AN INVESTIGATION OF THE REPRESENTATIONS OF USERS' REQUIREMENTS IN THE DESIGN OF INTERACTIVE SYSTEMS

By

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AUTHORS' RESPONSIBILITY FOR THE WORK SUBMITTED

The investigation described in this thesis was undertaken by the author as the sole investigator. The exact responsibility of the author is described below.

The methodology applied to the investigation of the design of interactive systems was developed by the author. The methods applied to the data collection were drawn from the field study approach and were adapted to enable the data collection to focus on areas relevant to the research. The design of the interview format, the design of the pro forma applied to the observational data, and the design of the pro forma applied to the documentation data, were developed by the author. The analysis of the data collected with these methods is also the authors' responsibility.

The identification of the key factors in design that led to the findings discussed in the thesis was the result of the author's analysis of the data collected from the investigation. The discussions of the results of the investigation, and the discussion of the implications for the field are the responsibility of the author.

ABSTRACT

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The design of interactive computer systems was identified as an important area for investigation due to the increasing evidence of a discrepancy between the intended use of the systems, and the use by users. This led to the hypothesis that the discrepancies between systems and users were attributed to an inadequate representation of users' requirements in the design of the systems. Therefore, the research focused on the design process, and how users' requirements were represented in the process. The research was based on an investigation of two areas of design: the type of design processes that developed in system design, and the representations of users' requirements in design. Studies were based on structured interviews with designers, on observations of design teams engaged in design tasks, and on documentation from design projects.

A major component of the research findings concerns the design context. The research has made it possible to see how the variations in design relate to the context in which it takes place. Some of the primary contextual influences include the commercial constraint, the pressure to innovate, and the specialisation in user interface design. Another significant finding relates to the representations of users' requirements in the design process. Two key issues emerge from the findings. First, designers approach design tasks with a technical, system based design model. The application of this model to design tasks is often inappropriate; however, designers lack design schemas appropriate to user related tasks.

The second issue is that designers often work with inadequate information on users' requirements. The design process is characterised by limitations of information on users' information in design tasks. The extent to which these limitations are experienced by designers differs according to the design context.

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INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 ISSUES OF HUMAN-COMPUTER INTERACTION

The wide spread use of interactive computer systems in organisations to support users in their everyday tasks has given rise to a number of important issues relating to the interaction between users and computers. These issues have developed out of the increasing evidence of a discrepancy between the intended use of office systems and the usability of the systems. This discrepancy influences the degree to which the potential benefits of these systems to user organisations can be realised and is therefore important to address. The evidence from evaluation studies of implemented systems indicate that this discrepancy is primarily caused by basic incompatibilities between systems and users' requirements. The kinds of issues arising from this concern two aspects of human-computer interaction; the users of systems and the systems themselves. Among the issues relating to the users, are the requirements of the potential users, the characteristics of the users and their performance and usability of systems. Relating to the system, the issues concern how to improve the performance and usability of systems, how to develop prototypes rapidly, and ways to improve the user interface of systems. As a consequence the field of human-computer interaction has become important, and new strands of research have developed to address these issues.

The research project was stimulated by an interest in the causes of the mismatch between systems and users. Two questions in particular motivated the research: one, where do the primary causes of the incompatibilities between systems and users lie, with the systems or with the users, and second, how well are users' requirements represented in the design of systems? A starting hypothesis was that the design of the user interface of interactive systems was a crucial factor in the usability of systems, and that the misrepresentations of users' requirements in this part of the design could contribute significantly to the incompatibilities between systems and users. This was identified as an important area to investigate further. It was believed that research into the design of systems could make a significant contribution to the field by extending our understanding of design in this area. It was also believed practical implications could result from identifying problems in the design of systems that directly influence compatibility with users' requirements.

1.2 THE INVESTIGATION OF THE DESIGN OF INTERACTIVE SYSTEMS

The research project was based on the investigation of the design of interactive systems. The investigation focused on two areas of design, first, the types of processes that are involved in the design of systems, particularly the user interface, and second, the representation of users' requirements in the design process. The research consisted of three types of design studies that provided different perspectives on these two areas. The first study was based on observations of design teams engaged in the design of new systems; these were situated in a research-product environment. The second study consisted of interviews with designers specialised in user interface design, during which the critical incidents in previous projects were reconstructed by the subjects; these took place in a commercial-product environment. The third study used the documentation of design projects as data; this was from a research-product environment.

The research was directed by the following questions which were investigated in each of the studies:

a. ***<u>the design process:</u>***

- the types of activities designers engaged in;
- methods and techniques applied in design;
- the factors that inhibit the design process.

b. ***<u>the handling of users' requirements in the design process:</u>***

- the types of design decisions involving users;
- the sources of user information on which design decisions and solutions were based;
- the methods and techniques used to incorporate users' requirements into design solutions.

Although each study provided a different form of data, the combination of the data from the three studies enabled these questions to be examined from different perspectives. The objective of the studies was to gain as much of an understanding as possible of the kinds of factors that influence the representations of users' requirements in design.

1.3 OUTLINE OF THESIS

The thesis is organised around eight chapters and three appendices containing excerpts from the observational, interview, and documentation data. The core of the thesis is contained in Chapters 4, 5, and 6, in which the data and the analysis of each study is presented. Each chapter begins with a discussion of the methodology applied to the study, followed by an analysis of the data, and concludes with a discussion of the results which draws upon research in the field. The structure of the thesis is described as follows:

Chapter 2: State of The Art Review and Research Questions

Chapter 2 contains a state of the art review of the field; it provides the background for the research, and also highlights where in the field the research is situated. A literature review is not provided in this chapter because it was considered more appropriate to include a summary of the literature as it pertained to each study.

Chapter 3: Pilot Studies and Methodological Issues

Chapter 3 discusses the methodological issues of studying design in the field that emerged from pilot studies conducted in the early stages of the research. The methodological approach to the investigation is discussed in broad terms, because the use of three different data collection methods make it more appropriate to discuss each method in conjunction with the presentation and discussion of the data collected with each method.

Chapter 4: Observational Studies of The Design Process

Chapter 4 presents the data and the analysis of the two observational design studies. It begins with a discussion of the sampling frame, and a discussion of the methodology applied to the analysis of the data. The findings are presented at two levels, the first relates to the overall design process as represented by the data, and the second concerns the representation of users' requirements in the design process. The chapter concludes with a review of other research in the field to which the findings contribute.

Chapter 5: Design Through Critical Incidents in Interviews

Chapter 5 presents the data collected from the interview studies. The format is similar to the previous chapter, and begins with a description of the methodology used for collecting the data. It presents the data in terms of the critical incidents reconstructed by the subjects during the interviews.

Chapter 6: Design As Represented Through Documentation Data

Chapter 6 is based on the data collected from the two documentation studies. The analysis of the data focused on two particular parts of the documentation; first, the types of tasks designers engaged in, and second, the types of user representations evident in the data.

Chapter 7: Factors That Shape The Design Process

The findings from the three studies are individually summarised in Chapter 7. The methodological and contextual influences on the findings are discussed. The dominant themes that were evident across the studies and the key points to arise from these themes are also discussed in this chapter. Possible explanations for the factors that shape the design process are explored.

Chapter 8: An Evaluation of The Methodological Approach and Considerations for Future Research

The thesis concludes with Chapter 8, which provides a critique of the methods used for studying design, and also identifies further areas for research. The practical ramifications of the research findings are also discussed in the chapter.

Examples from the data are provided in each chapter, and longer excerpts from the data and the pro formas used for collecting the data, are provided in Appendices A, B, and C.

1.4 CONFIDENTIALITY OF THE DATA

Confidentiality agreements were made with each of the organisations from which the data was collected. This was particularly important as the system designs studied were potential products for the market. All possible measures have been taken to ensure the confidentiality of the designers, the organisations, and of the systems under design. This has been done by changing project names wherever necessary, systems have been referred to by generic types, and no references have been made to designers' identity. The examples provided in the thesis from the data, have omitted specific references to products, designers, and to the organisations.

Due to the confidentiality of the source data it has remained with the author. However, the process data from the three studies are available from Professor Ken Eason at Loughborough University. The author can be contacted for assistence in evaluating this material should anyone be interested in doing so.

1.5 ACKNOWLEDGEMENTS

I am deeply grateful to the organisations that granted permission to have the design of their systems studied either through interviews, observations of design meetings, or through design documentation. In consideration of the sensitivity surrounding the study of design, due to confidentiality issues, and the exposure of design practices, I am especially appreciative to these organisations for being willing to have an outsider closely examine such a sensitive area. I am also indebted to the individual designers in the interview studies for their valuable time and willingness to freely discuss design projects in order to contribute to the research project. Special thanks are also given to the designers who permitted themselves to be observed while engaged in design tasks, without them the research would not have been possible.

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CHAPTER 2

STATE OF THE ART AND RESEARCH QUESTIONS

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2.1 STATE OF THE ART

The current trend in computing has given rise to a number of important developments concerning the impact of integrated office systems on organisations. The impact is seen in terms of the potential of office systems to meet user and organisational requirements and also in the changes office systems affect in organisations. The growing interest in this area has resulted in a number of studies of the potential benefits and impact of office systems on organisations. The findings from the majority of these studies conclude that office systems continually fall short of achieving intended benefits due to a combination of inhibiting factors (Boddy et al, 1983; Eason et al, 1974; Bjorn-Anderson et al, 1979; Keen, 1981). Unfortunately, the results of many of the studies conducted during this period have been unpublishable due to confidentiality, however, in several instances the results became unofficially available. In the capacity of an office systems consultant during this period, the author participated in the specification and implementation of several office systems, and engaged in evaluation studies of newly implemented office systems. A common theme emerged in the experiences gained from these studies and in those reported by others involved in similar studies. There was increasing evidence of a mismatch between the intended use of office systems, and the actual use of these systems; office systems were not meeting their anticipated potential in organisations. Evidence of this was also visible in the programme of office automation pilot projects in 21 different sites launched by the U.K. government in 1982 (in which the author participated as consultant). Evaluation studies of these sites revealed a combination from unreliability affecting usage, to word processors without printers, to the lack of senior management commitment. An important point made in the final report of the pilot project evaluation studies was that "Systems are likely to have the most impact if they address fundamental operational activities and are coupled with changes in organisations" (Information Technology in The Civil Service, 1986).

The research project was stimulated by the issues that arose from the incompatibilities between systems and users and the dilemma this presented to the field. Two questions in particular motivated the research in this area; firstly, where do the primary causes for the mismatch between systems and users lie, with the systems or with the users, and secondly, how well are users' requirements represented in the design of office systems?

2.2 INCOMPATIBILITIES BETWEEN USERS AND SYSTEMS

The community of HCI researchers responded to this dilemma in different ways. Some research was directed towards improving system design, and other research addressed understanding users; however, it was commonly recognised that the incompatibilities between systems and users resulted in unsuccessful systems, regardless of where the problems were rooted. Winograd and Flores claimed that most unsuccessful computing systems have been relatively successful at "the raw technical level but failed because of not dealing with breakdowns and not being designed appropriately for the context in which they were to be operated" (Winograd and Flores,1986, pp.84). A commonly recognised cause of system failure was user rejection, due to its threatening nature to the users (Ingersheim, 1976). Others in the field also recognised users' rejection of systems could be potentially related to issues of system design and performance (Uhlig, Farber, and Bair,1979). Flores claimed that "a system that provides a limited imitation of human facilities will intrude with apparently irregular and incomprehensible breakdowns" (Flores, op.cit., pp.137).

It became widely accepted during this time that there were certain basic criteria office systems needed to meet in order to stand a chance of success. Among these were a) to support a range of different functions, b) provide an aid to problem solving activities, and c) to integrate different processes (Newman,1987). A number of principles emerged from the experiences that aimed at reducing the probability of system rejection by users. One of the important principles was to ensure user feedback to system developers and to management; this became recognised as an important part of the system design (Uhlig, op.cit.).

2.3 RESEARCH APPROACHES TO DEVELOPING SOLUTIONS

The focus of interest in the field at this time was on improving the usability of office systems, through the application of engineering principles to system design, through improvements to task performance, and through gaining a better understanding of users' characteristics. The underlying philosophy was "know thy user", (e.g. Rubinstein and Hersh, 1984) out of which terms like 'easy to use' and 'user friendly' arose. New principles for interactive design emerged, for example, "an early focus on users, interactive design, empirical measurement and iterative design" (Gould and Lewis, 1983). It was proposed that designers go one step further than human factors and also understand "....the cognitive and emotional characteristics of users as they relate to a proposed system" (Gould, op. cit., p.51). Design steps were outlined with the intention of providing a guide for designers in this new focus in design. The following are two examples of popular design approaches proposed to designers during this period.

Example #1:		**Example #2:**
1. Define the tasks the user has to perform.	1.	Defining an appropriate metric for measuring usability.
2. Setting explicit levels of usabiity.	2.	Setting explicit levels of usability to be achieved.
3. Gather relevant hardware/software constraints.	3.	Determining an appropriate methodology for building usability into the system.
4. From guidelines, design a first prototype		
5.Test the prototype with users.	4.	Delivering a seemingly functional system with an
6. Iterate changes in the design and is reached.		repeat tests until the deadline
		easily changed interface very early in the development cycle.
	5.	Recognising the tentative nature of the initial design.
(Olson, 1985)		(Wixon and Whiteside, 1985)

The HCI field developed researchers adopted divergent approaches to finding solutions to system-user incompatibilities. One approach focused on the design of systems and aimed at an iterative design approach based on rapid prototyping and the evaluation of interfaces (e.g. Carroll and Rosson, 1984; Gould op.cit.). The philosophy underlying this approach was to quickly build a user interface which could be modified and refined after user testing. In this way the system-user incompatibilities could be identified early on and therefore eliminated in the final design. One strand of research in this area was directed at developing rapid prototyping techniques that could support this process (Roach et al; Jacob; Whiteside et al, 1983; (Richards et al; Henderson; Hix et al,1986). Another focus of research was on the development of interface simulations for studying user interactions (e.g. Kelley, 1984; Good; Whiteside; Wixon and Jones, 1984).

Another research strand steming from this approach was based on the development of methodologies for the evaluation and benchmark testing of interfaces (Moran and Roberts, 1983; Lund, 1985; Good, 1985). The focus was on the development of empirical methods such as verbal protocol techniques with which to identify user problems with systems (e.g. Lewis,1982; Mack, Lewis and Carroll, 1983). The development of analytic performance models with which to predict user behaviour also formed part of this research (Carroll; Moran; Pew; Wixon,1986).

Other solutions to the user-system dilemma were investigated through the exploration of the statement "know thy user". The research in this area focused on the cognitive understanding of users through the development of user models and different classifications representing user types (Douglas and Moran,1983). The identification of user expectations became an important focus of research in this area as researchers attempted to understand how users perceived systems and performed tasks (Payne, Green, Bannon et al,1983; Mack,1984).

Another approach in the field focused on the development of user-centred techniques that aimed at users and system developers working together in the development of end user systems (HUSAT, Loughborough University). Studies based on an action research approach were concerned with the development of techniques that could be applied to the design process, and thereby improve the usability of systems (Bjorn-Anderson; Eason and Robey, 1986; Eason et al,1987).

The primary focus of research in the field at this time lay in the development of solutions that would lead to improvements in system usability, and therefore implied the incompatibilities between users and systems principally rested with the user. Very little attention was directed towards identifying the problems designers incurred during the process of designing interactive systems, or to the problems that might exist with incorporating users' requirements into the design process. Nevertheless, it was becoming apparent that both of these areas required further attention. With regards to users' requirements, it was acknowledged that designers seldom had adequate information on potential users of systems or on the application domain and often resorted to piecing together bits of information. An illustration of this is seen in the following example:

> "During the design of the user interface, the development group spent a lot of time trying to anticipate what the user would want and expect from the application. There was a large amount of information gathered from user comments on the predecessor product, some ideas gathered from reading articles on human factors, and some new ideas which were all considered in the design" (Lund, 1985, pp.107).

A panel discussion on the controversial issues arising from designers being instructed to "know thy user" raised some critical points. One point was that information about users is seldom, if ever applied to the design of real systems. There were a number of important questions addressed by the panel; two key questions were a) what types of information about users are relevant to design, and b) how can this information be applied to the user interface? (CHI'86) Whiteside focused on the lack of the application of user information in design in his reply to the first question "apparently none, for it usually proceeds without any." Whiteside's reply to the second question is provided in full because it encapsulates the kinds of issues that originally motivated the research.

> "The simple answer is that information about users is not integrated into the design process. Further, the coherent design process into which such information might be integrated does not exist. The design process is disorderly and radically transformational, bearing little resemblance to the mythical state of affairs portrayed in orderly, stage-wise diagrams found in text books and engineering manuals. In actual design, politics, emotional commitment to one's own ideas, fatigue, personality differences, mistakes, misconceptions, and the like exert a powerful influence on the end result.
>
> User interface design often rests upon a lost distinction -- that of ourselves vs. others.For the most of us, ease of use to ourselves means the same as ease of use to the other person. When it comes to the fundamental act of creation that is design, designers don't consult guidelines, don't -- for the most part -- run experiments, and do not seek to transcend their private view of the user". (Whiteside, 1986, pp.86) .

Several points in Whiteside's argument echoed the concerns underlying the research questions, two points in particular stood out:

"the coherent design process into which such information might be integrated does not exist", and the "lost distinction - that of ourselves vs. others", and that designers "do not seek to transcend their private view of the user" (Whiteside, op.cit.). There were reiterations of this argument by others who also made the claim that when designers did not have sufficient information, nor understanding about potential users, "they are less able to grasp 'user logic', and may rely more on familiar 'logics' or intuition" (Grudin, 1986, pp.281), or hypotheses (Newman, op.cit.) or assumptions based on "common sense theories" (Hammond, Jorgensen, Maclean, Barnard, Long, 1983). The designer is often "left to create his own organisational reality and this may not coincide with the reality of people in user organisations" (Hedberg and Mumford, 1975, pp.15). Hedberg and Mumford (op.cit.) hypothesised that system designers work from a model of man that is different from a model of man held by users. They argued that a poor fit between these models of man is likely to make computer systems unacceptable to users. Gentner and Stevens (1983) also claimed that often there was little correspondence between what they describe as the conceptual model of the design that guided the designers, and the "system image" presented to the user.

The controversy that developed in the field from the different conceptions on solutions to improving system usability thus far was polarised around the system and the user. System oriented solutions were based on developing technical tools for prototyping and simulations of interfaces, and thereby aimed at improving the system (Carroll, op.cit.; Gould, op.cit.; Roach, op.cit.; Jacob, op.cit.; Whiteside, op.cit.). Further improvements to systems were sought through the development of evaluation and benchmark testing techniques that would enable user feedback into the system design and would also identify user problems with systems (Moran, op.cit.; Lund, op.cit.; Good, op.cit.). User oriented solutions instead, focused on research that would provide a further understanding of user characteristics through the development of user models that would allow users' requirements and performance to be predictable (Moran, op.cit.; Payne, op. cit.). Solutions were also approached through improvements to the design process by developing design principles that designers could abide by, and through the development of user centred techniques to involve users in the design process (Olson, op.cit.; Whiteside, op.cit.; Eason, op.cit.).

