunities of future work for the company.

144. Design and Management work opportunities is part of the sales directors strategies.

145. A company response to proposed work would be to decide which professional is best suited to head the project.

146. Company business is generally the result of strategies that have been campaigned by the sales department.

147. Different philosophy by different professional groups.

148. The marketing strategy is to develop a relationship with a client rather than target projects.

149. Decisions are made at director level about the most appropriate way to approach a client.

150. Selective marketing and advisory service to customer helps to secure future work.

151. Work is done to develop social contact with prospective clients to build up personal relationships.
Appendices

152. Business development managers bring in the bread and butter contracts and look for prospective future income for the company.

153. Local satellite companies will pass larger enquiries up to the main board for processing.

154. Through nurturing past and older acquaintances, the marketing manager has developed new business opportunities for his company that can bring in multi million pound deals.

155. Company mergers within the group have provided opportunities to develop relationships with new clients.

156. Company mergers have provided the company with additional resources to enable them to seek larger projects.

157. Social networking is seen as one route to promoting business.

158. The marketing department have used social networking to provide the company with exclusive enquiries.

159. The company also relies on its reputation for providing recommendations and repeat orders.

160. Social networking with wives and families is seen as one type of promotional method.

161. Future contracts are often negotiated.

162. Future contracts are sometimes secured by tendering.

163. Clients expect comparative estimates.

164. Although elements of competition exist when seeking new work existing relationships promote mutual understanding and help with negotiation.

165. The company often use free consultancy to promote enquiries.

166. Core multi disciplinary teams are quickly formed to help negotiate an enquiry with a new client.

167. The marketing manager first secures the enquiry for the company.
Appendices

168. The marketing manager will continue his involvement to monitor the interaction between the design team and the client.

169. The marketing manager will continue to make social contact during an enquiry with the client to help promote company strategy.

170. At the start of a new project, the marketing manager will stand in as a quasi project manager during the pre contract phase.

171. The project manager that is brought in later will have total responsibility for the project operation.

172. Interdisciplinary rivalry between professions is still apparent in the company.

173. The design professionals have their own philosophy with prevents them embracing the values of others.

174. There is too much ‘I’ and not enough ‘we’.

175. Project co-ordinator manages the team better than individual design professionals.

176. No acknowledgement or routine involvement of the person who negotiated the contract I the first place.

177. Different professional groups are seen to be jostling for place in the hierarchy of the design management organisation.

178. Marketing people think of their role as facilitators both dealing with the client requirements and acting as an intermediary between the client and the design team.

179. The lead role that a director assumes is sometimes required of the marketing manager.

180. The marketing manager needs to be able to interpret his client’s strategic and building requirements.

181. The marketing manager using his personal experience is able to match the client’s expectations with his budget.

182. Big companies can sometimes work blindly with no fixed fees.

183. Estimates are given by the designers, but these are often a part of on-going negotiation.
184. Marketing manager continues to work with the client as a moral responsibility providing advice.

185. Clients prefer to know £+0-% rather than £+/-% and the marketing manager works with the company economist to help communicate the clients requirements.

186. Other team players that do not know the client run the risk of producing something that is outside the client cost and outside what he wants.

187. Close cross-disciplinary interaction is required if the best overall solution is to be achieved for both the client and the design management organisation.

188. The client led engineering group plays a leading role in the project and becomes the intermediary between the designer and the higher-level stakeholders.

189. Unusual flexibility towards payments from clients.

190. Reimbursable prime cost is the clients preferred method of tendering and the add-on GMP cap will allow the project to start earlier.

191. The clients PQS checks our numbers on negotiated contracts to be satisfied that we have done our job properly.

192. The procurement process has evolved to assists the project participants when tendering for complex buildings.

193. A lump sum tender is less demanding for the clients PQS and provides better continuity and flexibility for the client project team when compared to GMP.

194. Lump sum contracts also offer us the opportunity to make money on the buying gains.

195. There is a professional pecking order within Design and Management companies.

196. Design Management is viewed by team players as a more sophisticated type of organisation but splits remain in the ranks due to interdisciplinary rivalry.