2.4 A GAP IN THE FIELD - RESEARCH QUESTIONS

Although the research in the field addressed the user-system dilemma from these different angles, the views expressed on the incorporation of user information in design, (Whiteside, op.cit.; Grudin, op.cit.; Hedberg, op.cit.; Gentner, op.cit.) pointed to a gap in the research on how designers approached design tasks and the representation of users in the design process. The research in this area so far, only touched upon some of the issues raised above (Hammond et al,1983) or focused too narrowly on designers engaged in programming tasks (Soloway et al,1983). This highlighted an important gap in the research of human computer interaction that was considered worthy of further investigation.

The gap in the research in the HCI field during this period appeared to lie in the understanding of the design process and how users' requirements were represented in the process. These two areas were considered essential to achieving a better understanding of the incompatibilities that existed between users and systems. For this reason the research project was directed first, at the investigation of the types of design processes that occurred in the design of interactive systems and second, at the representation of users' requirements in the design process. It was believed research in these two areas would contribute to the field by extending our knowledge of design practice, and also on how users factored into the practice. In this way the research would fill an important gap in the field of HCI research.

A set of research questions was developed to address the issues related to the types of design processes designers engaged in, and how users' requirements were represented in the design of systems. These were:

The Design Process

a. *What types of processes occur in the design of interactive systems?*
b. *What types of design tasks and activities do designers engage in?*
c. *What methods and techniques do designers apply to design tasks?*

Users' Requirements In The Design Process

a. *How are users' requirements incorporated into design?*
b. *What kinds of decisions pertaining to users are designers faced with?*
c. *Are design decisions based on user requirements information?*
d. *To what extent do designers draw upon their own conceptual models of users' requirements, instead of information derived from studies and established facts?*

The primary hypothesis underlying these research questions is that the design process will be significantly undermined by inadequate information on users' requirements, and therefore will lead to the absence of coherent representations of users in the design process. It was also hypothesised that designers, in the absence of information on users, will draw upon conceptual user models for guidance during periods in the design process when difficult decisions occur. These models are often unconsciously formulated, and applied by designers to design solutions. The coherence and accuracy of these models is directly related to the designers' understanding of users' requirements and the application domain. In the absence of this understanding, designers will formulate highly personalised models based upon their own beliefs and experiences. These models often do not reflect users or their requirements.

It was also hypothesised that user models developed from an understanding of users' requirements offer designers a rational basis for design. Without this, designers are often without adequate reference points in the design process to which they can refer when faced with difficult design decisions; therefore decisions relating to users will present difficulties for designers. A final hypothesis was that an understanding of users' requirements derived from user studies provides clear reference points with which designers can evaluate design solutions. Without this, designers will have difficulty in determining whether the design criteria have been met.

CHAPTER 3

PILOT STUDIES AND METHODOLOGICAL ISSUES

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3.1 INTRODUCTION

Chapter 3 covers the methodological approach to the investigation of the design process of interactive systems, and how users' requirements are represented in the process. It provides an overview of the issues involved in the study of design, and explores the approach adopted in the search for explanations to the questions driving the research. It discusses the methods used to narrow the investigation to specific areas of design. A summary of the methods employed for the data collection in the individual studies is also provided. A more detailed description of the methods and issues associated with the methodology applied to the investigation is contained within the chapters pertaining to the individual studies.

3.2 KEY ISSUES IN THE STUDY OF DESIGN

The original hypotheses directed the research to investigate two primary facets of the design of interactive systems. First, the design process involved in these systems, including key elements within the process, for example, design methods and tasks. Second, the area of users' requirements, and the extent to which these were represented in the design process.

The process of considering an appropriate methodological approach to the investigation and the available techniques for data collection raised several issues that influenced the investigation. The first issue concerned the particular part of the design process on which to focus the investigation. The design of interactive systems encompasses a number of stages, beginning with the development of conceptual ideas, through to the implementation of the system in organisations; each stage involves a different level and kind of design. For purposes of the research, it was important to ascertain which part of the design process would yield the information that would best address the hypotheses. It was also important to consider which part of the process would be the most representative of design. This led to the second issue related to the part of the system on which to focus the study. It was hypothesised that the user interface of systems was critical in influencing the usability of systems. However, it was not clear whether it was possible to isolate this part of the design from the rest of the system or how to make this distinction.

The third issue addressed the direction of the investigation, whether it should be on the design activity, or directed at the designers. The difference was seen in terms of focusing the investigation on the design process or on the designers of the systems. Each direction raised further issues; for example, which design artefacts represented the processes involved, and which particular designers to study, those who designed the concepts for the system or those who wrote or implemented the code. Underlying each of these issues was the key question, how to study the design process? It was not clear how to study designers, the design process, and the design artefacts so that an understanding could be gained of the kinds of processes that are involved in design, and how users are represented in these processes. The essential research issue underlying these questions was, where to focus the research.

3.2.1 THE EXPLORATION OF ISSUES THROUGH PILOT STUDIES

To address the issue of where the research focus should lie, and also to define more closely an appropriate set of research questions, preliminary investigations of users' requirements in the design process were made by conducting pilot studies in the field. The aims of the preliminary investigation were twofold. The first aim was to refine the original research questions, and the second was to identify the parameters and conditions in the field. Very little was known in the field about users' requirements in the design process, and also there were few existing studies of design. For these reasons it was decided to treat the pilot investigations as an exploratory process. It was not clear at this early stage the kinds of field enquiries that made sense or indeed, the kinds of information that could be obtained from different research techniques. In keeping with the spirit of an exploratory process, it was considered appropriate to have a broad focus and a loose structure to the pilot investigation. In this kind of situation where the basis for formulating specific areas of enquiry is insufficient, and/or the research area is broad, an exploratory approach involving a minimal structure and without a specific focus can yield a rich source of information. (Campbell et al, 1982).

This approach led the investigation to consist of two separate studies. The objective of the first study was to identify the part of the design process that would render the most information about the representation of users' requirements in the design of interactive systems. This first study was based on three implemented systems in user organisations. The focus of the study was to gather information on how users' requirements were addressed in the design of the system, and on users' perceptions of how well their requirements were matched by the system.The design setting for the systems was similar for two of the systems and differed for one. Two of the systems had been designed within a commercial environment in which the systems were intended for a general population of users within a specific application domain. The third system had been designed especially for a specified user group within a particular organisation. The study of the three systems was based on interviews with the designers of the system, and with a number of the system users. The study included an evaluation of two of the three systems. In considering the data it became evident that there were common themes for both the designers, and for the users. One particular theme for designers that was considered relevant to the research, was one in which the designers were unclear about how users' requirements were factored into the design of the systems in recent projects. There was a common set of reasons provided in the interviews:

a. Designers reported it was typical of the systems they designed to evolve over a long period of time and to involve a number of different designers at the various stages of the process. Designers claimed these two factors contributed to their lack of knowledge on how users' requirements were incorporated in the design of the systems.

b. The designers indicated that users' requirements were most likely to be considered in the early stages of the design process. It was commonly agreed by the designers that the further into the design cycle, the less likely users' requirements would be considered.

c. There was a tendency in the interviews for designers to attribute the incompatibilities between systems and users to factors external to the system design. Among the possible factors for system/user incompatibilities given were implementation and organisational conditions. The inappropriate choice of system by the user organisation was also considered to be another possible factor.

The theme regarding users to emerge from considering the data, was one in which users perceived their needs had not been adequately met by the system they were using. An examination of the data highlighted a consistency in the following points in support of this theme:

a. The majority of users reported that it was necessary for them to significantly alter the way tasks were completed in order to accommodate the system. In many cases this involved more time and effort for the users.

b. Two thirds of the users interviewed claimed that if the people designing the system had understood what the system would be used for and who would be using it, a number of the problems they experienced might not exist.

c. None of the users interviewed believed their requirements had been adequately considered. The majority claimed they had not been consulted at any time during the design or development of the system.

The outcome of this first pilot study was helpful in shaping the research in two ways. First, the themes to emerge from the consideration of the data suggested it was not clear how users' requirements were incorporated into system design and also that users experienced a discrepancy between their requirements and the systems' capabilities. These themes were consistent with the starting hypotheses and therefore served as a confirmation of the direction for the research.

Second, the outcome of the pilot study was helpful by flagging areas that were potentially difficult to investigate. For example, it became evident a lengthy design process in which several different projects and designers are involved, would encompass a complexity of variables. This raised the potential difficulty in attempting to study either the entire design process of a system or in isolating a particular part of the process as a key area on which to focus.

The second pilot study focused on designers; how they approached design tasks, and the extent to which users' requirements were incorporated in the design tasks. The aim of the study was to determine whether an understanding of design and users' requirements could be gained through interviewing designers about their design practice. Two extensive interviews were held with designers who held considerable experience in the design of interactive systems. The designers worked within a research product environment in which the product designs were intended for end users however, were innovative and unlike existing systems in the market. The interviews were purposely unstructured to learn about the areas of primary interest to the designers, and to allow them to freely express their views on design. The interview material was primarily examined for evidence of how users' requirements were represented in the designers' discussions of their practice. There were similarities in how the subject of users' requirements featured in the designers' discussions. The common points to emerge from the interview material were flagged as relevant to the research. The main points were:

a. The designers made statements to the effect that it was important to address users' requirements in the design of systems. The inclusion of users' requirements in design was considered to be key to their design philosophy;

b. The designers seldom referred to users' requirements during their discussions of design projects. The designers' recollections were uncertain when asked specific questions regarding how users' requirements were handled at certain points in design projects;

c. The designers focused their discussions on the technical design details of the system they were discussing. Two points were emphasised throughout the interviews: how to make the system work and how to design something different;

d. The designers claimed they formulated a picture of a user/s and their possible responses to the system, in order to assist in formulating system requirements. For example, one designer envisaged his wife as a potential user and imagined her criticisms of the system;

e. The designers claimed they did not attempt to validate their assumptions or decisions against users' requirements. It was part of their usual practice to incorporate decisions into the design without further reference.

This pilot study consisted of only two designers, however, the points that arose from the consideration of the interview material were considered relevant to the research for the following reasons. First, it appeared that although the designers' design philosophy was based on the importance of incorporating users' requirements into designs, in fact users' requirements did not feature very highly in their recollections of design projects, and were seldom referred to during the interview. This discrepancy between intention and professed practice was seen as significant because it suggested that a lapse of users' requirements might occur early in the design process. The discrepancy also flagged a potential problem with applying interview techniques. It suggested there was potentially a difference between what designers claimed to be important and their actual practice. Therefore it was important that care be exercised about the validity of the data based on designers' claims about design practice.

Second, it was considered noteworthy that both designers attempted to formulate some kind of a conceptual "model" of a potential user as a way of determining whether their designs would work. One of the things this suggested was that although users' requirements did not feature highly in the recollections of the designers' accounts of design, it was nevertheless helpful for them to be able to pull together a "model" of a user in order to test their ideas. This indicated that users' requirements were perhaps more important than first suggested, and that designers find it useful to think about users in the form of a coherent picture they can apply to their designs.

A combination of the themes and points drawn from the two pilot studies provided indicators of some of the key factors to consider in approaching the research. These led to the following tentative conclusions that helped to shape the direction of the research:

- Inasmuch as the subject of users' requirements did not significantly feature in the recollections of the designers and the designers were uncertain about how users' requirements had been factored into the design of systems, it was considered unwise to focus the research solely on the area of users' requirements. Instead, it was decided to broaden the sphere of investigation to include the design process as a basis for studying how users' requirements were handled in design.

- This decision was strengthened by two points that emerged from the studies. The first was the focus of the designers' recollections on the technical design details of the system. One of the things this suggested was that perhaps during the course of design, designers were more concerned with what they were designing, than with how they were designing. Within this context it would be possible to see how users' requirements might be overlooked. By extending the area of enquiry to include the design process, it would be possible to investigate what happened when designers engaged in the design of systems.

- There was a discrepancy between the designers' design philosophy and actual practice as reported. This flagged design practice as an area of enquiry that could provide insight into what happened to users' requirements during design.

In summary, the consideration of the points raised in the pilot studies led to the conclusion that an investigation of users' requirements in design was perhaps usefully approached through an understanding of what happened during a design process. Designers' tendency to rationalise previous designs, and their difficulty in recollecting how users' requirements were handled in design, indicated an investigation should, as far as possible, be based on "real-time" design activities, and not rely entirely on recollected accounts of design.

3.2.2 RESEARCH QUESTIONS

On the basis of the conclusions drawn from the pilot studies and others drawn from the examination of the literature, it became possible to narrow the area of enquiry, and to formulate an approach to the investigation. For example, it became clear that the complexity of variables involved in an investigation that included both the design end of the process as well as system usage would be too complex to consider for this research project. It appeared likely that the research questions could be instead addressed by directing the focus of the research at the design end of the process. This would significantly reduce the area of enquiry by focusing the research on the design process of the system, instead of including the implementation of the system within the organisation as well.

The approach to the research was defined by the decision to begin with understanding what happened in the design process as a precursor to gaining an understanding of what happens to users' requirements in design. It became possible to begin to outline the type of field sites that would be desirable to include in the investigation. The characteristics of suitable field sites led to the following criteria for identifying appropriate sites to study:

- Where possible studies should be based on observations of "real-time" design activities. A number of points emerged from the pilot studies to indicate that interviews were not a reliable source of information on design practice, and how users' requirements were represented in design. From this it was concluded that interview data should not be the primary source of data;

- If possible studies should include teams of designers. This criterion grew out of the practical implications of studying design. The three systems included in the first pilot study were designed by teams of designers. The second study included systems which were designed both by teams and also by a solo designer. It appeared more common for systems to be designed by teams of designers than by solo designers. In addition, the methodological issues involved in the study of solo designers were evident in previous field studies of solo designers. It was believed these would impose limitations on the type of information that could be obtained and would make it difficult to address the research questions.

- Projects should include the early stages of the design process.There were indications in both pilot studies that it was more likely for users' requirements to be considered in the early stages of the design process than in the later stages.

- Studies should include design projects in the beginning stages of the design, through to final completion if feasible.

3.2.3 CONSTRAINTS IN THE FIELD

Although these criteria provided a basis for the selection of design projects to study, the number of constraints in finding opportunities for field investigations influenced how many of the criteria could be met. In reality, the opportunities for field studies were extremely limited. The constraints that influenced the opportunities for field studies were:

- ***Confidentiality***: organisations were reluctant to have an outsider study the design of systems that would later become commercial products;

- ***Privacy***: designers were reticent to have their design practice closely examined;

- ***Project Timing:*** the stage of a design project often limited the opportunities for an investigation. The further the project was into the development phase, the less there was to investigate, and designers were less willing to be studied. It was extremely difficult to find a project in the early stages;

- ***Scheduling:*** design meetings were often unscheduled and spontaneous, therefore it was difficult to arrange to be present at design meetings;

- ***Artefacts:*** design documentation was not common in the projects approached. When there was documentation, it could not always be released due to confidentiality;

- ***Context:*** design was often carried out by one primary designer, which raised issues of how to study the practice of one designer without interfering with the process.

These constraints significantly narrowed the opportunities for investigating design in the field. They were also key in influencing the methodologies and techniques employed in the investigation.

The first three constraints mainly influenced the investigation by delaying it by almost two years, until a combination of a cooperative organisation and a project in the early stages of design coincided. The result was that few projects were available to study. This led to the decision to include design interviews as part of the investigation in order to increase the data available on design. The fourth constraint, the scheduling of projects, raised the difficulty of observing a continuous sequence of meetings. This led to the decision to consider individual design meetings as separate entities for purposes of the research. Therefore, individual meetings were regarded as an episode in design. This resulted in the data consisting of a collection of design episodes, instead of a continuous sequence of design meetings. This shift in focus provided more flexibility in accessing projects. A combination of the difficulties experienced in obtaining access to design projects, and the lack of design documentation (the fifth issue), led to the decision for the investigation to encompass both design artefacts and design projects. The final constraint resulted in the investigation excluding designs projects carried out by single designers.

3.3 THE SAMPLING FRAME

The sampling frame was largely determined by the resolution of the above constraints and the extent to which organisations were prepared to participate in the research project. A combination of research opportunities eventually developed. Two organisations made available the documentation of previous design projects, two other organisations were prepared to have design teams observed, and one organisation was prepared to have designers talk about design projects, but not to be observed during design activities.

It became evident after a thorough search for design projects that met the selection criteria, that it was virtually impossible to find projects able to address all of the criteria. Of the opportunities available, only one project matched all criteria, and another project matched three of the four. The remaining three field opportunities involved projects that did not meet all of the criteria. It was decided to include the projects in the sampling frame nevertheless, because they represented different aspects of design. The diversity of data that would result from the design studies would provide different perspectives on design. In this situation it would have been ideal to be able to look at each project through each perspective; however, the nature and the timing of the projects did not permit this. It was considered important to gain as much information about the design process as possible, and from whatever sources available. The outcome of these field opportunities shaped the investigation by providing the following sampling frame.

Two Observational Studies:

A research laboratory in a commercial organisation had an interest in the design process, and therefore permitted observations of design meetings from a current project. Regular scheduled meetings took place each week, these were observed and audio-recorded. These occurred over a period of three months and covered the conceptual stage of the design through to the implementation stage.

A team of designers from a University Computer Science Department permitted observations of design meetings from a project. The meetings were unscheduled and sporadic; this resulted in only a few observations of the meetings. The observations took place during the early conceptual stage of the design project.

One Interview Study:

A large international organisation, specialising in interactive systems, permitted nine designers from a user interface design group to be interviewed on their design activities in recent projects. Observations of design meetings were not permitted due to confidentiality.

Two Documentation Studies:

An organisation made available the documentation of a project that terminated a number of years prior to the study. The documentation consisted of design notes written by the various project members. These had been distributed between the project team and to members of the laboratory external to the project. The design documentation of the design came from a research laboratory within a large international commercial organisation, specialised in interactive systems across a number of industry sectors.

A different part of the same organisation provided the documentation from a current design project. The documentation was prepared for purposes of the research, because observations of the design meetings were impossible due to geographical distance. The documentation covered the three month period of the project.

3.4 CHOICE OF METHODOLOGICAL APPROACH AND TECHNIQUES FOR DATA COLLECTION

The choice of methodological approach was influenced by the philosophy underlying the research; there were two views on which the philosophy was based. One view concerned the current lack of knowledge in the field on users' requirements in the design process. This indicated that information in this area was required before hypotheses and theories could be tested in the field. The second view was that in order to obtain this information, it would be necessary to study design from as many different perspectives as possible, so as to gain a holistic view of design. In an holist approach, the information gathered in the field is used to build a model that serves both to describe and to explain the system. The model is derived from 'connecting themes in a network or pattern', these are 'discovered empirically, rather than inferred logically' (Diesing,1972, p.155). These two views influenced a methodological approach that did not attempt to reduce or to manipulate the variables under investigation. Instead, the objective of the research was to encompass the study of all variables in the natural design environment, and thereby identify the significant variables. The aim was to generate the information required to develop hypotheses and theories about design, by studying design in the field. The term 'grounded theory' is applied to this methodological approach, and refers to the development of hypotheses derived from the study of phenomenon, as a basis for generating abstract theories with increased applicability (Glaser et al, 1967).

This philosophy directed the research away from a scientific approach, where the requirements of control, operational definition, and replication, would limit the inquiry to experimental methods. Instead, the research was drawn to a descriptive research approach, whereby the primary aim is to provide an accurate description or picture of a particular situation or phenomenon. The objectives of this approach are to identify the variables that exist in given situations, and to describe the relationship that exists between these variables (Christensen, 1980). This approach appeared to be compatible with the philosophy underlying the research.

3.4.1 A DESCRIPTIVE RESEARCH APPROACH: THE FIELD STUDY APPROACH

The inappropriateness of an experimental approach to address the questions posed by the hypotheses led to the consideration of the field study approach. Both the advantages and disadvantages of applying this methodological approach to the research were examined. The research techniques available within this approach were also considered.

The two categories of a field study approach as defined by Katz (1953, in Kerlinger, 1973) provided a choice of hypothesis testing or hypothesis exploration. The primary objectives of the exploration of hypotheses are to establish correlations between significant variables, and to create the groundwork for hypothesis testing. This appeared to be compatible with the grounded theory approach, and therefore was adopted as the most appropriate direction for the research to follow.

The field study approach offered a number of advantages for example, the investigator is able to collect data in naturalistic settings without disturbing the situation. Furthermore, the observations of interest to the investigator can be focused on specific aspects of the situation. Another important advantage was that field studies draw upon a variety of diverse approaches; this was considered important in achieving a holistic approach to the research (Christensen, op.cit.).

There are several major drawbacks to the field study approach however, which were carefully considered. The first is the lack of control of the variables, therefore it is difficult to seek answers to specific questions, as in an experimental approach for example. A second drawback, is the inability to manipulate variables, therefore it is not feasible to specify the exact conditions of the investigation (Christensen, op.cit.). One of the important criticisms of the non-experimental field study approach is one of validity. The understanding and the interpretation of the phenomenon is subject to the investigators' bias and explanation (Rowan and Reason,1981).

Although these drawbacks were important considerations, the first two were not considered to affect the research because the research aims did not require control and manipulation of variables. The third issue of validity was relevant to the research. Therefore, the validity of the field study findings was carefully considered when developing the methods and techniques for the investigation.

3.4.2. EMPIRICAL STUDIES OF DESIGN IN THE DOMAIN

The methodological approaches applied in previous studies of the design process were examined for their appropriateness to the research investigation. At this stage of the research very few empirical studies of design in the field existed. The few studies there were, applied the verbal protocol technique pioneered by Newell and Simon (1972). The primary studies in the field were based on the method of protocol analysis, in which a design problem of reasonable complexity was set for individual designers during which they verbalised the process they engaged in to solve the problem. For example, a task based on the design of a solution to a book indexing system (Jeffries et al, 1981) or in another example, an unfamiliar task was specified, but within a familiar domain (Adelson and Soloway, 1984). Further studies of designers were conducted where designers worked on an existing design problem while describing to the researcher the methods applied (Kant and Newell,1984; Ratcliff and Sidigi,1985).

These approaches fell into the category of field experiments, and therefore were considered inappropriate to address the main questions posed by the research hypotheses. These previous studies were not based on design activities in "real-time". The nature of field experiments as defined by Runkel and McGrath (1972), involves the manipulation of variables by the researcher, in order to observe behaviour within a natural environment. This was considered to have too many of the disadvantages similar to laboratory experimentation. The incompatibilities of field experimentation with the research objectives were:

- the focus on problem solving and decomposition;
- the focus on programming;
- the artificial design context;
- the lack of opportunity to capture design behaviour in a realistic context;

- the imposition of variables upon the design task.

For these reasons the research departed from the present trend in the domain of empirical design studies. Instead, other approaches were considered that could offer methods for studying design within a larger context.

3.4.3 OTHER APPROACHES TO FIELD STUDIES

The hermeneutical approach to the study of human behaviour was considered because of its philosophy of interpreting, explaining, and making clear, that which is being studied, through the elucidation of the meanings of actions. Several of the concepts which figure in hermeneutical explanation, namely, agent, action, intention, purpose, desire, etc, offered ideas for the investigation (Gauld and Shotter, 1977). In particular, the focus of hermeneutical approaches on 'action-meaning' provided clues that perhaps the research should look at the actions performed by designers in the design process, as a way of understanding the factors underlying the process.

Ethnomethodology was also identified as an approach that might offer methods appropriate to the investigation. Ethnomethodology was originally designed as a label to capture a range of phenomena associated with the use of ordinary knowledge and reasoning procedures by people. The term refers to the study of a particular subject matter through the body of commonsense knowledge. This includes the range of procedures, and considerations of the means by which people make sense of, find their way about in, and act on the circumstances in which they find themselves (Heritage,1984).

This approach appeared to embrace the aim of the investigation to understand by what means designers approached design activities. One particular aim of ethnomethodology considered compatible with the research aims, was the search for patterns. Ethnographic methods involve a collection of different kinds of information and relations among them. The ethnographer uses an holistic search for a pattern by building an account for events, that are not well enough understood to represent formalisations (Agar,1980).

Both ethnographic and hermeneutical approaches provided indicators of some of the important areas to focus the investigation. The research methods applied to the investigation were influenced by the hermeneutical search for meaning through actions as a means for interpreting and explaining observed phenomenon; and also by the ethnographic holistic search for understanding through identifying patterns in different kinds of information.

3.5 EXPLORATION OF SPECIFIC METHODOLOGIES

The constraints in the field significantly influenced the kinds of opportunities that were available for field investigations. As discussed earlier, it was a primary aim to base the investigations on "real-time" design activities. Every attempt was made to meet this aim; projects in the early stages, consisting of a team of designers engaged in the design of interactive systems were actively sought. However, the search yielded opportunities to collect design documentation, to interview designers, and to observe design meetings. The implication of this outcome was that the investigation would be based on a sampling frame consisting of three different sources of data. From the point of view of the overall objectives of the research, this did not present a problem. It was in fact seen to be consistent with the philosophy underlying the research. The philosophy was based on the view that all information is perceived as a potential contribution to the area, due to the lack of knowledge in the field. Also, in order to obtain a holistic view of design, it was considered important to study design from as many different perspectives as possible. For these reasons it was decided to base the investigation on the three different field studies.

It was believed that several of the research questions could be addressed in an interview study based on designers' recollections of design activities. For example, specific information about design practice and users' requirements could be obtained which could help to identify some influencing factors in design. This was considered to be a potentially valuable piece in the holistic picture of design.The study could have an important part to play in the development of this picture by providing a particular slice of design that differed from the other two studies. There was the potential to obtain designers' perceptions and selective recollections, as opposed to written recollections, or "real time" activities. Additionally, the difference in design context from the other two studies, offered an opportunity to look at design in contrasting contexts.

A study based on design documentation was seen to complement the other two studies. The documented accounts of design tasks by designers, provided an opportunity to obtain information on design from a retrospective point of view. Similar to the interview studies, the study was based on selective recollections however, written instead of oral, therefore there was the opportunity to see the kind of rationale designers created after a particular design activity. The nature of documenting accounts of design involved designers in considering what had occurred in design, and to decide what was appropriate to record. This was considered to be a potentially valuable source of information on the representation of users' requirements during design. For these reasons, a study based on design documentation was considered worthwhile. The information from the study could provide yet a different slice of design, and hence contribute another valuable piece in the development of an holistic picture of design.

The observational study was considered key in the development of an overall picture of design. It provided an unique opportunity to observe teams of designers engaged in tasks aimed at designing systems for end users. This had been the original aim of the research. In an ideal setting, the interview and documentation opportunities would have been with the same projects as those in the observational study. This would have made it possible to obtain three different slices of design from each project, thus providing a holistic picture of design. Instead, the observational study was regarded as contributing the primary piece to the picture, with the interview and documentation studies providing different perspectives, but nevertheless serving as an important complement to the observational study. This resulted in an investigation based on a triangle of studies; the observational study at the base and the other two studies forming the apex.

Although an investigation based on a triangle of different studies was consistent with the overall methodological approach of the research, the diversity in the data the studies would yield made it apparent that more than one methodology was necessary; this raised two important points. The first was the importance of considering the relationship between the method and the research questions; one method can seldom address all the questions (Kahle, 1984). The second was that each method potentially obscures some important phenomena, and 'flaunts some phenomena that are trivia'. Therefore, in order to take this into account, 'no one methodology should ever be the exclusive workhorse for an entire area of research' (Kahle, op. cit., p.86).

This raised some key questions about appropriate methods for data collection, particularly since the interviews in the pilot studies were found not to provide sufficient information. The important issue was to find a set of complementary techniques that would collectively provide the data required to address the research questions.

3.5.1 INTERVIEWS

The pilot studies conducted during the preliminary investigation identified a number of drawbacks with using interviews as a method for data collection in design studies. These were:

- In the field studies, designers' recollections focused on the technical design details of projects. There was a tendency towards poor memory recall in the areas of design decisions or difficult points that had occurred during the process. This was considered an important drawback because the areas most pertinent to the research were those in which the designers' recollections were bare.

- The designers interviewed professed to have a design philosophy that influenced their approach to design and also guided their practice. The drawback with this was it resulted in a selective account of design that was influenced by the designers' philosophy.

- The designers' claimed their design philosophy was based on the importance of considering users' requirements in design. However, users' requirements were seldom mentioned in their recollections of previous designs. This highlighted a potential descrepancy between what designers professed and their actual practice, and therefore it was considered to be a drawback.

Most of these drawbacks coincided with the disadvantages normally associated with interview techniques. For example, a problem often associated with interviews is one in which dependent variables can confound, or even obscure the information being sought. The interpretation of the questions asked of subjects, and the associations that can be triggered by the questions, can lead to inappropriate causal patterns and relationships (Kahle, op. cit.). Another important drawback is the problem of selective memory recall. It is a common view that the past is reinterpreted and explained over time, and people unwittingly fill in gaps in memory, by inferring events that probably never occurred (Bartlett,1932; Berger and Luckmann, 1967; Lindsay and Norman, 1972; Mead,1959; Taylor and Crocker, 1981).

Despite the disadvantages of interviewing techniques, an important characteristic of the method offered significant benefits to the study of design. The first was by interviewing designers, specific topics could be explored with the subjects. Second, insights could be gained into the reasons underlying the subjects' actions and beliefs about design (Sommer, 1980; Kerlinger, op.cit.). This could not be achieved through observational techniques, therefore interview techniques were considered important to include in the methodology.

The interview techniques applied to the investigation incorporated two key elements aimed at addressing some of the drawbacks. The first was to focus the subjects' recall of specific incidents in design projects by instructing subjects to reiterate the steps taken in these incidents. By focusing the subjects' recollections on the sequential steps taken in design projects, this approach aimed at obtaining as full a picture as possible and to avoid the bare patches in designers' recollections that had occurred in the pilot interviews. Secondly, an attempt was made to reduce the level of questioning during the interview time through a highly structured interview format. Subjects were provided with instructions at the beginning of the interview, and then were guided with a minimal dialogue with the researcher. They were led through the interview with questions like, "and what was the next step you took". This approach served different purposes. In terms of interview time, it helped to focus the subjects' recall on the specific areas of enquiry, and therefore it was more likely that the information obtained would be directly applicable to the research. It was seen as an economic approach to interview time. Another important aim of this approach was the question, " and what was the next step you took", this served as a trigger to the subjects' memory. This approach also avoided the drawback of the misinterpretation of questions, and the potential bias of the researcher. The specific techniques used in the interview study are discussed in Chapter 5.

3.5.2 OBSERVATIONAL TECHNIQUES

The application of observational techniques to the study of the design process offered several opportunities to collect data at different levels. Observations of design activities would provide the opportunity to observe the design space and how it was utilised in the context of design teams. This was the primary aim of including observations in the investigation. Although it was not an aim of the investigation to study the behavioural aspects of designers' interactions with each other and non-verbal communications, it was nevertheless considered one of the advantages of observational studies. It was not within the scope of the research to analyse data at this level, however, the consideration of the non-verbal interactions nevertheless enriched the picture of design that developed. The information gathered from observations of design in this context was considered valuable in developing a comprehensive picture of the design process. For these reasons, observational techniques were explored further to determine how they could be applied to the investigation.

The types of observational methods available offered three options. The first was unstructured observations whereby the researcher acts as a silent witness to the events observed. The second was systematic observation where the researcher applies a structured format to capture the phenomena which occur. The third option was participant observation which involves the researcher becoming part of the situation in some way. None of these approaches appeared to fulfill the research needs. It was considered inappropriate to conduct participant observations, due to the potential interference of the phenomena as a result of researcher involvement. Although unstructured observations offered the opportunity to witness all the phenomena that existed in the design space, it also presented the problem of the quantity of data. The amount of data would require a vast amount of time to filter and to analyse. It was considered too important to apply a structure to the observations to counteract this disadvantage. Therefore the systematic approach to observations was considered a complement to the casual approach. A combination of the two methods permitted all the phenomena in a situation to be recorded; and yet, the application of a system to record the phenomena, provided sufficient structure to assist with the final analysis. It was believed that the level of information required to address the research questions could be obtained with a combination of approaches. The unstructured approach appeared to be most appropriate at capturing information at a more global level, for example, looking at how the design space was organised and at the development of the design process. The systematic approach was seen as suitable for gathering information on areas of specific interest to the investigation, for example, design decisions regarding users' requirements.

Observations of designers engaged in design activities offered the opportunity to investigate the attributes of the situation. The attributes identified as important for the research were those defined by Kahl (op. cit.) as (1) the attributes of participating individuals and groups, (2) the objective or task of participation, and (3) the location, settings, etc. Despite the difficulties typically associated with observational methods, for example, the filtering of information through the observers' bias and the changing perceptions of the observer as familiarity with the situation increases (Bouchard, 1976), it was considered important to persevere with observational methods for two reasons. The first was the valuable contribution observational data could make to the research, and the second, was the lack in the field of observational studies of design teams in a naturalistic situation. This was considered an important gap for the research to address.

3.5.3 CONTENT ANALYSIS AND CATEGORISATION

In considering methods appropriate for analysing design documentation, it was important to focus on the objectives of including documentation in the research sample. Documentation data was viewed as contributing to the understanding of the design process gained from the other sources of data. It was not considered key to developing an understanding of design. Instead, documentation data was viewed as a source of information on specific areas of the design that were identified as important in the other two forms of data.

For this purpose, a form of content analysis was applied as a method to determine the key elements in the design process, and the representations of users in the process as reflected through the documentation. Key design tasks and questions were extracted from the documentation, and categories for these were established. This also applied to the references made to users' requirements in the documentation. The major content categories were noted, and under each category the questions designers asked were listed. The development of the categorisation was intended to summarise, and to communicate the major interests of the designers. This method provided a reflection of the concerns of the designers and also was able to reflect the nature of design as it was documented (Campbell et al, op. cit.).

3.6 DIFFERENT DATA FROM DIFFERENT DESIGN CONTEXTS

The research was significantly influenced by the constraints experienced in attempting an investigation of design in the field. The area in which the effect of the constraints was most evident was in the selection of the sampling frame. Concerns for confidentiality and privacy on the part of the organisations approached, meant that many organisations refused to participate in the research. There were additional constraints relating to the scheduling and timing of projects which imposed further limitations on opportunities for field studies. After a considerable search, only two organisations were willing to participate in the research by permitting a design team to be observed during design activities. In addition, one organisation was prepared to participate by making design documentation of projects available and another was willing for a number of its user interface designers to be interviewed.

It was necessary to review the research objectives in view of the limitations these constraints imposed on the data sample. It had been an original aim of the research to base an investigation on observational studies of design teams engaged in the design of a system in the early conceptual stages of the project. However, it had become possible and necessary to include other forms of data in the investigation. This was seen as consistent with the philosophy underlying the research; the data from different design contexts would provide diverse perspectives on design, and thereby could contribute to the picture of design.

It was recognised that the collection of different kinds of data in different cases of design would make it unlikely that an integrated model of design could be developed from the investigation. This would have been a major problem if the study had been intended to test a particular theory of design. However, this was not considered a drawback because the aim of the research was not to provide a coherent model of design. Instead the aim was to obtain information that could contribute to a first stage of understanding of what happens to users' requirements in design. Each set of data represented a particular design context and therefore a separate picture of design. This picture could reveal how users' requirements were handled and some of the characteristics of the type of design process that occurred in that particular context. Although it was possible to search for parallels across the data, the direct comparisons were very limited. Therefore what resulted was a separate slice of the design process from each set of data that contributed to an overall picture of design and to an understanding of some of the factors that inhibit the design process.

3.7 SUMMARY

A number of factors influenced the approach adopted for the research. The first important influencing factor was the current lack of knowledge on design in the field. This indicated the research should be aimed at gathering information and developing hypotheses. The research was led towards a grounded theory approach based on field studies, instead of an experimental approach in which experiments are used to test hypotheses. Due to the lack of information in the field, preliminary investigations were conducted in the field to ascertain how to approach the study of design. The conclusions from the pilot studies led to specific criteria for the selection of design projects to include in the investigation. An important criterion was to study design teams engaged in design tasks during the early stages of a project. The second factor to significantly influence the direction of the research, was the number of constraints imposed by the limited opportunities to study design in the field. This resulted in a sampling frame that consisted of a combination of design situations; individual designers prepared to discuss projects, the documentation from design projects, and observations of design meetings. Although each of these situations did not meet all of the criteria, the majority of the criteria were addressed through a combination of the three kinds of studies.

To a large extent the opportunities for field studies determined the methods used for data collection. Interview techniques were appropriate for the designers prepared to discuss design projects, observational techniques were considered best for studying design activities, and a categorisation of design content was applied to the study of design documentation. Various adaptations to these techniques were necessary, partly to address the disadvantages inherent in each one, and also to accommodate the information requirements of the research. It is believed the combination of the methods provided a rich source of data that enabled the research questions to be addressed from a number of different perspectives.

The discussion of the research now turns to the results of the investigative design studies. The next three chapters, 4, 5, and 6, contain the analysis and discussion of each of the studies. Chapter 4 contains the analysis of the two observational studies, Chapter 5 presents an analysis of the data from the interview studies, and Chapter 6 focuses on the results from the documentation studies. The findings from the investigation are drawn together in Chapter 7, which discusses the major factors that influence design, and the representations of users' requirements in design.