197. Client prime negotiator has the flexibility to spread payment for design over later stages in the project if the costs exceed the budget.

198. The marketing manager needs to have a comfortable relationship with the client to be able to negotiate payments.
Appendices

199. Marketing involvement in negotiation depends on an individual’s ability and experience.

200. The whole process requires constant monitoring by marketing.

201. Marketing manager can determine the finer details of a project and has the influence to call on directors for assistance.

202. Depending on experience, marketing managers have the ability to carry a project vocally and strategically.

203. There is no company direction on how programmes are altered.

204. If a design project overruns the marketing manager seems to be the one questioning the cost implication for the company.

205. Other professional groups are not concerned about costs implications.

206. Designers are seen as concerned with designing and not with company income or about their fellow disciplines.

207. Estimators are seen by marketing as essential facilitators to the design project.

208. Marketing manager recognises the cost implication for not working together as a team and with the client.

From the 208 codes – 27 sub-categories were derived with the numbers in brackets providing reference to the original code.
10.1 THE 208 CODES ARRANGED INTO SUB CATEGORIES

Designers are Seeking Improved Methods of Relating to Client's

A. Architects like to create a building block of the building to better understand the client's requirements. (98)

B. There is a danger of developing too many options early in the design of a building. (105)

C. Architects will help the client to understand how best to use the available space within the new building. (106)

D. Computer simulation (CAD) is used to help client visualise the developed designs. (107)

E. Design options are tested by using the premise of satisfying the client's needs and then revisiting them in terms of commitment with the user group to test the flexibility of the options. (110)

Corporate Level Design Decisions Effect Design Teams

1. Cost planners say they work to a code of practice and await a signature from a director before starting work. (16)

2. Corporate level decisions are made outside the multi-disciplinary teams remit on the type of work undertaken by the company. (67)

3. Economist has to await corporate sanction before starting to process an enquiry. (68)

4. Decisions are made at director level about the most appropriate way to approach a client. (149)

Designers are Concerned about Design Changes

1. Frequent design changes require a Design Change Control document and a budget costing is applied before the designer starts the new process. (78)
2. The project economist keeps a note of all changes in project cost to get an overall picture of cost and this is fed back to the client. (79)

3. When budgets have been set architects worry about variations and additional requirements emerging from the developed options. (108)

4. Architects expressed concern that the user wish list would allow the floor plate to expand and that this would be capped by the corporate stakeholders forcing further redesign. (112)

5. There is no company direction on how programmes are altered. (203)

Designers Sometimes Act on own Initiative

1. Where there is no project co-ordinator the architect will negotiate fire and other regulatory/statutory constraints with the appropriate outside authority and advise the engineer accordingly. (127)

2. Structural engineer sometimes raises extra price costing for further investigation on site soil and the client will pay for all surveys sometimes directly and sometimes indirectly. (128)

3. Structural engineers make professional decisions sometimes on already existing buildings. (131)

4. Certain professional groups indicated that they would continue with the next stage of a project in the absence of a project co-ordinator. (133)

5. Structural engineers would prefer a more organised structure to that they fully understand their design requirement. (135)

6. Structural engineers see their selves taking risk separately to other colleagues and sometimes work on their own. (137)

7. Structural engineers seem pressurised by start dates of a project irrespective of the company decisions about the project. (138)

8. Although elements of competition exist when seeking new work existing relationships promote mutual understanding and help with negotiation. (164)
Appendices

Designers Rely on Company Standard Procedures

1. Designers have a standard VM approach meeting to help the client and establish needs. (71)

2. Value management is a standard approach with all clients to help identify opportunities the client may have overlooked. (72)

3. Cost planners and project costing follow a standard procedure within the company. (81)

4. The cost headings used by cost planners are generic and translate to their bills of quantity. (93)

5. Building design modules will generally follow industry standards. (100)

Team Cooperation in the Interest of the Client

1. Project economist has weekly meetings with designers. (75)

2. Project economist helps the designers to stay focused on the job in hand. (76)

3. Project economists work alongside designers to the end of the project and produce packages for the sub-contractors. (86)