CHAPTER 5

THE DESIGN PROCESS AS REPRESENTED THROUGH CRITICAL INCIDENTS

CHAPTER 5 THE DESIGN PROCESS AS REPRESENTED THROUGH CRITICAL INCIDENTS

5.1 INTRODUCTION

In Chapter 4, the investigation was concerned with observations of the design process as it developed in the context of project team meetings. The findings from the observational studies provided a characterisation of the design process, and how users' requirements were handled within the process. The investigation of the design process was extended by collecting data through detailed interviews with a number of designers, who specialised in user interface design. This was intended to provide an additional perspective on the development of the design process of user interfaces, and also on the handling of users' requirements in the design. The methodological constraints created by including a study based on a different method, in a different design setting, resulted in a different set of conclusions. The implication of these differences was that the findings from the study were treated as a separate entity from the other two studies, and the findings were seen in terms of the individual contribution that could be made towards an understanding of design.

Chapter 5 presents the findings from the study of design through designers' recollections of the critical incidents that occurred in specific projects. The chapter begins with outlining the methodology applied to the data collection through the interviews, and the methods used for the analysis of the data. The first part of the chapter focuses on the design process as it was represented in the data. The second part of the chapter concentrates on the two key areas in the design process that emerged from the data; the first is users' requirements and the second is the assessment of design solutions.

5.2 METHODOLOGY FOR DATA COLLECTION

The objective of the investigation was to focus on the depth of information regarding the design process, and not necessarily the breadth. This influenced the choice of methods and the structure applied to the data collection. The sample was limited to a small number of designers, to enable the investigation to focus on the areas of the design process that were relevant to the investigation. The structure and the methods applied to the interviews supported this objective. The four primary areas of design addressed in the investigation were the:

- approach to design: methods and techniques;
- type of design process;
- factors influencing the design;
- handling of users' requirements in the design process.

A structured format was applied to the interviews to enable the data collection to focus on specific areas of the design process. The format drew on the representation of the design process as a collection of incidents; this was the same format applied to the observational studies (Chapter 4). The term critical incident is defined as specific points in the design process where decisions or design issues occur. At the beginning of the interview the term was defined for the subjects; when the concept was understood, the subjects were asked to recall specific incidents in one current and two previous projects that involved design decisions or issues. In three instances, long development cycles limited the subjects' project experience to one project, consequently, the interview material consisted of only the one project. Subjects were encouraged to recall as many incidents as possible within the time available. This resulted in a variation in the number of incidents recorded per subject (See Table 5.1 on the following page).

The interview format was based on retracing the specific steps that lead to decisions, or to the resolution of issues in critical incidents. A method was applied to direct subjects in the recollection of specific critical incidents. Subjects were guided through the reconstruction of events from the beginning to the conclusion of an incident (See Appendix B). The method consisted of specific questions to focus the material on the sequential steps incurred during the incident, for example:

> "*What was the first step you took,*
> *Then what happened,*
> *What was the next thing you did,*
> *Then what happened,*
> *What was the next step.....*"

5.2.1 THE SAMPLE

The interview sample consisted of designers drawn from a large, international commercial organisation. The organisation developed and manufactured products aimed at a wide distribution across a number of industry sectors. All of the products discussed during the interviews were directed at commercial markets, and typically incurred design cycles of 2 to 5 years. The subjects had had continuous involvement in the projects until the completion of the product development. Product design in the organisation was organised by separating the different parts of the system under design and allocating the responsibility for the design of these parts to different project teams.

Table 5.1

Sample Of Critical Incidents

Subject	# Proj.	# Incidents	Focus
1	2	6	Define features Concepts for UI Define UI rules Hypenation feature Usability problems Define prompt feature
2	2	5	Support simultaneous voice Design main menu Interface problems Define documentation Printing problem
3	2	3	Screen layout Interface Applications Choice of interface style
4	3	4	Implementation of design Alternatives for display Size of display Level of user support
5	2	5	Dispense w/displays Combine sets/displays No. of states w/LCD No. of functions per key Design of conferencing
6	1	5	Design interface package Formalise code -interface Access features fm.screen
7	2	2	Interactive tool for users Requirements for users
8	2	5	Features for new product Problems users have Level of feedback to users Time detector-interruptability Choice of voice for interface
9	2	8	Develop cognitive models Changeable main menu Physical struct. f/ screen What to display on screen Display of printing information Supporting user printing Market intelligence in system Exploration of new application
Total: 9	18	43	

Consequently, a group of user interface designers existed in the organisation, which was responsible for the design of the user interface of systems. The sample of designers were drawn from this user interface group.

The sample consisted of interviews lasting between two and three hours, with nine designers specialised in user interface design. Although all subjects were members of the user interface group in the organisation, there was no overlap of information because they were from different projects; in many instances the designers were from separate geographical locations.

The designers interviewed were from project teams comprising of five to sixteen members. The design teams were interdisciplinary, and included designers from a number of different backgrounds; these varied between computer science and ergonomics. The subjects represented the following range of disciplines:

- computer science
- cognitive psychology
- ergonomics
- computer science and psychology
- engineering and ergonomics

The data collected from the sample of nine interviews consisted of a total of 18 projects and 43 critical incidents, consisting of between six to twelve recorded steps per incident. The number of projects and incidents per subject varied according to the designers' involvement in recent projects, and the number of critical incidents they were able to recall. There were three cases where the subjects' work was, or had been recently focused on one long term project. In other cases, subjects recalled incidents from as many as three recent design projects. Table 5.1 provides a summary of the sampling frame. The table shows the number of projects recalled per subject, the number of incidents within each project, and the topic of focus for each incident.

5.3 THE ANALYSIS OF THE DESIGN PROCESS

The first level of analysis was directed at the purpose of the critical incidents to identify the key areas of the design process. The decisions and issues recorded in the incidents were analysed to determine the kinds of factors that influenced the design. At another level, the analysis focused on the steps taken in the incidents, in order to determine the types of tasks designers engaged in, and also the kind of design process underlying the tasks.

The reconstruction of the critical incidents began with the subjects' explicit statement of the primary objective of the incident. For purposes of analysis, these statements were classified according to decisions and issues. Decisions were defined as incidents involving a conclusion or a resolution, and issues were defined as incidents that were based upon issues of contention. Two categories of decisions and issues emerged from these classifications; these are summarised in Table 5.2 on the next page.

Table 5.2

Categorisation of Design Decisions & Issues
(Sample: 43 incidents)

Design Decisions (24)

Design Choices(13)	Design Specification(11)
advant/disadvant of design solution	*design goals*
different types of applications	*user support*
style of interface	*documentation*
multiple vs single users	*users' requirements*
choice of layout for main menu	*level of feedback*
selection of features	*new application*
choice of voice	*old system/new functions*
information on screen	*the type of application*
editing while printing	*system features*
system features	*users' conceptual model*
certain type of menu scrolling	*user interface rules*
system with/without display	
LCD states	

Categories of Design Issues(19)

Approval/Acceptance(5)	Design Problems(14)
design concensus on solution	*screen size*
users' requirements with client	*communicating design concepts*
inclusion of specific function	*method for develop. language*
management on design concept	*function in user interface*
justification of rapid prototyping tool	*missing component in interface*
	evaluation feedback: to users & management
	conveying interface issues
	change in UI slows system
	changes in UI expensive/difficult
	printing compromises for user
	resolution of conflicting goals
	additional functions diffic.users
	usability problem
	how to solve prompt problem

A number of design attributes emerged from the analysis of the decisions and issues in the incidents. There were two common decisions evident in the data that indicated a primary focus of design activities was on choices relating to the presentation and functionality of the system. For example, decisions concerned with the choice of features to include in the design, or selecting from alternatives for menu layout were typical of the kinds of decisions visible in thirteen incidents. Another focus is evident in the second type of decision, where designers try to reach a conclusion on the specification of the design, or are involved in the definition of a part of the design. For example, the specification of users' requirements, or the definition of the level of system feedback, were typical of the kinds of decisions visible in eleven incidents.

These decisions highlight the focus of design activities, and also provide indicators of the key problem areas in user interface design. Two design issues emerged from the data: one related to the approval or acceptance on some aspect of the design, and the second issue related to problems with the design. Three areas were identified in which design problems were particularly visible: technical constraints, design trade-offs, and the communication of design concepts. The findings indicated that design was influenced more by specific design problems such as those described, than it was by problems related to acceptance and approval. In the data there were almost three times more design problems visible in the incidents than there were approval related problems.

At an overall level, the two categories of design decisions and issues convey design as being characterised by design problems, or the consideration of design alternatives. In Table 5.2 we can see that in terms of the number of incidents based on decisions and issues, these two rate the highest, fourteen and thirteen respectively. The types of decisions and issues conveyed an element of contention in design solutions, which highlight the importance of achieving resolution in incidents. Situations develop in which design solutions cannot be reached, until problems are addressed or specific design alternatives are chosen. In these situations, we would expect design activities to be concentrated on achieving a resolution of the problems and issues. This raised a number of questions with respect to how the design process is influenced by the decisions and issues that arise, and also the kinds of strategies designers employ to achieve resolution. These questions guided the investigation to a further examination of the representation of design in the critical incidents.

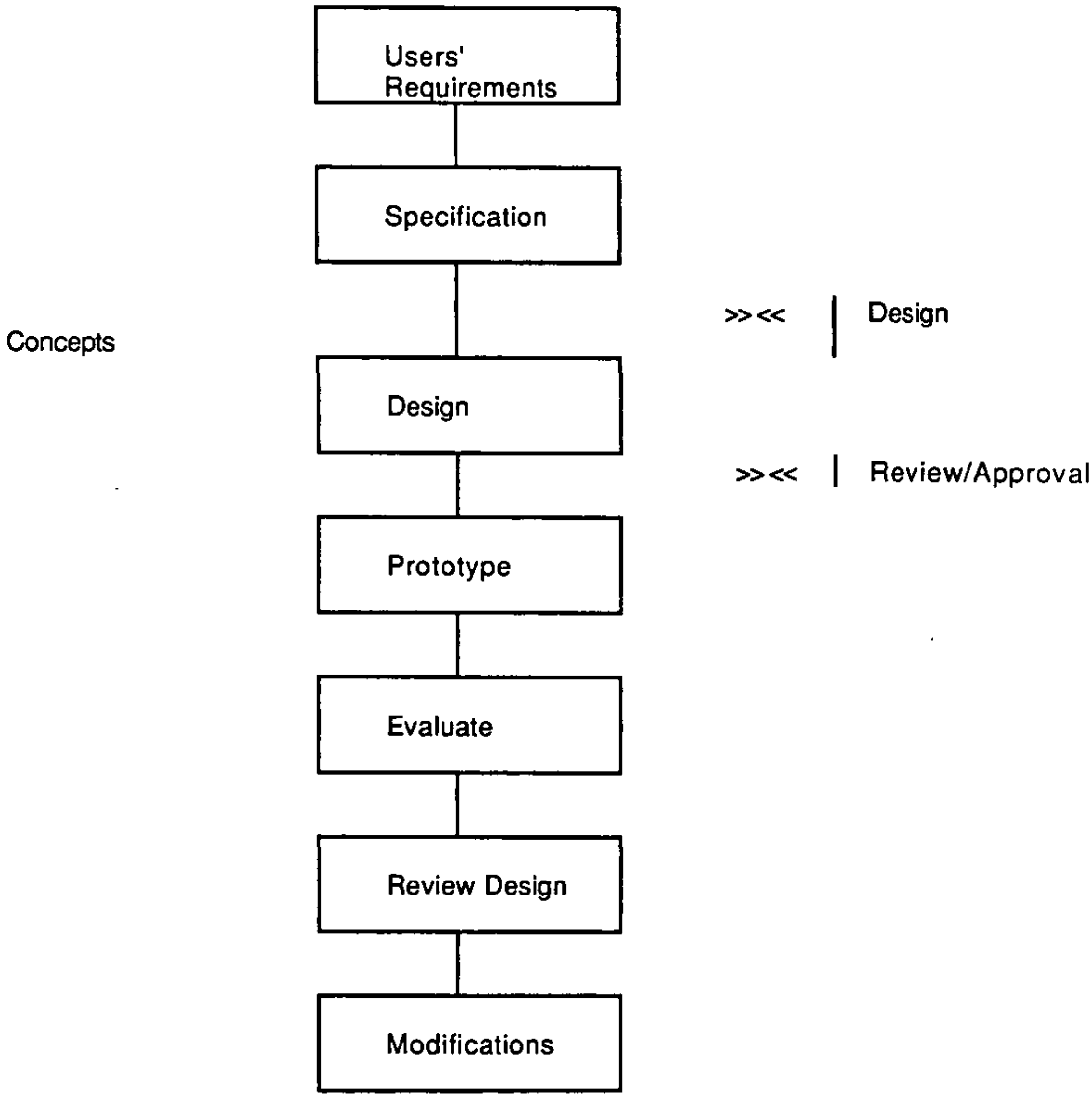
5.4 A FRAMEWORK FOR THE DESIGN PROCESS

The analysis of the focus of critical incidents showed that designers were primarily involved with making decisions, or in resolving design issues concerned with the technical aspects of the system. This raised questions about the strategies designers applied to solutions. The sequential steps recorded in the incidents were examined for similarities and differences in designers' approaches, to determine the type of design process that developed.

The findings are discussed in terms of a generalised framework, depicting the type of design process that emerged from the sample of critical incidents. The framework presented embodies first of all, a consistent ordering to the methods used during the design process. Second, the framework recognises the existence of a common focus found in the majority of critical incidents. The framework is presented in Figure 5.3, and is followed by examples of two critical incidents from the data.

Figure 5.3

A Framework of The Design Process



The first incident reflects the design process as it is represented in the framework, and the second incident shows a variation in the framework. This is illustrated in the following example (5.4).

Example 5.4

The Design Process in Two Critical Incidents

Example 1: Within Framework	Example 2: Variations
Steps:	Steps:
1. Develop users' requirements	1. Develop users' requirements
2. Design	2. Design concepts
3. Prototyped design	3. Present concepts f/review approval
4. Evaluation	4. Proceed with design
5. Presented to review team	5. Prototype
6. Proceed with full design	6. Present to review team
	7. Modifications/Redesign

The design process in the incidents began with some type of requirements specification for the design; in some cases this required further development. This was followed by a design phase, that could involve either a complete design or a mock up of the design; this was then prototyped and evaluated in some way. A review of the design occurred which usually included members outside of the project team, such as the product manager and the implementation team. As a result of the review, the design is subject to modifications and an interation in the process occurs in the design, e.g. prototype, evaluate, and the review stages of the process.

Variations in the framework occur when a design concept requires acceptance by the review team before the designers can proceed with the design and prototyping; one example of this was found in the data. A similar variation occurs after the design review, when the modified version of the design requires approval before a complete redesign takes place. This particular variation appeared in seven of the critical incidents.

Within this design framework the analysis highlighted two areas of the design process as being central to the incidents; users' requirements and evaluation. The high number of steps recorded in the incidents identified these as key to the design process, therefore the analysis focused on these two areas for the remainder of the investigation.

5.5 USERS' REQUIREMENTS IN THE DESIGN PROCESS

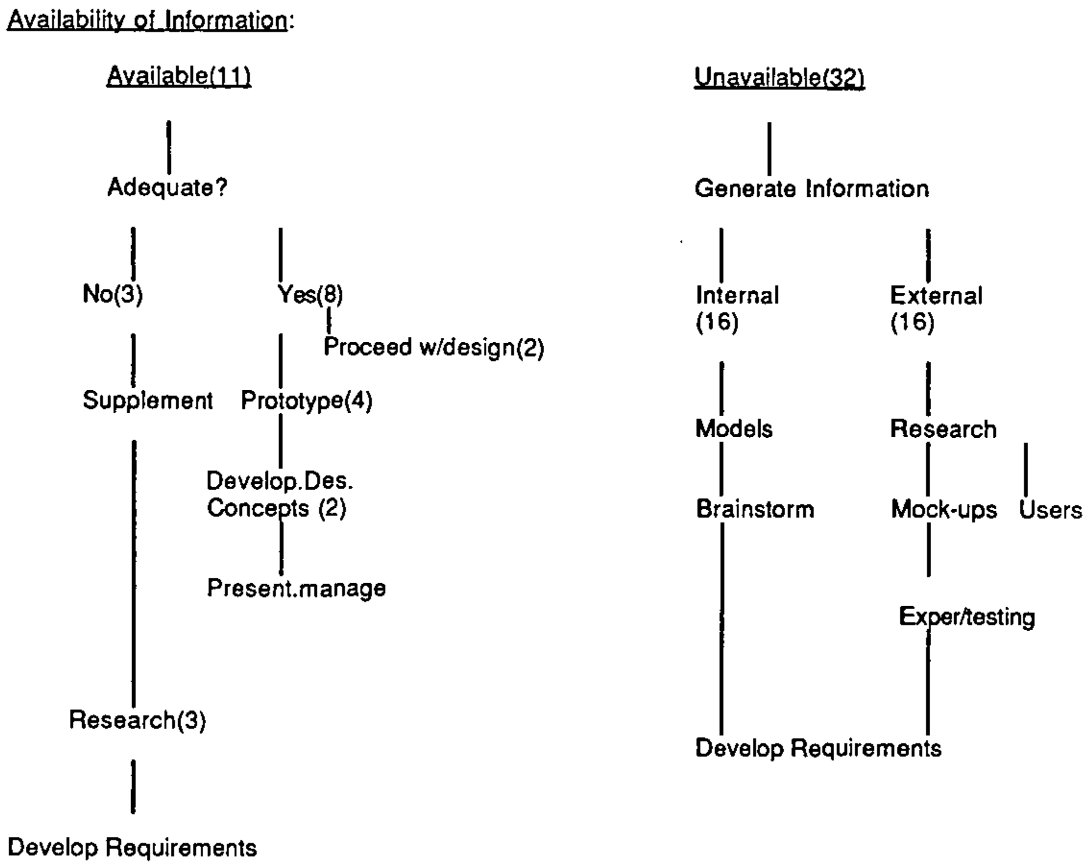
The design framework discussed in the previous section was used to guide the analysis of the data to examine the handling of users' requirements in the incidents. A primary interest of the examination was the source of information upon which requirements were developed, and how this factored into the design process. The findings pointed to important differences in the area of users' requirements that significantly influenced how designers proceeded with the design, and as a consequence, on the development of the design process. Seen within the framework presented, the design process begins with users' requirements; however, a closer examination of this part of the process revealed two points relating to the management of users' requirements in the process.

One, information on users' requirements was not always available to design teams; this was evident in 74% of the critical incidents. This resulted in designers approaching the design task without a specification of users' requirements, or any knowledge of these requirements at the beginning of the incident, which often was the beginning of the project. When requirements information was provided to designers, which was visible in 26% of the incidents, designers often decided to supplement the information. This suggests that at the beginning of the design process designers are faced with certain decisions regarding users' requirements; what to do when information is not available, and whether the information they have provides a sufficient basis for the design. The second point relates to the information on users' requirements in terms of its availability, and the form in which it is presented to designers. Information is seen to have a significant influence on the way designers approach design tasks, and as a consequence, on the overall design process. Diagram 5.5 on the next page provides an overview of the ways in which information on users' requirements influences the design process.

The findings highlighted differences in the kind of design process that develops as a result of the strategies designers apply to handling information on users' requirements in design. These differences were explored by examining the incidents in terms of the availability of requirements information to designers at the time of the design task.

Diagram 5.5

Users' Requirements Information in Design
(Sample: 43)



5.5.1 DESIGNING WITH AVAILABLE USERS' REQUIREMENTS INFORMATION

The data was examined for instances where designers had information on users' requirements at the beginning of an incident; eleven examples were found in the sample of forty three incidents. These eleven cases were examined to identify, a) the type of information provided to designers, and b) the kind of design process represented in the incident. The objective of the examination was to determine the kinds of information on users' requirements designers worked with, and whether the type of information influenced the kind of design that developed. The findings from the analysis are presented in Table 5.6.

Table 5.6
Users' Requirements Information In Design
(Sample:11)

Information Source	# Incidents	Subsequent Tasks	#
Specification	6	Prototyped	4
		Full design	2
Data	3	Supplemented	2
		Design concepts	1
Existing Designs	2	Supplemented	1
		Design concepts	1

The findings showed a relationship between the form in which requirements information was provided to designers, and how they were able to apply the information to the design task. We can see in Table 5.6 that in the incidents where a specification of the requirements was available to designers, they were able to proceed directly with a prototype or a full design. However, when the information existed in the form of data, or if it was necessary for designers to translate the information into requirements, designers supplemented the information or developed design concepts on which they obtained feedback before proceeding with a full design.

There were three forms in which users' requirements information was provided to designers. The form to appear most frequently in the data (six incidents) was a specification or a detailed list of requirements. In most of these cases, the requirements were provided by product management. In four incidents, designers developed prototypes on the basis of the information provided, which were presented to management for validation, and subsequently, underwent user evaluations. There were two examples in the data, where designers proceeded with a full design of the user interface, on the basis of the requirements information provided.

The second form in which requirements information was available to designers was through data on users and technical details. In three incidents, information was available in the form of data on user testing and on the technical constraints of the system. When the information was provided in this form, designers found it necessary to extrapolate the requirements from the data; two approaches were adopted in these situations. In two incidents, designers supplemented the information with additional information through research on user needs and on other similar systems. In the remaining incident, designers used the information to develop and assess design concepts before proceeding with a full design. The concepts were presented to management for a validation of the requirements.

The third form in which requirements information existed was through the designs of current systems. There were two incidents where requirements information was embedded in existing designs of similar products. Similar to the situations where the information was in the form of data, designers found it necessary to decipher the requirements. In one case, an existing product provided the basis for the design of the new product, and in the second case, the information was based on a competitors product. Designers adopted different approaches in these situations. One approach was based on an evaluation of the strengths and weaknesses of the products; this provided the basis for developing the requirements for the new design. In the second approach, design concepts were developed and assessed on the basis of the information provided.

The relationship between the type of users' requirements information and the development of designs, underlines a fundamental design requirement. The findings so far highlight a consistent need for information; designers are unable to proceed with a design unless they have sufficient details on the users' requirements for the system. What emerges as being particularly important in the information designers require, is clear details on the functionality of the system. The analysis suggests that requirements specifications identify the required functionality, however, information in the form of data, leaves the functions unclear. As a result it becomes difficult for designers to work out from existing designs, how to change or make improvements to the functionality of the system.

This relates to the types of design problems and issues visible in the majority of incidents discussed earlier, where the primary focus was on the functionality of the user interface. The development of the design process appears to be dependent upon the resolution of these issues, which is dependent on the information designers have to make choices and decisions.

5.5.2 DESIGNING WITHOUT AVAILABLE INFORMATION ON USERS' REQUIREMENTS

The examination of the data turned towards the remaining thirty- two incidents where designers did not have information on users' requirements at the beginning of the incident. The analysis highlighted two strategies designers apply to compensate for the lack of information; both involve designers developing the information themselves. One strategy was based on designers generating the information within the design team; in the second strategy, designers turned to outside resources to generate the information. The first strategy is defined as "internal" because the information is generated within the context of the design team. This is differentiated from the second strategy defined as "external", where the designers use resources outside of the team to generate the information. Both strategies were equally applied in the incidents; there were no examples of both approaches in the incidents. A summary of these strategic approaches is provided in Table 5.7.

Table 5.7

Design Strategies for The Development of Users' Requirements
(Sample: 32 incidents)

Internal Resources	No. Occur (16)	External Resources	No. Occur (16)
Conceptual User Models:		**Research:**	19
Creative			
1.scenarios	6	-technical/user studies	
2."creative insight"	3	-marketing	
3.brainstorms	3	-competition	
4.designer in role of user	2		
Formalisms			
5.UCM/models/profiles	6	**User Involvement:**	7
6.mock-ups	5	-field exercises	
7.logic/definitions	4	-talk/interview	
8.global UI rules	2	-feedback	
		Design Reviews:	2
		-group of external members of project	
		Formal:	2
		-experiments	
		-usability testing	

The findings highlight a contrast between the methods used in the two strategies to develop users' requirements. The diversity in approach is especially visible in the strategy based on developing requirements from the teams' internal resources. This strategy is based on the designers' conceptual models of users and their requirements; the designers generate requirements information by applying the model in different ways. A distinction can be seen in the application of these models, for example, the first four methods shown in Table 5.7 draw on the designers' creative and imaginative faculties to generate the information, like brainstorming and scenarios. Methods five through eight in the table, reflect a certain formalism or abstraction applied to the designers' conceptual models. The methods the designers use in this strategy, such as design models, and global rules, suggest an attempt to make explicit, the implicit knowledge from which the requirements are being developed.

The remaining half of the sample adopted a strategy based on consulting resources external to the design team to develop the requirements. There were four primary sources of information designers drew upon (See Table 5.7). Gathering information from studies, reports, and experiments, was the most frequently used method for developing requirements information. Designers also drew on user involvement as a means for developing requirements; the level of involvement varied considerably, and included field exercises, informal talks with users, user interviews, and user feedback on early design ideas. This method rated second in the number of occurrences in the sample of incidents. Design reviews and experiments were used less frequently as a means for developing users' requirements information; there were two occurrences of each in the data. Design reviews were based on a group of people external to the design team, who had some level of involvement in the project, to generate and review the requirements for the design. There were two examples of incidents where an experiment was conducted and a usability test was carried out to generate user data and information.

What immediately stands out from the findings is that first, designers always chose a strategy to generate requirements information when it was not provided; and second, how this influenced the initial design activities to focus on obtaining the information necessary to develop the design requirements. There are clear distinctions visible in the type of strategies applied, and also in the methods used in the strategies. In one strategy, we see designers developing the requirements among themselves, and in the other, designers engage in what appears to be a research mission. It was not part of the investigation to examine the reasons underlying the designers' choice of strategy; therefore the data does not address the question why internal strategies were chosen over external ones. However, there was no evidence in the data available to suggest why one strategy was chosen over another. Some of the factors that could have influenced the choices did come through the data, such as the possible limitations around the accessability of external resources for example, research material and users, and also likely variations in the ease and level of access to external resources among the project teams.

The question of choice raises a query about the equal split between the two strategies visible in the sample of incidents, and the fact designers did not appear to mix strategies within individual incidents. For example, there was no evidence in the data of an incident that drew on both internal and external strategies during the course of developing requirements. However, this did not mean that individual designers did not adopt different strategies in different incidents. It was common for designers to report an internal strategy in one incident, and an external one in another for example. The data was examined to establish whether there was a relationship between the choice of strategy and the designers' backgrounds. The analysis provided no indication of such a relationship; designers with a computer science or engineering background were as likely to choose an internal or external strategy, as those with a psychology or ergonomics background.

On the basis of the findings so far which indicate the importance of information to designers, it appears likely designers adopt strategies to generate information themselves because it is not available; possibly no other alternatives exist. Similarly, designers adopt external strategies because it may be possible for them to easily obtain the information, therefore it is not necessary to draw on internal resources.

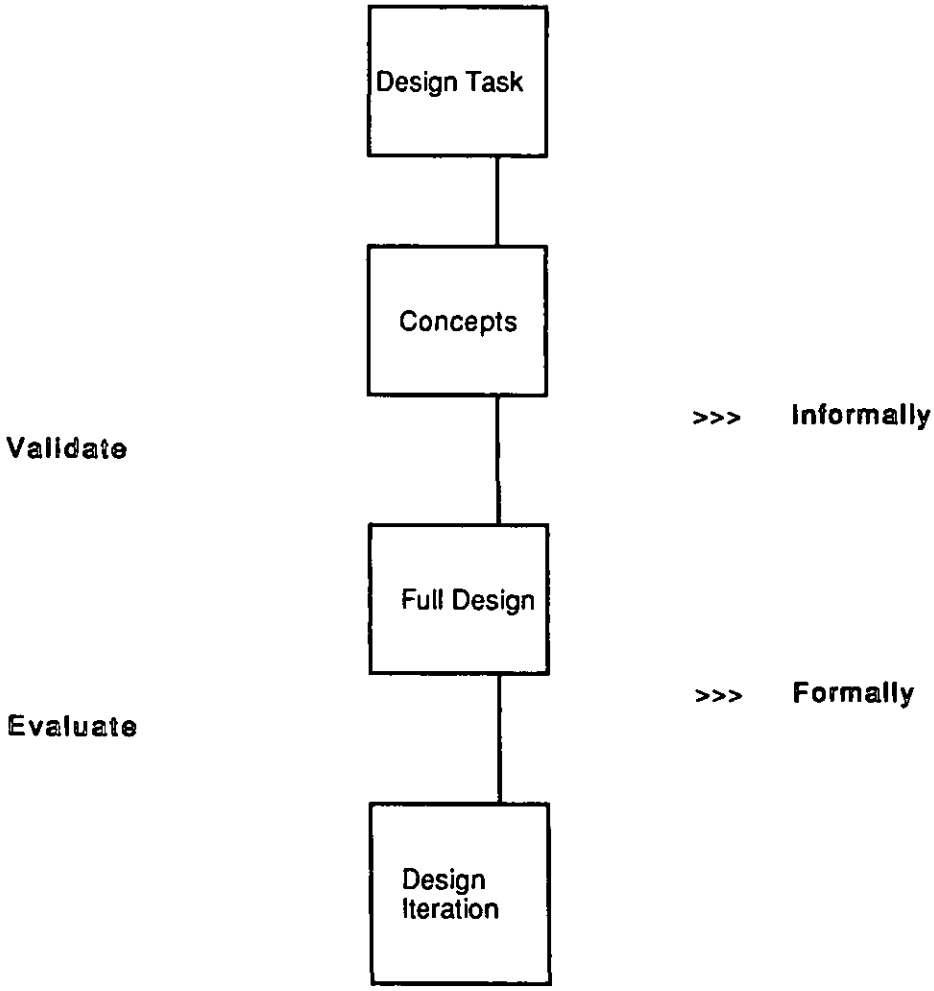
The close link between users' requirements and evaluation activities in the design process that appeared in the findings, suggested that a further understanding of users' requirements in design could be gained through an examination of the process by which designs were assessed.

5.6 DESIGN ASSESSMENT

The analysis turned to the second area identified in the data as key to the design process, the assessment of designs. A number of points arise from the examination of the process designers engaged in during the assessment of designs. The first point concerns the evidence of a design assessment in all of the incidents; there were no examples in the data of designs that were not subjected to some form of assessment. The second point to emerge from the data, relates to a similarity in the type of process designers engaged in during the design assessment. This process of assessment is represented within a single framework shown in Figure 5.8.

Figure 5.8

Evaluation in The Design Process



The process represented shows two categories of methods designers employed. The first category contains methods based on obtaining informal feedback from someone external to the project, for example, colleagues, management, and the occasional user or the consultation of references. This category is referred to as a method of "validation" because the methods used are based on casual feedback, and are applied to design concepts opposed to full designs. The second category of assessment shows methods involving prototyping or design mock-ups, and in some examples, included user testing. These methods are classified as "evaluation" inasmuch as they are concerned with a full design. Consequently, the methods aim at obtaining a high level of feedback, and are therefore of a more formal nature than the methods used in the validation process. A summary of the methods in the two categories is provided in Table 5.9.

Table 5.9

Design Assessment
(Sample: 43)

Assessment Methods	Users' Requirements Information	
	Unavailable(32)	Available(11)
Validation: (19)		
Feedback: manage.users.colleg.	11	4
lit/product references	2	
Consult Experts	2	
Evaluation: (24)		
Prototyping	7	3
Mock-ups	8	2
User Testing	2	2

The findings on the methods of design assessment highlight two strategies designers adopt to check out their designs. The first is to formulate design ideas or a partial view of the design, followed by an informal validation of the ideas for accuracy before proceeding with a full design. In the second strategy, designers immediately proceed with a full design which is evaluated and followed by design iterations. In both approaches full evaluations are conducted at the completion of the full design. This process can be seen in Figure 5.8.

There were indications in the data of a tendency toward the evaluation of designs (See Table 5.9). In twenty-four incidents, designers adopted the approach of developing a mock-up or a prototype as a method for evaluating the design. This is contrasted with the remaining nineteen incidents, where designers formulated design ideas on which they obtained feedback from management, users, or colleagues; sometimes the ideas were validated against similar designs. In terms of the forms of validation methods applied most, obtaining feedback rated the highest, followed by design mock-ups, and prototyping.

The findings point to a relationship between the strategies designers apply in the validation/evaluation process, and the strategies applied in the specification of users' requirements. This can be seen in Table 5.10. There are several indications in the data that the user's requirements information designers have available, influences the type of assessment that occurs. A different type of evaluation process occurs for example, when designers begin a task with a specification of users' requirements, than when designers are involved in developing a specification as part of the design task. The contrast in the three types of incidents, and also the relationship between the strategies applied to users' requirements in design and the assessment process, is illustrated in the three examples provided in Diagrams 5.10 through 5.12.

In these examples the relationship between users' requirements and the methods applied to evaluation is visible. There are two types of incidents where an evaluation process appears most; one is when designers are provided with sufficient users' requirements information, and the second is when designers develop the specification from external resources. The exceptions to this appear in examples where designers decide to supplement the information provided (See Diagram 5.10), or in the examples where user and system research was conducted (See Diagram 5.11).

A similar split is visible in the approach to the design assessment in incidents where designers developed users' requirements information internally within the team (See Diagram 5.12). Designers applied two different techniques to generate the information in these incidents, based on creative and technical methods. The technique applied to generating the information led to a particular kind of evaluation. For example, in the incidents where creative techniques were applied, such as brainstorming, there was a tendency to informally validate the early design concepts. However, the incidents that drew on technical techniques, like user modeling, tended to validate designs with a more formal approach.

It appears the more certain designers are about the design, the more likely they are to proceed with a prototype or a mock-up, and with an evaluation process. To reach this stage in the design process, however, designers seem to require a certain level of knowledge about the design solution; hence we see the tendency towards a process of evaluation instead of validation, when the design is based on a complete set of users' requirements. This corresponds with the finding on users' requirements information discussed earlier in Section 5.5.1, where the data indicated the availability of information enabled designers to progress to a design stage, that led to the development of mock-ups or prototypes early in the design process. This did not occur in incidents where information was not available to designers.

5.7 SUMMARY

The findings on evaluation highlight a number of important points about the design process. The first point reflects the importance evaluation has in the design process. Evidence of this is found in the precedence given to the final evaluation in the design

Diagram 5.10

Design Assessment Process:
Requirements Information Available
(Sample:11)

Users' Requirements Information

Form: Data:3 — Supplement:3 — Informal:5

Current Design:2 — Design Concepts:2 — Informal:5

Specification:6 — Prototype:6 — Formal:6

Informal:5 >>> Evaluation <<< Formal:6

Informal:5 — Feedback:5 — Management/Client

Diagram 5.11

Design Assessment Process:
Requirements Externally Developed
(Sample:16)

Requirements Information Developed

Methods: Research:12 Des.Reviews:2 Experiments:2

Research:12 — Informal:4

Des.Reviews:2, Experiments:2 — Formal:12

Informal:4 >>> Evaluation:16 <<< Formal:12

Informal:4 — feedback:4 — colleagues:3, manage:1

Formal:12 — mockups:6 — feedback:2

Formal:12 — prototype:4 — usability:2

Diagram 5.12

Design Assessment Process:
Requirements Internally Developed
(Sample:16)

Requirements Information Developed
Methods:

Creative:7 Technical:9

Scenarios:8 Brainstorm:6 Mockups:5 Logic/Definitions:4 Models/Rules:8

Informal:9 >>> Evaluation <<< Formal:7

feedback:8 references:3 prototyping:5 mockups:3

users:2 manage:2 literature:2 user testing:3

products:1

experts:2 colleagues:2

process. The second point relates to the influence this has on the strategies designers choose; the data indicates the importance of evaluation motivates designers to validate their designs early in the design process. As a result, we see the majority of design tasks concerned with the validation of design concepts and the evaluation of designs.

Finally, the findings highlight two important relationships developing from the information designers have available on users' requirements at the beginning of an incident. The first relationship is between the form in which users' requirements information is provided to designers, and the nature of early design tasks. The more comprehensive the information is, for example, in the form of a specification, or a list of requirements, the more likely the early design tasks will focus on developing a full design. If however, requirements information is not provided, or if it is considered incomplete by the designers, for example, it is embedded in data, the early tasks will focus on developing the information and testing out design concepts before proceeding with a full design.

The second relationship is visible in the requirements information designers have available, and the methods they chose to validate designs. When the requirements information is relatively comprehensive, as in incidents where a specification is provided, or the designers have applied technical methods to generate the information, there is a tendency towards more formal methods of evaluation, for example, prototyping or user testing. If however, designers have applied creative techniques to develop the information, there will be a tendency towards an informal validation that draws primarily on feedback methods.

5.8 DISCUSSION

A particular design framework emerges from the findings in which design activities focus on users' requirements and on the evaluation of designs. The design process is strongly influenced by evaluation; as a result we see designers engaged in strategies to promote the design to the evaluative stage. According to the data, designers do not proceed with full designs until they have sufficient information on users' requirements; instead they adopt compensatory strategies to develop the information themselves. In these situations, developing the information becomes a design task and is incorporated into the design process, thereby delaying tasks concerned with the development of design solutions. Consequently, full designs are developed and evaluated later in the design process, than in situations where complete users' requirements are available to designers at the beginning of an incident. The findings suggest that both the type and the format of the information available to designers is crucial to the development of the design; therefore it significantly influences the type of design that occurs, and also how it progresses to a completed design.