4. Project economists negotiate with designers about estimating plans in order to get the pricing correct. (88)

5. Project economist work alongside other designers and clients to constantly review design and pricing. (90)

6. Architects collaborate with other architectural colleagues to develop their designs. (101)

7. Different professional groups are able to work together linked by the common need to satisfy the client’s requirements. (114)

8. The structural engineer will assist the cost planner when specialist information is required. (125)

Marketing Debriefing may Reveal Valuable Client Intelligence

1. The lead role that a director assumes is sometimes required of the marketing manager. (179)
Appendices

2. The marketing manager using his personal experience is able to match the client's expectations with his budget. (181)

3. Marketing involvement in negotiation depends on an individual's ability and experience. (199)

4. Marketing manager can determine the finer details of a project and has the influence to call on directors for assistance. (201)

5. Depending on experience, marketing managers have the ability to carry a project vocally and strategically. (202)

Improved Multi-Disciplinary Understanding of Cost Planning Required

1. Pricing is crucial to the project, which could mean profit or loss for the company. (2)

2. Cost planners acknowledge that it is important to know the client and the standard the client requires in order to arrive at an appropriate cost. (37)

3. Cost planners concern themselves with company profits. (40)

4. Cost planners acknowledge the market economy and sensitive areas of pricing to the client about his project. (54)

5. Designers can sometimes go down a route that is outside the cost plan. (77)

6. Unusual flexibility towards payments from clients. (189)

7. Other professional groups are not concerned about costs implications. (205)

Interdisciplinary Rivalry

1. Cost planners are only interested and concerned about their particular part in the design process. (26)

2. Cost planners refer to their colleagues as doing separate work. (34)

3. Cost planners do not feel part of a multi-professional team and refer to their colleagues in the company as other teams. (46)

4. Other disciplines are able to liaise with cost planners to verify specifications. This liaison is done outside the multi-disciplinary meetings. (49)
Appendices

5. Sometimes the structural engineer will work on his own initiative when negotiations with colleagues and clients are not possible because of shortage of notice. (130)

6. Structural engineers believe that their input is more complicated than their interdisciplinary colleagues they would like a bigger voice in the team. (136)

7. Different philosophy by different professional groups. (147)

8. Interdisciplinary rivalry between professions is still apparent in the company. (172)

9. The design professionals have their own philosophy with prevents them embracing the values of others. (173)

10. There is too much 'I' and not enough 'we'. (174)

11. No acknowledgement or routine involvement of the person who negotiated the contract I the first place. (176)

12. Different professional groups are seen to be jostling for place in the hierarchy of the design management organisation. (177)

13. There is a professional pecking order within Design and Management companies. (195)

14. Design Management is viewed by team players as a more sophisticated type of organisation but splits remain in the ranks due to interdisciplinary rivalry. (196)

15. Designers are seen as concerned with designing and not with company income or about their fellow disciplines. (206)

16. Marketing manager recognises the cost implication for not working together as a team and with the client. (208)

Some Professions see Themselves Working outside Interdisciplinary Teams

1. Economists believe they can influence good decision taking on strategic matters. (62)

2. Economists are able to educate their prospective clients about unnecessary buildings. (73)

3. Project economists see a project through to the end. (84)

xxxi
Appendices

4. A company response to proposed work would be to decide which professional is best suited to head the project. (145)

5. The marketing manager will continue his involvement to monitor the interaction between the design team and the client. (168)

6. At the start of a new project, the marketing manager will stand in as a quasi project manager during the pre contract phase. (170)

7. Marketing people think of their role as facilitators both dealing with the client requirements and acting as an intermediary between the client and the design team. (178)

8. If a design project overruns the marketing manager seems to be the one questioning the cost implication for the company. (204)

No Project Coordinator – Client

1. No clear project co-ordinator for the client user group has clouded decision-making and started delays in the project. (116)

2. Currently an ad-hoc advisor is being used by the user group but elements of mistrust are visible. (117)

3. No clear client project manager creates long waits for stakeholder decisions. (118)

4. Client professional advising the user group have been given the responsibility to try to provide solutions to client driven problems. (119)