This highlights users' requirements as a key area in the design process; without requirements information designers are not able to proceed with design tasks. The findings point to particular strategies designers adopt to compensate for the lack of sufficient users' requirements information; these are based on the internal resources of the team or the team consults external resources. This raises a number of important questions with respect to design solutions. The first, which was not part of the investigation to address, is why designers choose one strategy over the other, is it due to circumstances, or do they have a preference for a particular strategy because they believe it leads to a better set of requirements? Another important question to consider is does a particular strategy lead to a more successful design solution?

Similar questions apply to the strategies designers apply to the assessment of design solutions. A similarity appears between the strategies applied to design assessments, and the strategies applied to developing requirements information. One strategy is based on an informal validation, drawing on resources relatively close to the team, and the other applied more formal methods by extending the assessment to include resources outside the domain of the team. Again, this raises the question does one strategy lead to a more satisfactory design outcome than another. It is not possible to determine from the data the possible relationship between particular strategies, and the success of design solutions; however, these questions provide indicators of some of the key factors that influence the design process, and consequently, the design solutions.

To explore the underlying causes of these findings, it is necessary to consider the design context in which the incidents were situated. Two variables in the design context are identified as particularly important in influencing the type of design process visible in the findings. The first is the product orientation of the design environment, which is seen to be a determining factor in the design process, by influencing the strategies designers apply to solving design problems. The emphasis on a low risk design approach that is visible in the focus on the validation of early design concepts and the evaluation of full designs, is seen to be directly attributable to the close link between the design and a marketable end product. This link results in designers not being able to take risks with incorrect designs; hence, the careful approach to ensure the users' requirements are completed before proceeding with the full design.

The second variable identified in the design context as an important influencing factor, is the separation of the design of the user interface from the rest of the system design. Evidence of the effects of this separation are found in two areas of the data. The first is in the careful mapping between users' requirements and the functionality of the user interface. This is visible in the emphasis on ensuring the requirements information available is an accurate representation of the future users' requirements. This appears in the methods designers used to develop and also to validate requirements information. Through separating the user interface from the rest of the system, the designers are able to dedicate resources entirely to the design of the interface. Also by focusing the design on the user interface through the separation from the system, the designers' attention is directed towards a user oriented design process.

This closely relates to the influence the separation of the user interface has on the validation process in the incidents. The separation of the interface increases the visibility of the design, and therefore design flaws are more likely to be highlighted. This motivates designers to use strategies that will enable them to "get it right", which is reflected in the early validation of design concepts and in the evaluation of designs.

Another important consideration is the type of designers who are given the specific role of designing the user interface as separate from the rest of the system design. Although the backgrounds of the designers included in the sample were well distributed between computer science and psychology, two of the designers from computer science and engineering disciplines, also had a psychology or an ergonomics degree. This raises the question to what extent does the designers' backgrounds influence the emphasis placed on users' requirements, and whether this has influenced the findings. Although a direct answer is not found in the context of the investigation, the findings from the observational studies in Chapter 4 offer some clarification.

The observational studies were based on design teams comprising of designers from backgrounds from both computer science and psychology. The findings from these studies did not show a similar emphasis on the systematic development of users' requirements or on the assessment of design solutions, that appeared in the interview studies. However, there is a similarity in the type of compensatory strategies the designers in the interview studies used to internally generate requirements information, to those applied by the designers in the observational studies. The findings from the observational studies showed that designers also chose to generate requirements information themselves, and drew on a number of informal methods to do so. There are important differences in the design environments in which these two studies were situated, which are necessary to consider. The observational studies were conducted in research-product environments, where the user interface constituted an important part of the design, however, the designers were also responsible for the entire system design. This raises the possibility that there are variables other than the particular backgrounds of designers that influence the extent to which users' requirements become the focus of the design.

One final condition developing from a design context in which there is a separation of the user interface from the rest of the system design, is the design requisite for detailed requirements information. A consistent theme in the findings denotes the functionality of the interface as a major part of design tasks. Decisions around functionality appear to require detailed information on users' requirements; therefore, designers are unable to proceed with the design until this information is available.

5.9 SUMMARY

The findings from the interview design studies raised a number of significant points that provided a different perspective on the design process, and the handling of users' requirements within the process. The main points are:

1. A common design process emerged from the findings in which design tasks began with the specification of users' requirements, followed by a design phase, and an assessment of the design solution. This process was highly iterative, and involved modifications to the design.

2. The findings highlighted two key areas of the design process, users' requirements and the assessment of design solutions. Both of these areas dominated design tasks, and influenced the kind of process that developed.

3. The analysis of users' requirements in the incidents highlighted the importance of requirements information for designers. In 74% of the incidents, information on requirements was not provided; therefore it became necessary for designers to obtain the information, and to develop a set of requirements themselves. Two different strategies emerged that designers adopted to handle this task; one was to develop requirements among the team, and the second involved designers turning to resources outside of the team.

4. The importance of information in design is also evident in situations when requirements information was provided. The findings revealed that in many of these situations, designers still decided to supplement the information by turning to outside resources. The form in which information was provided, appeared to be an important factor in determining whether designers made this decision.

The findings highlighted the importance of assessment in design, it occurred in all incidents. Two forms of assessment emerged from the data, one was based on informal methods, referred to as validation; and the second drew on more formal methods, and is referred to as evaluation. A relationship appeared in the data, between the strategies designers applied to generating users' requirements, and the methods they used in the assessment of design solutions.

CHAPTER 6

USER REPRESENTATIONS IN DESIGN DOCUMENTATION

CHAPTER 6 USER REPRESENTATIONS IN DESIGN DOCUMENTATION

6.1 INTRODUCTION

The investigation so far has focused on examining the design process and the representations of users' requirements in design through data collection in two different design contexts. Field studies have been based on observations of design meetings and design interviews in which recollections of design incidents from projects were recorded. The findings from these studies have provided a snapshot of design tasks in the design process. Two different design perspectives have been gained from these studies, each have provided illustrations of the relationship between design tasks and users' requirements. This led to the development of a characterisation of the design process in different design environments. A further understanding of the design process and the approach to users' requirements has been developed by extending the investigation to include documented accounts of design projects. The first two parts of the investigation included data collected from designers' recall of the design process, and data from the observations of "real-time" design activities. The sample of documentation data was intended to contribute to the characterisation of design developed from the data so far, by providing accounts of the design process designers selected to document. The inclusion of the documentation study in the investigation would represent another difference in methods, in design setting, and in the findings, which would contribute to the constraint of reconciling disparate findings.

For this reason, the additional data from the studies was intended to provide another view of the design process, which in itself would make an individual contribution to an understanding of design and users' requirements.

Chapter 6 presents the findings from the studies of the design documentation collected from two projects involved in the design of interactive systems intended for end users.

6.2 METHODOLOGY FOR THE ANALYSIS OF DOCUMENTATION DATA

The sample of data consisted of two sets of design documentation from two projects involved in the design of interactive systems. The data consisted of documents comprising of written sequential accounts of the design activities that occurred during the process of designing the systems. The first objective of the analysis was to obtain an overall view of the type of design process portrayed in the data. For this purpose the documentation was examined for evidence of:

- design goals;
- detailed design tasks;
- discussions of alternatives;
- discussions of problems/constraints;
- design decisions.

The examination of these areas provided categories of data that formed the basis for a more detailed analysis of the documentation for the types of processes underlying design tasks. This led to a study of the organisation of the design process in terms of its underlying structure, through the examination of the types of tasks and activities documented in the data. The objective of the study was to obtain a description of the design process as it was represented in the documentation. A further analysis of the data was made to discover how users' requirements were represented in the design process. The categories of design tasks and activities obtained from the first level of analysis, were studied for references made to users' requirements. This led to the examination of the following areas:

- the kind of language applied to users' references ;
- the types of references made to users and the application domain;
- the types of references made to users' requirements;
- the places in the design process containing user references;
- actual involvement of potential users.

The focus of these three levels of analysis has been on obtaining a description of the design process as it is reported in documentation, instead of a detailed account of the design content. It is recognised that the nature of the data will influence the content; each designer will naturally record events in a particular way, and therefore, will reflect certain biases. The data is considered valuable nevertheless for two reasons. First, it portrays the areas of the design process designers consider important to document and second, it provides illustrations of designers' perceptions of users' requirements in the design process.

6.2.1 THE SAMPLE DESCRIPTION

The sample was drawn from the data collected from the design documentation made available by the two design projects. The focus of each project was the design of an interactive system in which the user interface constituted an important part of the design. The two projects were from the same organisation, but these occurred during different time periods and therefore were unrelated. The design teams were different for each project and were involved in the design of completely different systems. The circumstances which led to the availability of the documentation as data for the research were different for the two projects. The documentation for the first project was written during the period of the design project which ended prior to the research; it was subsequently made available for purposes of the research. In the case of the second project, the documentation was commissioned for the research, and was prepared specially for this purpose.

The first project is referred to as 'Ozone' (not the real project name), and the documentation was prepared as part of the project; it subsequently became available for use as data for purposes of the research. The documentation covered a period of approximately eighteen months. The project team consisted of three members who participated in the writing of the documentation. The second project, referred to as Project 'Snapper' in the chapter, provided documentation covering a two month period; the documentation was commissioned as data for the research. The project leader was requested to provide a documented account of the major steps incurred during the design, and to record important decisions addressed during the design process. The project included three team members, and the preparation of the documentation material was a combined team effort.

6.3 DESCRIPTION OF PROJECT A ('OZONE')

The documentation studies began with the examination of the data from Project 'Ozone', which was concerned with the design of an innovative system for use by a diverse user population in office environments. The type of application the system was intended for resulted in the user interface being a particularly important part of the system. The project was on a larger scale than the second project in the sample, and covered a longer period of time; consequently, substantially more documentation was available as data. The data consisted of documented accounts in the form of design notes exchanged between project members during the eighteen month period of the project. The distribution of the design notes extended beyond the project team to other members of the research laboratory. The influence on the documentation of the different audiences at which it was aimed was reflected in the different purposes it appeared to serve. These are outlined in Table 6.1.

Table 6.1
Distribution of Documentation

Audience	Purpose
Research Laboratory	Generate awareness/interest
Research Group	Review purposes/approval
Project Members	Design purposes

The documentation data from Project 'Ozone' was examined first for evidence of the organisation of the design in terms of the underlying process and for the types of design tasks recorded. Secondly, the data was analysed to determine how users' requirements were represented in the design process. The documentation data consisted of twenty-three separate design notes. The individual design notes focused on specific aspects of the design, which were often described and worked through in the notes. This led to the classification of design notes as primary design tasks, which were identified by topic, related activities, and the process underlying the tasks. The sample of documents from which the twenty-three design tasks were drawn is summarised in the list of the documents provided in Table 6.2.

Table 6.2: 'Ozone' Documentation

	Document Type	Audience	Document Focus	#Pages
1.	'Ozone': A Proposal	Group	Concepts	4
2.	Semantics of Ozone	Lab	Language concepts	8
3.	'Ozone' semantics	Individual	Comment on language	1
4.	Info flow in 'Ozone'	Lab	Language syntax	6
5.	Ozone	Individual	Rebuttal	2
6.	'Ozone'	Individual	Reply to Rebuttal	1
7.	Design Note 1	Group	Detailed design	3
8.	Forms editor	Group	UI spec for editor	7
9.	Internal repr of forms	Group	Implementation	6
10.	Procedures example	Group	Test data spec	2
11.	Ozone Filing System	Group	UI spec for filing	5
12.	Ozone UI: interim dsgn	SIG	Overall UI arch	4
13.	Ozone cacher	SIG	Implementation	3
14.	Use of WFS in Ozone	SIG	Implementation	3
15.	Filing System Design	Group	UI design consids	4
16.	Completion of Ozone	Group	Implementation	6
17.	Ozone/WFS interface	Group	Implementation	8
18.	OZIFY Implementation	Group	Implementation	6
19.	Ozone text editor	Group	Implementation	10
20.	Ozone file format	SIG	Implementation	2
21.	Ozone input processing	Group	Detailed design	5
22.	Design of Ozone Lang.	Group	Language design	4
23.	Ozone meeting	Prod. grp	Report on mtg	3

Table 6.3 provides an overview of the design tasks from these documents. An example of a typical task and related activities from the data is provided in Example 6.4, on the following page.

Table 6.3
Project 'Ozone' Design Tasks

Types of Design Tasks			*Corresponding Design Stages*
Doc.	1	Conceptual	
	2	Guidelines/exploration ideas	**Stage 1:**
	3.	Exploration of ideas	*(design preparation)*
Doc	4	User requirements analysis	**Stage 2:**
	5	User Interface scenario	*(requirements analysis)*
Doc	6	Design User Interface	
	7	Solutions Explored	**Stage 3:**
	8	Implementation Issues	*(technical solutions)*
Doc	9	Evaluation	**Stage 4:**
	10	Constraints	*(evaluation)*
Doc	11	Rework User Model	**Stage 5:**
	12	Redesign	*(design iterations)*
Doc	13	Check design	**Stage 6:**
	14	Work through example	*(validation)*

Design & Implementation

Example 6.4

Task 1: Description of Information Flow

Supporting Activities:

	A.1	Designing users' model of information flow
Cluster >>>	A.2	Definition of objects & actions
	A.3	Steps defined to describe procedures

The analysis of the processes underlying the design tasks revealed a structured and coherent design process; this suggested a methodological approach to the design. This was visible for example, in the sequences of steps in the data like planning, investigation, design, and evaluation; stages often associated with classic design methods. The analysis pointed to a particular organisation to the design process in which primary tasks consisted of a sequence of steps that led to the development of design solutions. This is illustrated in Table 6.3. Individual tasks consisted of a number of supporting activities that provided a task structure consisting of clusters of related activities around tasks. An illustration of the task structure is provided above in Example 6.4.

The type of design process that emerges from this, is one in which there are specific stages to the process. In Table 6.3 we can see a correspondence between the tasks, and the particular stages in the design process. For example, the first three tasks are concerned with preparing the ground for the design, and the third and fourth tasks focus on the analysis of requirements. The type of process evident in the data reflects a particular top down methodological approach to design that was also visible in the study of design recollections described in Chapter 5. Although the focus of the stages differs from that seen in the observational studies, there are similarities in the way the design process is organised around particular stages, and also in the type of task structure.

6.3.1 TYPES OF USER REPRESENTATIONS IN DESIGN TASKS

The investigation shifted from studying design tasks as part of an overall process, to the examination of tasks for the types of representations applied to users' requirements. Tasks were examined for evidence of references to users' requirements, and also for the application of these in the task. The findings highlighted a predominantly technical orientation to the design tasks, in which the majority of tasks were directed at detailed system design issues. In spite of the technical focus however, there was evidence in the data of references to users' requirements in tasks. For example seventeen of the twenty-three design tasks in the sample reflected some form of reference to users' requirements. Table 6.5 presents an overview of these tasks.

We can see from the table that user references are fairly well distributed among tasks during the first two-thirds of the design process, after which a shift occurs away from user considerations as design tasks increase in technical content.

A closer examination of user references in design tasks revealed a differentiation in the type of references applied in the tasks. Three types of references to users emerged from the data. The analysis of the types highlighted two points that contributed to an understanding of how users' requirements were represented in the design. The first point indicated that references to users were primarily based on designers' conceptual models of users, from which they constructed requirements. These conceptual models were visible in the types of references made to users in the data. The second point to emerge from the findings, highlighted the different ways in which user references were applied to design tasks. The analysis indicated that the particular constructs designers develop from their conceptual models serve a functional purpose in tasks.

TABLE 6.5

USER REFERENCES IN DESIGN

User Reference	Task#	Activity
	T.1	Ideas exploration
Representation Type A	T.1	Conceptual Design
	T.25	Establishing Criteria
	T.5/6	Technical
	T.7	Technical
	T.10	Constraints
Representation Type B	T.11	User Model
	T.14/15	UI Design
Representation Type C	T.17/18	Problems
None	T.12	Technical
	T.16	Technical
	T.19-24	Technical

The application of the different types of user references to design tasks was examined to determine the extent to which users' requirements were represented in the references. The findings pointed to significant variations in the representations of users in tasks that were related to the type of reference. The first type of user representation (Type A) is based on specific types of users drawn from the application domain, of which designers have first hand knowledge. Representations of this type are based on information obtained from the user studies conducted prior to the project. There is a distinct difference in the second type of representation (Type B), which consists largely of generalised concepts or theories of generic users drawn from hypothetical situations. Representations of this kind reflect designers' conceptual models of users. There are indications however, that in some cases these models may have been influenced by the knowledge gained from the user studies. The third type of representation (Type C) appears to be based on abstract models of users, and reflects neither the characteristics of users' requirements, or the application domain. In some instances, the level of abstraction applied to users' requirements is sufficiently high and results in the representation reflecting the abstraction, and not necessarily the users. Table 6.6 provides an outline of the three types of user references and a summary of the functions they often fulfill in tasks.

TABLE 6.6
CHARACTERISTICS OF USER REPRESENTATIONS

TYPE A	*TYPE B*	*TYPE C*
User Model:		
User Specific *Specific*	*Generic user types* *Generalised domain*	*AbstractDomain* *Concepts*
Basis of Model:		
User Studies *Domain knowledge*	*User concepts & theories* *General Knowledge*	*Abstractions* *of theories*

Representational Functions: Types A - B - C
- *to support task*
- *to contribute to development*
- *to develop & ground design concepts*
- *to understand requirements*
- *to work out design solutions*

The findings indicated that at certain stages in the design process, a particular type of user representation was more likely to be applied than the others. According to the data, there were few (five)Type A user representations visible in tasks in the early stages of the design process, with one exception. This contrasts withType B representations, which appeared in nine tasks during the middle stages of the design process. Type C representations were evident in four tasks towards the end of the design process.

6.3.2 THE APPLICATION OF USER REPRESENTATIONS IN DESIGN TASKS

The findings suggest that users' representations are primarily based on the conceptual models designers have of users, and of the application domain. There is evidence that these models are sometimes expanded to incorporate new information related to the requirements of the potential users. In the examples of user representations provided so far, the extent to which information on users' requirements has contributed to the representation is ambiguous. In most examples, it is unclear whether the representation reflects the designers' conceptual models of users' requirements or requirements obtained from studies, or an amalgamation of both. This was highlighted as an important point to investigate further because of the extensive user studies, some of which were observational, that were conducted prior to the design of the system. A further examination of user representations focused on the source of information from which they were formulated. The analysis indicated there were three types of information on users' requirements that designers drew upon to formulate user representations. These are summarised in Table 6.7.