5. Depending on the project one of the factors of delay can be getting the principle stakeholders to undersign what is being proposed and sign off the design. (134)

6. The project manager that is brought in later will have total responsibility for the project operation. (171)

7. The client led engineering group plays a leading role in the project and becomes the intermediary between the designer and the higher-level stakeholders. (188)

No Project Coordinator – Designers

1. Cost planers present their work to people higher on the decision ladder to seek approval before submitting their price. (41)
2. Cost planner hand their work over to quantity surveyors when their work is complete. (47)

3. The architect collects all the notes taken at user group meetings and provides them to the other disciplines so that intra-disciplinary problems may be uncovered. (113)

4. Where there is no project co-ordinator the architect will negotiate fire and other regulatory/statutory constraints with the appropriate outside authority and advise the engineer accordingly. (126)

5. Structural engineers are required to provide management role in the absence of a project co-ordinator. (129)

6. Project co-ordinator manages the team better than individual design professionals. (175)

7. Estimators are seen by marketing as essential facilitators to the design project. (207)

*Multi-Disciplinary Experience during Brief Development*

1. Each project is assessed for its potential worth both as a design commission and eventual construction. (21)

2. Cost planners rely on a good client brief to help define the scope of the cost estimates. (45)

3. Economists would prefer to introduce their experience during the brief taking process as they feel it helps to focus the design. (61)

4. Some clients provide a comprehensive brief with their own feasibility study. (64)

5. Economists sometimes try to win client contract and open themselves to be informed by the client who know what they want. (65)

6. Value management is undertaken at the start of the brief investigation process as it helps with understanding the client needs. (70)

7. The marketing manager needs to be able to interpret his client’s strategic and building requirements. (180)
Appendices

Risk Analysis is Under Employed at Early Stage Design

1. Risk is mitigated at the lump sum stage to the client. (5)

2. Cost advice on GMP contracts carry risk to the company as it is undertaking to cap the price. (30)

3. Risk analysis is only considered important at GMP or at lump sum stages. (38)

4. The risk analysis and knowing where risk resides is considered an intuitive part of a cost planners work. (39)

5. Overlap of project at different points means different disciplines introduce different elements of risk when stags have not been completely signed off. (132)

6. Structural engineers see their impact as sometimes reducing pressure on the team. (140)

7. Big companies can sometimes work blindly with no fixed fees. (182)

8. Other team players that do not know the client run the risk of producing something that is outside the client cost and outside what he wants. (186)

New Strategic Business

1. Sometimes estimated jobs can lead to further work for the company. (14)

2. Sales team members can have a varied background. (141)

3. Sales team canvas for company business. (142)

4. Organisational strategies allow the business development manager to tender for opportunities of future work for the company. (143)

5. Design and Management work opportunities is part of the sales directors strategies. (144)

6. Company business is generally the result of strategies that have been campaigned by the sales department. (146)

7. Selective marketing and advisory service to customer helps to secure future work. (150)

8. Business development managers bring in the bread and butter contracts and look for prospective future income for the company. (152)
Appendices

9. Local satellite companies will pass larger enquiries up to the main board for processing. (153)

10. Company mergers within the group have provided opportunities to develop relationships with new clients. (155)

11. Company mergers have provided the company with additional resources to enable them to seek larger projects. (156)

12. The company also relies on its reputation for providing recommendations and repeat orders. (159)

13. Future contracts are often negotiated. (161)

14. Future contracts are sometimes secured by tendering. (162)

15. The marketing manager first secures the enquiry for the company. (167)

Marketing Networking has Valuable Intelligence on Principle Stakeholders

1. Structural engineers believe AMEC Construction’s marketing department do a good job. (139)

2. The marketing strategy is to develop a relationship with a client rather than target projects. (148)

3. Work is done to develop social contact with prospective clients to build up personal relationships. (151)

4. Through nurturing past and older acquaintances, the marketing manager has developed new business opportunities for his company that can bring in multi million pound deals. (154)