Table 6.7
Types of Users' Requirements Information

Basis of Information	Example	Related to Studies
Knowledge from user studies	"*what we know about users is*"	yes
Designers' experience and personal requirements	"I find it difficult to remember..." "[therefore users will also find it difficult....]	no
Abstractions of user information	"one always needs clear reference points."	no

The examination of the sources of information reflected in the representations revealed variations in the types of information designers used to represent users' requirements. There were few examples in the data where the source of information was explicit in the representation; in the majority of cases, it remained unclear. We can see from the first example below, the representation is clearly based on information derived from user studies. In the second example however, it is unclear whether the representation is based on the designers' theories about the task or, if it is based on information obtained from the studies.

Example 1:

"The following example of a task is drawn from our studies......Individual tasks......are identified....they are performed by a single person; they commence when that person receives a document......"

Example 2:

"Most office workers are accustomed to check every document they received before doing anything else to it. If they discover an error, they generally return the document ....; sometimes they correct the error themselves after a discussion with the other party".

This suggests the source of the information on which requirements are based is not especially important. It also suggests that it may be more important for the representation to convey a particular point in the design. This led the investigation to examine the objectives underlying the representations.

6.3.3 THE FUNCTIONAL CHARACTERISTICS OF USER REPRESENTATIONS

A further examination of the representations pointed to the particular functions user representations can fulfil in tasks; this becomes evident in the contrast in the ways they are applied in tasks. Three specific functions were distinguished in the data that illustrated the ways designers apply user representations in support of tasks. The first function showed representations applied as a method for explication, to designers and also to others external to the project. The second function was based on representations being used as a tool to ground design concepts, particularly concepts that were highly technical and abstract. The third function, which was less apparent in the data, was the use of representations as an aid in the validation of design solutions. Examples 6.8 through 6.10 provide illustrations of the different ways representations were applied to support design tasks.

Example 6.8
User Representation Type A

"Each state is labeled with some important attributes; in particular, each has a name, and may have a recipient and a condition for progress. Thus the application form is first filled out by the applicant. It is now in the "needs approval" stage, and is therefore sent to the applicant's manager. He looks at it, signs it; it is now "approved" and moves on to the manager's secretary.

"The secretary handles these applications only on Fridays; every Friday she takes each application, makes out an invoice, and then computes a balance due."

The first example 6.8, provides an illustration of a representation that fulfils a descriptive function for the benefit of the designers, and also to others external to the project. The representation is applied to a task involving the procedural definitions for the language, and it forms part of the discussion of the choice of a procedural language for the software system. The representation appears to be based on the designers' direct knowledge of the users' tasks, as they are performed in the application domain. It is used in the task to enable the designers to formulate a description of a set of procedures required to perform a particular task. We can see how the reference to a specific type of user and the ways in which the user carries out the task, supports the procedural description.

A contrast in the function of a representation can be seen in the example below (6.9) of another type of representation applied in the same task. A difference is visible in the underlying function of the representation which comes through in the way users are referred to in the task. A shift is visible in the focus of the representation from the user to the system. In this way the references to users contributes to the development of the design concepts.

Example 6.9

User Representation Type B

"Not all of the steps in these procedures will be performed automatically. *Some information will be supplied by the user, and some conditional branching will be under the user's control.* [The language] will provide a written language in which to describe these procedures. A diagram compiler would, however, be useful......"

"......the reason for separating [the language] into two sub-languages is obvious.*The basic flow diagram is for the use of all people involved in the task. It helps them to understand their particular responsibilities.* It also suggests several attractive properties of the user interface......"

A significant difference from the first example also appears in the way users are represented in the task. In the first part of the representation, the task performance is the primary focus, and results in user references being woven into the technical discussion. The second part of the representation continues to refer to users in a broad sense for purposes of description. However, in the last sentence the objective appears to be aimed more at corroborating a particular design decision. The context of the reference highlights an underlying necessity to justify the decision for two separate sub-languages. The implication for the user representation is visible in the way it is drawn into the task to contribute to the justification of the decision.

The findings highlighted variations in how designers applied the knowledge and information they had available from the user studies. In the first example, the information from user studies is not made explicit in the representation. However, the clear description of users' tasks suggests the representation may be based on observations of users performing the task. The technical focus in the second example tends to obscure the basis on which the representation is constructed; this is particularly visible in the last sentence, *"It helps them to understand their particular responsibilities".*

Although this statement comes across as a fact, it is unclear whether it is derived from specific information on users' tasks, or if it is based on a value judgement drawn from the designers' collective knowledge gained from the studies. Other significant differences were visible in the application of user representations when they appear later in the documentation, as the technical detail of design tasks increased. In Example 6.10 we see an illustration of how a user representation is constructed to support a technical task.

Although the task is focused on the syntax of the language for the system, we can see how the design of the language is followed by a description of users' task procedures, and in a sense, the solution is mapped onto a typical office procedure. This is clearly for the purpose of specification; it also appears to contribute to an understanding of the language application. Although there is no explicit mention of users or to the studies, the procedures reflect users' task procedures.

Example 6.10
User Representation Type C

[Syntax of the Language]

"The first two lines of the procedure description identify the conditions for invocation, the name of the procedure, and the job title of the person performing it. They have the following syntax:

Invocation condition :=
On receipt of <form name>, <form state> [and <form name>
Every <interval> [at <time of day> }
Name :=
<name of procedure> (<job title>)

Following this heading are the steps of the procedures. Each type of step involves a slightly different statement syntax, as indicated in the following list:

Fetch statement :=
Fetch <form name> [, <form state>]
Fetch new <form name>
Fetch <folder or file name>

Example 6.11

User Representations In Describing Office Procedures

On receipt of TA, for approval,
Approve TA (Head of Department):
Check Departmental Approval on TA;
Send TA, needing logging, to Transportation Clerk.

"This is a typical operation performed on randomly-arriving forms, so that they may all be processed at once. Processing is done as follows:

Every day at 1600,
Log TAs (Transportation Clerk)
Fetch Daily TA Folde;r
Fetch TA Log;
On each TA in Daily TA Folder:
Fill in entry in TA Log using TA;
Fill in TA number on TA using TA log."

Another example of this is seen in Example 6.11. In the later stages of the design process, there are several examples of user representations applied to tasks to validate completed design solutions. This validation function is visible in Example 6.12 on the next page.

Example 6.12

User Representations In a Validation Task

"Editors of scientific and technical journals generally keep files of the manuscripts they receive, and store in these files all correspondence relating to the refereeing process each manuscript undergoes. Almost invariably the editor assigns a folder to each manuscript. Within each folder, a wide variety of documents are stored: current and earlier versions ....

In [the system] we might show the contents of one such folder thus: [diagram not shown]

Note that the sort keys are all blank: new labels are added in the order they are created. The editor uses the general-purpose fields to indicate the sender or recipient of letters and other documents and to indicate something about their contents.

In this representation we can see a mapping process occurring between the users' requirements and the design solution. During this process, designers appear to be working through the solution in order to identify inconsistencies in the design. In this way the representation provides a kind of validation function.

6.4 CONCLUSIONS

The findings from the examination of the documentation data highlighted two design characteristics that were considered significant to the investigation. The first characteristic to emerge was the substantial part the documentation played in the design process of the system; this was evident in two ways. The first way was in the development of a design rationale that was predominate throughout the documentation. This was seen as an influencing factor on the types of design tasks and user representations reflected in the data. The type of design process that emerged from the data was characterised by a gradual unfolding of design solutions, in which there was an emphasis on the definition and description of the design. The emphasis on a design rationale was also evident in the focus on design decisions in the documentation; the explanations and justifications for the decisions constituted an important part of tasks.

Two important factors influencing the focus of the documentation is the intended audience of the documentation, and also the objectives motivating the documentation process. It is important to consider that the documentation was aimed at an audience external to the project, partly to acquaint others with the development of the new system, and also for possible review purposes. The type of system under development was the first of its kind, and was based on a different approach to the application. As a result, we see an emphasis on the presentation of design concepts, and on the accurate representation of the design throughout the documentation.

Although the emphasis in the documentation is on the presentation of the design as logical and consistent to others, there appeared to be another underlying purpose. The findings suggest that the process of documenting the design step by step, is an important design exercise for designers. This process appears to support design tasks through providing a mechanism for designers to develop design concepts and solutions, and also to check for consistency in design solutions. In this way the documentation becomes a design exercise, and consequently, becomes an important part of the design process.

The second characteristic to emerge from the findings was the significant part user representations played in the documentation. This was evident in their contribution to the development of a design rationale, and also through the functions they served in support of design tasks. User representations were characterised by:

- the kinds of conceptual user models designers held;
- the basis of information for the models;
- the purpose and function of application in tasks.

An important point relating to the application of user representations in design tasks, is the way designers formulate representations from different sources of information. The analysis revealed designers tend to construct users' requirements by drawing information from the following areas:

- specific users and application domains;
- generic users and application domains;
- theoretical and hypothetical users

User representations contributed to the overall design by providing building blocks at various stages in the design process. There are a number of ways this is visible; for example, in the way they are applied in the development and the grounding of design concepts. It is also evident in the way in which representations are woven into the design for explanatory and definition purposes, and to clarify specific concepts. There was a fairly consistent pattern of representations intermixed with the design, either preceeding a specific solution to lay the groundwork for the design, or subsequently, to explain the application of the solution. One of the important functions of user representations to emerge from the findings, was the validation mechanism they provided in the design process. Designers created and applied representations to design solutions, and engaged in a mapping process between the requirements and the solutions. In this way, designers were able to check for inconsistencies in solutions and for inappropriate user-task mapping.

6.5 DESCRIPTION OF PROJECT B ('SNAPPER')

The investigation of documentation data was based on the analysis of the documentation from the second project referred to as Project 'Snapper' (fictitious name) in the chapter. This project was involved with the design of a digital colour scanner for use in an office environment by a wide range of users. The intended casual use of the system made the user interface an important part of the design. The documentation covered the two month period of the project; it was commissioned for purposes of data for the research. The same methods for the analysis of the data used in the first project, were applied to the analysis of this project. Table 6.13 provides a list of the documents included in the data sample.

Table 6.13

Project 'Snapper' Documentation

Document Type		Audience	Document Focus	#Pages
1.	Project Methodology	Team	Project concepts &org.	4
2.	Project Definition	Team	System concepts, goals	2
3.	Constraints	Team	Time, budgets,manpower	1
4.	System Req.Analyis	Team	Requirements,sys/users	2
5.	Processors & S/ware	Team	Possibilities considered	2
6.	Technical Survey	Team	Survey of technology	4
7.	System Design Manual	Team	Drawings of system	4
8.	Part Require. Analysis	Team	Operators spec & UI	8
9.	Relay Racks	Team	Technical survey	4

The first point to emerge from the examination of the documentation data was the particular approach to the design. This appeared to be influenced by the designers' model of the design process which they attempted to map onto the project. There is clear evidence of this mapping process during the early stages of the design. It becomes apparent in the first task concerned with the organisation of the project.

In this task the concepts underlying the design model are visible, this is illustrated in Examples 6.14 and 6.15. The model is also visible in a task in which a description of the components and the structure of the design process is developed (See Table 6.16). The model underlying the description is based on the concept of a collection of documents describing the states of the design, and an activity graph showing the interdependencies of the documents.

Example 6.14
Example of a Task

"There are many ways of viewing the design process. In fact it is very likely that every designer has their own unique mental model of [design]. Moreover this is probably one of the major problems facing any design team about to embark on a project involving design. When viewed from a distance, the various activities that the team performs appear uncoordinated and contradictory."........

Example 6.15
Example of a Task

" This note is an attempt to try and improve the situation. The notion behind it is that any reasonable design method is better than none. This stems from a belief that if all of the members of the design team have a common view and faith in the method, then less effort will be wasted..... "

As a result we see the documentation organised within the framework of the model represented in Table 6.16. Consequently, a design process emerges in which the tasks and activities develop in a top down approach. This process is illustrated in Table 6.17, where the primary tasks are presented in the order in which they appeared in the data. An examination of the primary tasks showed that each task was supported by one to three closely related activities. The clustering of tasks and activities is shown in the examples provided in Table 6.18. This task structure was also visible in the first project studied, and in the design process represented in the observational studies.

<u>Table 6.16</u>

<u>Project 'Snapper' Design Process Model</u>

<u>The Key Documents</u>:

Goals, Concepts and Completions Tests
Output of Project Definitions activity

Technology Subsystem Comparisons
Output of Technology Survey activity

Project Constraints and Assumptions
Output of Constraints Analysis activity

User Data and Examples
Output of User Studies activity

Needs Specification
Output of Needs Analysis activity

Requirements Specification
Output of Requirements Analysis activity

Design Specification
Output of Design activity

Prototype
Output of Implementation activity

Release
Output of Testing activity

User Documentation
Output of User Documentation activity

Table 6.17

PROJECT 'SNAPPER'

		Types of ***Design Tasks***	***Corresponding*** ***Design Stages***
Doc	1	Organise Design Process	
	2	Project Goals Established	***Stage 1:*** *Preparation*
	3	Design Criteria Set	
	4	Constraints Discussed	
Doc:	5	User Needs Analysed	**Stage 2:**
	6	Hardware/Software needs	*Analysis of Needs*
Doc:	7	Technology survey	**Stage 3:**
	8	Technical configuration	*Technical Solutions*
	9	Technical design	
Doc:	10	Requirements Analysis:	**Stage 4:**
		Decisions	*Specification of Design*
		Steps towards Implementation	*Stage 5:*
			Implementation

Table 6.18

Task-Activity Clusters

	Task 1: *Determine System configuration*		
	Activities:		
Cluster #1		A.1	*drawings of physical layout*
		A.2	*System configuration*
		A.3	*Control features worked out*
	Task 2: *Establishing Project Goals*		
	Activities:		
		A.1	*Determine what system will do*
Cluster #2		A.2	*Question purpose of designing system*
		A.3	*Establish vision of use*

Table 6.19

User References in Design

User Reference	Stage	Task#	Activity Type
	1	T.2	establishing project goals
yes	1	T.3	establishing design criteria
	2	T.5	analysis of user needs
	1	T.1	organising design process
none	1	T.4	design constraints
	2	T.6	h/w & s/w needs
	3	T.7	technical solutions
	3	T.8	system configuration
yes	3	T.9	communication needs
	4	T.10	requirements specification

Another similarity to the other design studies appeared in the organisation of the tasks around a specific focus. An example of this is seen in Table 6.19 where the first four tasks relate to the preparation for the design, and are followed by tasks concerned with requirements analysis, both user and hardware/software. Tasks 7, 8, and 9 have a technical focus, and are concerned with design solutions; the documentation ends with a specification of the requirements in Step 10. In spite of a few minor variations in the focus of the stages, there is the reoccurring theme of design stages in the design process that was evident in the other studies. The differences are visible in the first stage concerned with the organisation of the project, which was not present in the observational studies, and in the final stage focused on the development of the specification, which was also absent in the other studies.

6.5.1 REPRESENTATIONS OF USERS IN DOCUMENTATION

The primary tasks were examined for evidence of references to users' requirements and for the types of users representations and their application to design tasks. In the sample of ten primary tasks there was evidence of references to users in four tasks. Table 6.19 shows where in the design process these occurred. We can see from the table that references to users occurred in the early stages of the design process, for example, the second, third, and fifth tasks. There is an absence of explicit references to users in the remaining process, with one exception in the last task which is based on specifying the requirements.

The findings suggest that the infrequent references to users may be closely related to the technical level of the tasks. A relationship appears between the level of technical detail in tasks, and the presence of user references. This is visible in Table 6.19 where the tasks containing user references are relatively non-technical, in the sense they are concerned with issues other than system design details. As tasks become more focused on the technical details of the design, there is a decrease in references to users.

A closer examination of the characteristics of user references in the design tasks highlighted a number of points about the application of user representations. The first point relates to the levels of abstraction visible in the user references. Although the references related directly to users' requirements, there was no evidence to suggest these were connected to a specific user population or domain. An examination of the types of representations applied revealed they were essentially abstractions of users' requirements, inasmuch as they referred to generic types of users, for example, "a secretary", or "a casual user". For this reason, they are classified as Type C representations which are derived from abstract models of users, discussed earlier in the section on Project 'Ozone'. There was no evidence in the data of user studies or an analysis of users' requirements prior to the documentation of the project. Consequently, the source of the information from which the representations are drawn remains unclear. The type of representations applied in the tasks, together with the level of abstractions with which users' requirements are presented, suggest that the designers drew upon their conceptual models of users and the domain.

The second point pertains to the application of user representations to design tasks. Similar to Project 'Ozone', the representations in Project 'Snapper' appeared to serve different functions according to the type of representation, and the way it was applied in the task. The data highlighted four purposes for the application of user representations to tasks:

- to contribute to the development of design goals;
- to establish completion criteria;
- to develop requirements;
- to create operational scenarios.

The three examples provided in Example 6.20 illustrate the different ways user representations were applied to design tasks. The examples are drawn from user references in the first and second stages of the design process. After this there is an absence of user references until later in the documentation, when they appear in a task on the specification of requirements. Example 6.21 provides an example of a technical task immediately following the first example that illustrates the shift in the task focus. Example 6.22 provides examples of the last reference made to users during the specification stage, the final stage before implementation.

In the first example shown in 6.20, the user representation is applied to the task of developing goals for the new system. The representation is used to aid the designers in developing a vision for the system. Expressions are used in the representation that display certain elements of idealism, for example, "the vision", "should be able to", "the aspiration is to". This suggests the designers are exercising their imagination to think about how they would like the system to be used. In spite of the visionary aspect to the task, there is evidence to suggest the designers have a clear conceptual model of how the system should be used, and by whom. The emphasis in the task on the criteria for usability is visible. The focus on the ease of use for both novice and casual operators of the system, indicates the designers have clear perceptions of what users will demand from the system in terms of usability. The designers' model of the user appears to be constructed from concepts and theories of users, combined with factors known to influence system usability. The model does not appear to be substantiated with information from specific users or from the application domain.

The second example in 6.20 is taken from a task based on establishing design criteria; the major part of the task is to formulate criteria for testing the system. The user representation applied to the task is oriented towards the collection of data on the systems performance, and reflects a certain level of abstraction; users are referred to as "subjects" and "individuals". This is a contrast to the

EXAMPLE 6.20
User References In Design Tasks

User Reference 1.

Task: *Establishing Project Goals*

"The vision is that any computer user, for example a secretary familiar with the operation of a [system] or IBM PC should be able to digitize several magazine pages, 35 mm slides or live scenes in 30 minutes, *with no training or prior experience of this system (i.e. "cold").* On the other hand, a more experienced but nevertheless casual user should have no trouble in digitizing a single image in under 60 seconds. The aspiration is to produce a system that has the same sort of "user-investment" characteristics as a simple photocopier."

User Reference 2.

Task: *Establishing Design Criteria*

Acceptance Tests

"Five individuals with [system], IBM PC, or equivalent experience will be selected as "subjects". No subject will have experience of using [the type of system under design]. Each subject will be given 30 minutes to perform a task that includes scanning some opaques, some slides and their own face. The data is to be delivered to a predetermined file service."

The same test will be conducted about a week later.