5. Social networking is seen as one route to promoting business. (157)

6. The marketing department have used social networking to provide the company with exclusive enquiries. (158)

7. Social networking with wives and families is seen as one type of promotional method. (160)

8. The company often use free consultancy to promote enquiries. (165)
9. The marketing manager will continue to make social contact during an enquiry with the client to help promote company strategy. (169)

10. Marketing manager continues to work with the client as a moral responsibility providing advice. (184)

11. The marketing manager needs to have a comfortable relationship with the client to be able to negotiate payments. (198)

**Cost Planners Rely on Information from Others**

1. Cost planners feel they are always waiting information from others. (36)

2. Cost planners rely on other disciplines to see or write to them about specifications in order to provide a cost. (50)

3. Cost planners rely on building up historical rates when providing cost advice to clients. (51)

4. Cost planners working on complicated designs will often use provisional sums and rely on negotiating the elements of cost with the client. (52)

5. Cost planners use benchmarking to demonstrate the validity of their pricing to a client. (53)

6. Economists rely on the quality of the information taken from the client by the designers. (60)

7. The project economist relies on costing of some items outside the company and overall project costing will depend on the information provided from design colleagues. (80)

8. Project economists rely on drawings submitted by other design colleagues for costing. (87)

9. Building up a price structure will depend on the expectations of the client and the extras required. (91)

10. The whole process requires constant monitoring by marketing. (200)
Appendices

Cost Planning Follows a Set Procedure

1. An enquiry plan is raised for each enquiry as it arrives it will show scope and the client's estimate of costs. (12)

2. Cost planners establish whether an enquiry is formal or informal. (17)

3. Fee managers oversee the enquiry and cost planners prepare the cost advice. (18)

4. Fee managers issue the enquiry plan. (19)

5. The enquiry manager will take the enquiry plan and produce a method statement that outlines design cost responsibilities to the client. (22)

6. The project economist will decide with cost planners how they are going to build up the cost. (24)

7. An estimating plan is produced by the cost planners and issued to the design team. (25)

Designers Require Quality Information from the Client

1. Cost planners recognise where the client's brief is not well defined and claim in such cases the process is likely to take much longer. (35)

2. The type of contract will depend on the information given to the client about his project. (63)

3. User group meeting with various stakeholders provides the basic accommodation requirements. (102)

4. Floor plans emerge after co-ordinating all requirements. These are then arranged to suit the site location. (103)

5. Once a starter footplate is agreed, the cost planners will be asked to apply money against square area and start developing the cost. (111)

6. The lead architect has to wait for information from other disciplines before a clear indication of cost can be established. (115)

7. The end solution is chosen by the Structural Engineer for its engineering merit after first receiving the cost advice provided by the cost planners. (122)
Appendices

Project Participants prefer Lump Sum Cost Advice

1. Lump sum payment to the company can sometimes work in the company interest and sometimes against the company interest. (4)

2. Project economists will give final lump sum pricing after the work has started on site. (95)

3. Project economists cut off point for lump sum pricing depends on other departments providing their work details and schedules on time. (96)

4. A lump sum tender is less demanding for the clients PQS and provides better continuity and flexibility for the client project team when compared to GMP. (193)

5. Lump sum contracts also offer us the opportunity to make money on the buying gains. (194)

Clients prefer Guaranteed Maximum Price Cost Advice

1. GMP is a type of cost advice used in Design and build procurement projects. (7)

2. Cost planners ask for market rates at GMP stage to mitigate their exposure to risk. (31)

3. Bills of quantity are produced for a GMP. (32)

4. By the time GMP is finished a large part of the detail design will have been completed. (33)

5. At GMP stage, cost planners negotiate with contractors to hold their quoted prices. (57)

6. Clients prefer to know £+0-% rather than £+/-% and the marketing manager works with the company economist to help communicate the clients requirements. (185)

7. Reimbursable prime cost is the clients preferred method of tendering and the add-on GMP cap will allow the project to start earlier. (190)

Order of Cost Advice during Conceptual Design

1. At +/-20% order of cost a nominal fee of 5-10% of the contract value may be quoted for the design. (20)

2. At +/-20% order of cost, estimates are based on block floor plans that outline the functional area to be designed. (27)

xxxviii
Appendices

3. At +/-20% order of cost it will normally take two days to confirm a price once all the documents have been received from the designers. (29)

4. At +/-20% order of cost, cost planners provide estimates based on general floor area. (42)

5. At +/-20% order of cost, cost planners will have a general specification to help them. (43)

6. At +/-20% order of cost changes to specification can be handled on a pro rate basis. (55)

Two Stage Tendering Mitigates Risk

1. Cost planners use outside companies to verify pricing for specific elements. (56)

2. If a GMP is negotiated then it is up to that company to take on the construction work, as other companies would not wish to proceed on the cost advice provided by another company. (59)

3. Two-stage tendering is where AMEC Construction chose a partner from a list of contractors who must first tender for the contract then designs the element with a view to carrying out the work as a sub-contractor. (82)

4. Outside contractors participating in two-stage tendering will be expected to work at AMEC Construction’s offices and will become part of the multi-disciplinary team. (83)

5. Work packages comprise of bills of quantity made up for a particular trade to tender for the works. (94)

6. Project economists rely on all the various disciplines producing their part of their work on time in order to do the costing. (97)

7. The procurement process has evolved to assist the project participants when tendering for complex buildings. (192)

+/-10% Cost Certainty at Scheme Design

1. Cost advice will depend on client requirement and the design team /stage. (1)

2. Cost planners can provide cost certainty and help fix the contract price. (3)
Appendices

3. Type of cost advice to the client will depend on the scope of the project. (6)

4. Costing can vary considerably in its accuracy. (11)

5. The enquiry plan will also identify the level of cost certainty required. (13)

6. At +/-10% cost certainty, the areas are broken down into measured elements and bills and schedules are priced. Documents are prepared for collecting market rates. (28)

7. At +/-10% cost certainty the cost advice is usually delivered with the definition brief it is then up to the client on how they wish to proceed. (58)

8. The process of detail design will allow accurate pricing that will be acceptable to the client. (89)

9. Cost will eventually drive the architectural design and it is hoped that this will not provide further constraints. (120)

Cost planners Importance during Client Negotiation

1. Some clients have already decided the procurement route. (8)

2. Sometimes the cost planner will provide robust cost advice that can follow a number of routes. (9)

3. The liaison between the cost planner and the client depends on the enquiry manager. (23)

4. Cost planners are often given specifications and drawings without prior knowledge of the project. (44)

5. Economist sometimes quotes to the client fixed rates if the client knows what they want. (66)

6. Economist find clients are often enlightened about their needs and wants and already have their own PQS on their team. (69)

7. Project economists work along with the client and their budget to look at various options. (85)

8. Clients expect comparative estimates. (163)

xl
Appendices

9. Estimates are given by the designers, but these are often a part of on-going negotiation. (183)

10. The clients PQS checks our numbers on negotiated contracts to be satisfied that we have done our job properly. (191)

11. Client prime negotiator has the flexibility to spread payment for design over later stages in the project if the costs exceed the budget. (197)

Coordinated Gathering of Information

1. Cost planners receive their enquiries in a number ways. (10)

2. Cost planners are able to identify areas on paper that require specific treatment. (48)

3. Cost planners are divided into specialist teams who deal with specific disciplines. (92)

4. Architects generally collect more information than they will use but feel that necessary to provide sufficient choice. (99)

5. Different structural frame types are assessed before structural engineer makes decisions on the best solution for a given project. (121)

6. Structural engineer would have a professional bias on a particular style of building and would push for this after first observing the project specific requirements. (123)

7. Cost planners are provided with floor plans, frame section dimensions and weights from which they prepare their estimates. (124)

Multi-Disciplinary Teams Understand Client Best

1. Economists accept there to be a need for further training on how best to prescribe to their clients needs. (74)

2. In multi-disciplinary laboratories, relationships between disciplines are taken into account before establishing layouts. (104)

3. Architects have employed design strategists to liase with client specialists and users to negotiate finer details. (109)

4. Core multi disciplinary teams are quickly formed to help negotiate an enquiry with a new client. (166)
Appendices

5. Close cross-disciplinary interaction is required if the best overall solution is to be achieved for both the client and the design management organisation. (187)

The 27 Sub-Categories were crashed to establish the 8 Core Categories discussed in the main text.
11.1 THE 27 SUB-CATEGORIES

1. Designers are Seeking Improved Methods of Relating to Client's

2. Corporate Level Design Decisions Effect Design Teams

3. Designers are Concerned about Design Changes

4. Designers Sometimes Act on own Initiative

5. Designers Rely on Company Standard Procedures

6. Team Cooperation in the Interest of the Client

7. Marketing Debriefing may Reveal Valuable Client Intelligence

8. Improved Multi-Disciplinary Understanding of Cost Planning Required

9. Interdisciplinary Rivalry

10. Some Professions see Themselves Working outside Interdisciplinary Teams

11. No Project Coordinator – Client

12. No Project Coordinator – Designers

13. Multi-Disciplinary Experience during Brief Development

14. Risk Analysis is Under Employed at Early Stage Design

15. New Strategic Business

16. Marketing Networking has Valuable Intelligence on Principle Stakeholders

17. Cost Planners Rely on Information from Others

18. Cost Planning Follows a Set Procedure

19. Designers Require Quality Information from the Client

20. Project Participants prefer Lump Sum Cost Advice
Appendices

21. Clients prefer Guaranteed Maximum Price Cost Advice
22. Order of Cost Advice during Conceptual Design
23. Two Stage Tendering Mitigates Risk
24. +/-10% Cost Certainty at Scheme Design
25. Cost planners Importance during Client Negotiation
26. Coordinated Gathering of Information
27. Multi-Disciplinary Teams Understand Client Best
DEFINITION BRIEF OR SCHEME DESIGN?

It has become important to understand the difference between these two descriptions relating to a stage within the design process employed at AMEC Construction. At the outset of this research into Early Stage Design, the boundaries within which the research was to concentrate were constrained by the start of Concept Design and the end of Scheme Design. A decision was made to base the research on the development of Scheme Design after initially shadowing a concept study into a new drug research complex undertaken by AMEC Construction that have continued through to the construction stage.

The production of the Scheme Design is considered to mark the end of a front-end study period used by designers to develop the initial client brief. This period is generally recognised as stages A-D or Inception - Scheme Design in the RIBA Plan of Work. (RIBA 1973) This culminates with a report that can be signed off by the client before starting the Detail Design stage E and forms the design brief for the design team.

After the initial Concept Study for the drug research complex was signed off and agreed to by the client a further stage of development was undertaken before entering into Detail Design, this stage was for the production of the Definition Brief. The Definition Brief outwardly employed all the elements usually associated with Scheme Design. However, the lead architect for the project considered it important for there to be a distinction between the Definition Brief and the end of the Scheme Design process. The lead architect pointed out that, had the Concept Study been carried out by another firm of designers, then a further full period of consultation and development would be required to confirm the information provided in the Concept Study. This would have been called Scheme Design that formed the basis for the Detail Design stage. Hence, for an initial explanation of where a Definition Brief is different to Scheme Design, it may be said that where a project is developed by one design company then the full Scheme Design would not be necessary.

In the instance where the same design team was to be used for the Concept Study and the Detail Design, it was not deemed necessary to conduct this further full period of consultation and development. In this particular case sufficient understanding of the project
had been established by the team to enable them to deliver a Definition Brief that would form the basis for Detail Design.

The lead architect for that project provided an example this point:

At the end of a Concept Study when a client is asked to sign off and agree a developed brief for a proposed development, consideration will have been given to meeting the client's requirements. This will be in terms of practical responses to the functional requirements and esoteric responses to the aspirations of that client for the building and its proposed location. It will include all the elements deemed necessary to meet these criteria and include a clear understanding of, and response to, both user and engineering requirements in order to relate these requirements to the existing physical site restraints. These proposals will generally be confirmed in the form of sketch layouts and a document defining the selected option together with the design philosophies used for the proposed building design. In addition to this, the Concept study will also include benchmarking data, a commercial strategy proposal and a cost plan summary that will allow the client to establish the budgetary targets for the development.

Following this a further period of consultation between the design disciplines is required before a design brief is produced that can be used by the design team to develop Detail Design. This document will form the Scheme Design document at stage D of the process. It will involve the development of spatial arrangements, materials and both the internal and external appearances of the building. The process would generally be architecturally led. However, depending on the type of building being considered and/or the priorities of the client identified during the Concept Study, the dominant design discipline in the process would dictate this stage of the design process (Table F.1). Increasingly this stage is used to develop the cost plan and is subjected to strong financial influence from both client and design team surveyors and cost planners respectively.
Appendices

<table>
<thead>
<tr>
<th>Discipline in order of design priority</th>
<th>Type of building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural (A)</td>
<td>General building requirement such as</td>
</tr>
<tr>
<td>Structural Engineer (S)</td>
<td>Office Accommodation</td>
</tr>
<tr>
<td>Civil Engineer (C)</td>
<td></td>
</tr>
<tr>
<td>Mechanical Engineer (M)</td>
<td></td>
</tr>
<tr>
<td>Electrical Engineer (E)</td>
<td></td>
</tr>
<tr>
<td>Process Engineer (P)</td>
<td></td>
</tr>
<tr>
<td>P M A S C E</td>
<td>Processing Plant</td>
</tr>
<tr>
<td>A S C P M E</td>
<td>Manufacturing Plant</td>
</tr>
<tr>
<td>A M E S C P</td>
<td>Hospital, Laboratory or other highly engineered building.</td>
</tr>
</tbody>
</table>

Table F.1: Lead Design Disciplines against Project Type

Both the Definition Brief and Scheme Design will include a detailed brief that describes the functional requirements, design principles and how they are to be developed into the building form. These are then developed into the building architectural, structural and services requirements. This brief contains general statements covering issues such as engineering requirements, floor and wall finishes and will form the contract between client and designer for the detailed design and construction of the building. Typically, it will also include:

- A developed cost plan to a +/-20% or +/-10% accuracy of the final construction cost including provisional sums.

- Architectural Layout Drawings at a 1/200 scale

- Civil and Structural Engineering General Arrangement Drawings at 1/100 scale

- The Mechanical and Electrical schematics with layouts and general philosophies

- Copies of Standards and Studies used in the preparation of the report

- Room Data, Equipment Lists and 1:50 scale room layouts.
According to the lead architect, once all the design work and all cross-disciplinary negotiations have been completed the architects will generally be allowed a further period to consider the impact or visual consequence of the design decisions before submitting the completed Scheme Design. It is in this further period that the Definition Brief and Scheme Design vary as the lead architect claimed it to allow the architect to consider the overall ambience of the design solutions before committing the project to Detail Design.

Increasingly, in order to save time and help reduce design costs as in the case of the drug research complex, the final part of the Scheme Design process is incorporated within the initial stage of Detail Design, generally without causing any significant impact on the process.

The difference therefore between the preparation of a Definition Brief and the completion of the Scheme Design process is subtle but considered non-the less architecturally important. The concern from some architects is that this difference, usually involving a further period, may be overlooked on commercially driven projects, with the resulting diminution to the value of the service provided by the architectural profession.

A commercial opinion on the Definition Brief and Scheme Design was sought from the project economist. The project economist confirmed that in terms of the cost plan the point at which the Definition Brief is produced would fall is somewhere between the cost certainty of +/-20% and +/-10% accuracy and provided a sketch of the process for the drug research complex. (Figure F.1)

Clearly, achieving a working design brief for this project at a slightly earlier stage than normal had allowed both the client and design team the opportunity to continue onto Detail Design. This was achieved at an earlier point than would have otherwise been possible had all the requirements of a full Scheme design been met before doing so.

In the field of multi-disciplinary building design where the process is being monitored and negotiated with a single design body as in this case, the advantage in terms of time and cost to the client is evident. Given alternative circumstances, where either the stages of the design are negotiated with different organisations or there is a requirement to create periods from which to review the development of the design, a full Scheme design stage would be unnecessary.
Figure F.1: Commercial Explanation