"NB: Prior to these final acceptance tests it may be useful to perform similar tests with pairs of subjects. The verbal exchanges that occur between the subjects while they explore the system can provide useful insights into flaws in the design."

User Reference 3.

Task 5: *Needs Analysis*

"A description of user needs for the [system] for the [project]. This includes both physical constraints as well as functional constraints.

Example 6.20 ***(continued)***

Typical User:

A Novice computer user.

- Should be a public system
- Examples:
    - writers
    - graphic artists
    - general office people
    - casual users(once a year)
    - expert users (Joe Bloggs)

Typical Tasks:

Capture color or B&W images for:

- incorporation into technical documents
    - images used as scanned ("as is"); no processing done
- artwork
    - posters
    - sliders
    - However, not graphic arts quality (Vogue)

Requirements:

Use
- intuitive & simple
- "frame & fire"
- easy to start; easy to reset.
    - should be obvious when not in the default setup
- little training needed; no in-House expert
    - reasonable defaults for the first time user
    - overrides for the experts

models
- good: telephone, new automatic cameras
- bad: certain microwave ovens (need more examples)

- robust
    - should instill confidence
    - software & hardware
    - obvious when broken
        - hopefully user fixable(???)what does this really mean.....
- relatively quick
    - <20 secs per image ....

-replicable

Example 6.21
Shift In Task Focus

Task: *Processors and Software - Possible Choices*

Processors

"There are several factors that affect the choice of hardware. Since the station is to be on the network, there must be an ethernet connection available. Also, the frame grabber hardware is IBM PC compatible thus access to a PC bus is necessary. Standard "off the shelf" hardware is desired in order to make the system easier to replicate as well as repair. And of course, cost is always a factor."

Software

"A major concern in choosing a software environment is the ease with which can develop a prototype system. Of the software available for the hardware discussed, [sic] is the best environment for prototyping. The various choices for the IBM PC all had similar drawbacks (eg a lack of support software, poor error handling, etc.) They would have required much more work than a [sic] environment which has been designed for prototype work."

Example 6.22
User Representations In The Validation of a Design Task

User Reference 1.*

Task: *Operational characteristics: Overview*

"The I/O for the [system] will consist of several major components....... In a typical scenerio for scanning an 8 x 10 opaque, a *user* will log in on the terminal, 'frame' the picture using the front panel switches, and then save the image by pressing another front panel switch. The lighting, camera height, and default file name will all be handled automatically with the ability for the *user* to override the defaults. When scanning other than an opaque the scenario may vary slightly."

User Reference 2.

"When a *user* logs in, the power should be turned on to the camera, the color display and the lights. Logging in consists of entering a user name and password on the VDU. After the *user* has successfully logged in, the 'active' LED should be lit on the front panel.......

After a *user* has logged in, a file name should be proposed. First the user's profile should be checked for a list of file paths. If one is found, then the first entry in the list should be the path proposed. If there is no *user* profile entry, then the station log file should be checked for a file name from a previous session. If this is a new *user* with no log entry then a path should be 'guessed at' and checked for 'reasonableness.' If the proposed file name is not acceptable to the *user*, a new one may be entered from the keyboard."

User Reference 3.

"When the *user* presses the active/idle button the 'idle' LED should be lit. Then the log file should be updated, the station should be set up to scan an 8x10 opaque, and the power should be turned off for the lights, VDU, color display, and camera." *[Italics mine]

6.6 CONCLUSIONS

The findings from Project 'Snapper' have highlighted several design characteristics which contribute to our understanding of the design process, and the representations of users in the process. The level of contribution however, is influenced by two important limitations of the documentation as data, which are necessary to consider in the final analysis. The first influencing factor was the commissioning of the documentation as data for the research. This is reflected in the careful representation of the design as a coherent and structured process. This raises the question to what extent did the designers portray the type of design process they thought would meet the expectations of the research. There is the possibility that a different type of process would have been documented, if the designers did not expect it be subject to a careful examination. The second limitation was evident in the absence of users' requirements in the design process. In spite of these limitations, the documentation data has nevertheless contributed to our understanding of design. It has done this by extending and confirming our knowledge of design in some areas.

The most significant contribution the documentation data has made to the investigation of the design process lies in the illustrations provided of the conceptual models designers have of users' requirements, and how these are mapped onto design tasks. Evidence of one type of model is found in the beginning of the documentation, where designers hold a particular model of the design process, and attempt to organise the project according to the model. What emerges from this, is a discrepancy between the design intentions underlying the model, and the actual representation of the design in the documentation.

This raises a number of interesting points with respect to the causes contributing to the discrepancy. One point relates to the lack of continuity between the early design tasks focused on design goals, criteria, and system requirements, and the more technical tasks focused on detail design issues that occur later in the documentation. One possible explanation for this lack of continuity, is the difficulty designers experience in sustaining the outcome of non-technical tasks throughout the design process. This results in the outcomes from earlier tasks not being incorporated into design decisions and solutions.

Another contributing factor to the lack of continuity in the design, is visible in the particular approach to design portrayed in the documentation. The "lets build and see" design approach represented in the documentation, can be seen to influence the design in a number of ways:

- it influences a technical orientation to design tasks;
- it promotes design towards rapid implementation;
- users' requirements are developed quickly; accuracy is not particularly important;
- user considerations can be deferred to the post implementation stage.

The representations of users in design tasks in the documentation provide another example of the conceptual user models designers apply in the development of design solutions. Although there was no evidence of requirements studies prior to the project, the designers nevertheless, developed users' requirements for the system based on the abstract conceptual models they held. This is significant for several reasons, first, the lack of information on users' requirements did not appear to inhibit the design, as was almost always the case in the other design studies. The fact the designers were able to proceed with the design, despite the lack of information appears to be related to the "lets build and see" design approach. This particular approach made it possible for requirements issues to be deferred until implementation when user testing and an evaluation were planned.

Another point relating to designers' conceptual user models is that these models formed the basis for user representations which were applied to design tasks. Conceptual user models were used to support design tasks in some very fundamental ways, for example, to develop the system concepts and to validate the specification of the user interface. The application of these representations to tasks in this way makes it important to consider the source of information on which these representations are based. This relates to a theme evident in the other research studies; the source of users' requirement information often is not particularly relevant during the design process. However, what consistently appears to be crucial for designers, is that they are able to develop user representations which they can apply to the task, to fulfil a supportive function.

6.7 UNDERSTANDING DESIGN THROUGH DOCUMENTATION

The findings from the analysis of the two sets of design documentation, Project 'Ozone' and Project 'Snapper', raises a number of important points with respect to the type of design illustrated in the documentation and the ways in which users' requirements are represented in design. In spite of the differences in the two projects, for example, the length of the projects, the access to users' requirements information, and the intended purpose of the documentation, a similar set of conclusions can be drawn.

One of the first conclusions that can be drawn is the influence the intended audience has on the type of documentation that is generated. Very different types of documentation emerge from the two projects which is seen to be a direct result of the differences in the intended audience. In Project 'Ozone', the audiences ranged from project team members to colleagues, to possible management reviews. Consequently, the documentation attempts to represent the design so that it addresses the interests and concerns of those readers. We see evidence of this in the focus in the documentation on detailed functional specifications, user scenarios, and comprehensive descriptions of the intended system. Also evident in the documentation was an underlying attempt to develop a rationale for the design.

This was very different for Project 'Snapper', where the intended audience of the documentation was limited to the project members and the reseacher. This resulted in a very different focus to the documentation, which does not appear to play such a key part in the overall design as it did in Project . In Project 'Snapper', the focus of the documentation was more on representing a coherent and methodological approach to the design process, than to develop a rationale as in Project 'Ozone'. Instead, the underlying theme in the documentation of Project 'Snapper' was that of "look, we have a good design practice".

An important outcome of these variations lies in the type of design rationale that is developed through the documentation. Both sets of documentations reflect the tendency to create a rationale for the design of the system, however, the two projects set about it very differently. For example, Project 'Ozone' begins the documentation with detailed explanations of users' requirements, and the ways in which the intended system will address these requirements. Almost at each stage of the design, decisions and solutions are juxtaposed to users' requirements, which contributes to a gradual development of a coherent and consistent picture of the design. The intended audience is of course an important influencing factor that must be considered. There is an absence of this in Project 'Snapper', where the emphasis is placed on developing a rationale based on relating the sequences of design steps followed in the process. The focus of the rationale is more on the process followed in the design, rather than the design itself. Again, the intended audience of the documentation is considered to be an important influencing factor. In spite of these differences, the rationales developed in the documentations reflect the tendency designers have towards the reconstruction of design events into some kind of logical and consistent form. This tendency was also evident in the interview and observational studies, where the design processes reported were embedded in an overall rationale of the design. This relates to a point that is consistent throughout the research findings; it is evident in the studies that designers hold conceptual design models which they may or may not apply to the design. The design rationales reflected in the documentation highlight these models, and illustrates that though they may not be applied during the design process, they are often applied afterwards in the form of a design artefact.

This raises a question regarding the function the preparation of the documentation serves designers during the design process. The use of the documentation in design was very different in the two projects. In Project 'Ozone', the act of preparing the documentation became an integral part of the design process. The exercise of documenting the design as it developed, was seen to support a variety of tasks ranging from the development of design concepts, to full specifications. A factor contributing to the major part the documentation played in the design process, was that the design and the documentation occurred as parallel activities.

This is contrasted with Project 'Snapper', where there is an absence of a close relationship between the two activities of design and documentation. The impression is that the documentation was prepared separately from the design activity, and very likely prior to the beginning of the design. It reflects more of a reference document than a design document, and therefore, becomes a resource for designers to match original design intentions with the outcome, and it can also be used for historic purposes.

The second important area highlighted in the findings from the two sets of documentation data, is the application of user representations in design tasks. The analysis of the data indicated that the representations of users' requirements constitute an important part of the design process, because of the contribution they can make to design tasks. There are two factors that influence the level of contribution user representations can have in tasks.

The first factor relates to the finding that a decrease in the application of user representations, corresponds to an increase in the technical content of tasks. This correlation suggests that as tasks become more focused on the design details of the system, users' requirements become less appropriate to tasks. This raises the question of how users' requirements considered in the early stages of the design, are incorporated in the detailed design later in the process. There was very little evidence in the documentation of a design continuum between the two points. This suggests the existence of a design discrepancy between users' requirements and the system design that is present regardless whether users' requirements are developed early in the design process.

The second factor influencing the contribution of user representations to design tasks, is the way they are applied to tasks. The findings indicate user representations fulfil particular functions in support of tasks. There were essentially three types of user representations designers formulated in the documentation. These were based on models derived from a) specific/genuine users' requirements, b) generic/hypothetical users' requirements, or c) abstract or theoretical users' requirements. The information on which these models were based varied considerably in the data, from observational user studies, user testing, and designers' conceptual user models. A significant finding was that the source of information upon which representations were formulated, did not appear to affect the usefulness of the representation. Regardless whether the information was grounded in user studies, or based on designers' personalised models, the value of the representation, in terms of its functional support to tasks did not appear to be diminished.

The reason why the validity of user representations does not seem to influence their level of contribution to design tasks, is due to the functions they serve in enabling designers to work through solutions.

informality of the subscript where another type of evaluation is proposed as a possibility for providing "useful insights into the flaws of the design." There was no evidence in the data to suggest these tests were carried out, and no further reference to the tests or to the results appeared in the remaining documentation.

In the third example in 6.20 we see another illustration of a representation derived from the designers' conceptual models of users. The task in this example is based on the analysis of users' requirements. There is a similarity to the first example, in the designers' clarity on the generic types of users and the focus on the usability of the system. Again, the basis of the analysis appears to be based on the designers' conceptual model of the user, and not from external sources of information on potential users. The brevity, and also the content of the requirements description highlights the influence of the designers' conceptual user model on the task.

The user representations in these three examples were the only ones found in the documentation; subsequent tasks had an entirely technical orientation. The shift in focus from users to processors and software is illustrated in Example 6.21. This orientation remained until the final task in the documentation which was based on the requirements analysis for the system. Examples of the three references to users in this task are presented in Example 6.22.

We can see from these examples, the underlying function of the user representations is one of supporting tasks in the specification of the functional operations of the system. Another function is visible in the use of scenarios in the representations; these provided designers with a validation mechanism to check for inconsistencies in the task mapping between the user and the system. The detailed descriptions of task performance in the representations focused on what the user will do with the system, this also enables the designers to check the dynamics of the user interface.

Example 6.21
Shift In Task Focus

Task: *Processors and Software - Possible Choices*

Processors

"There are several factors that affect the choice of hardware. Since the station is to be on the network, there must be an ethernet connection available. Also, the frame grabber hardware is IBM PC compatible thus access to a PC bus is necessary. Standard "off the shelf" hardware is desired in order to make the system easier to replicate as well as repair. And of course, cost is always a factor."

Software

"A major concern in choosing a software environment is the ease with which can develop a prototype system. Of the software available for the hardware discussed, [sic] is the best environment for prototyping. The various choices for the IBM PC all had similar drawbacks (eg a lack of support software, poor error handling, etc.) They would have required much more work than a [sic] environment which has been designed for prototype work."

Example 6.22
User Representations in The Validation of a Design Task

User Reference 1.*

Task: *Operational characteristics: Overview*

"The I/O for the [system] will consist of several major components....... In a typical scenerio for scanning an 8 x 10 opaque, a *user* will log in on the terminal, 'frame' the picture using the front panel switches, and then save the image by pressing another front panel switch. The lighting, camera height, and default file name will all be handled automatically with the ability for the *user* to override the defaults. When scanning other than an opaque the scenario may vary slightly."

User Reference 2.

"When a *user* logs in, the power should be turned on to the camera, the color display and the lights. Logging in consists of entering a user name and password on the VDU. After the *user* has successfully logged in, the 'active' LED should be lit on the front panel.......

After a *user* has logged in, a file name should be proposed. First the user's profile should be checked for a list of file paths. If one is found, then the first entry in the list should be the path proposed. If there is no *user* profile entry, then the station log file should be checked for a file name from a previous session. If this is a new *user* with no log entry then a path should be 'guessed at' and checked for 'reasonableness.' If the proposed file name is not acceptable to the *user*, a new one may be entered from the keyboard."

User Reference 3.

"When the *user* presses the active/idle button the 'idle' LED should be lit. Then the log file should be updated, the station should be set up to scan an 8x10 opaque, and the power should be turned off for the lights, VDU, color display, and camera." *[Italics mine]

6.6 CONCLUSIONS

The findings from Project 'Snapper' have highlighted several design characteristics which contribute to our understanding of the design process, and the representations of users in the process. The level of contribution however, is influenced by two important limitations of the documentation as data, which are necessary to consider in the final analysis. The first influencing factor was the commissioning of the documentation as data for the research. This is reflected in the careful representation of the design as a coherent and structured process. This raises the question to what extent did the designers portray the type of design process they thought would meet the expectations of the research. There is the possibility that a different type of process would have been documented, if the designers did not expect it be subject to a careful examination. The second limitation was evident in the absence of users' requirements in the design process. In spite of these limitations, the documentation data has nevertheless contributed to our understanding of design. It has done this by extending and confirming our knowledge of design in some areas.

The most significant contribution the documentation data has made to the investigation of the design process lies in the illustrations provided of the conceptual models designers have of users' requirements, and how these are mapped onto design tasks. Evidence of one type of model is found in the beginning of the documentation, where designers hold a particular model of the design process, and attempt to organise the project according to the model. What emerges from this, is a discrepancy between the design intentions underlying the model, and the actual representation of the design in the documentation.

This raises a number of interesting points with respect to the causes contributing to the discrepancy. One point relates to the lack of continuity between the early design tasks focused on design goals, criteria, and system requirements, and the more technical tasks focused on detail design issues that occur later in the documentation. One possible explanation for this lack of continuity, is the difficulty designers experience in sustaining the outcome of non-technical tasks throughout the design process. This results in the outcomes from earlier tasks not being incorporated into design decisions and solutions.

Another contributing factor to the lack of continuity in the design, is visible in the particular approach to design portrayed in the documentation. The "lets build and see" design approach represented in the documentation, can be seen to influence the design in a number of ways:

- it influences a technical orientation to design tasks;
- it promotes design towards rapid implementation;
- users' requirements are developed quickly; accuracy is not particularly important;
- user considerations can be deferred to the post implementation stage.

The representations of users in design tasks in the documentation provide another example of the conceptual user models designers apply in the development of design solutions. Although there was no evidence of requirements studies prior to the project, the designers nevertheless, developed users' requirements for the system based on the abstract conceptual models they held. This is significant for several reasons, first, the lack of information on users' requirements did not appear to inhibit the design, as was almost always the case in the other design studies. The fact the designers were able to proceed with the design, despite the lack of information appears to be related to the "lets build and see" design approach. This particular approach made it possible for requirements issues to be deferred until implementation when user testing and an evaluation were planned.

Another point relating to designers' conceptual user models is that these models formed the basis for user representations which were applied to design tasks. Conceptual user models were used to support design tasks in some very fundamental ways, for example, to develop the system concepts and to validate the specification of the user interface. The application of these representations to tasks in this way makes it important to consider the source of information on which these representations are based. This relates to a theme evident in the other research studies; the source of users' requirement information often is not particularly relevant during the design process. However, what consistently appears to be crucial for designers, is that they are able to develop user representations which they can apply to the task, to fulfil a supportive function.

6.7 UNDERSTANDING DESIGN THROUGH DOCUMENTATION

The findings from the analysis of the two sets of design documentation, Project 'Ozone' and Project 'Snapper', raises a number of important points with respect to the type of design illustrated in the documentation and the ways in which users' requirements are represented in design. In spite of the differences in the two projects, for example, the length of the projects, the access to users' requirements information, and the intended purpose of the documentation, a similar set of conclusions can be drawn.

One of the first conclusions that can be drawn is the influence the intended audience has on the type of documentation that is generated. Very different types of documentation emerge from the two projects which is seen to be a direct result of the differences in the intended audience. In Project 'Ozone', the audiences ranged from project team members to colleagues, to possible management reviews. Consequently, the documentation attempts to represent the design so that it addresses the interests and concerns of those readers. We see evidence of this in the focus in the documentation on detailed functional specifications, user scenarios, and comprehensive descriptions of the intended system. Also evident in the documentation was an underlying attempt to develop a rationale for the design.

This was very different for Project 'Snapper', where the intended audience of the documentation was limited to the project members and the reseacher. This resulted in a very different focus to the documentation, which does not appear to play such a key part in the overall design as it did in Project . In Project 'Snapper', the focus of the documentation was more on representing a coherent and methodological approach to the design process, than to develop a rationale as in Project 'Ozone'. Instead, the underlying theme in the documentation of Project 'Snapper' was that of "look, we have a good design practice".

An important outcome of these variations lies in the type of design rationale that is developed through the documentation. Both sets of documentations reflect the tendency to create a rationale for the design of the system, however, the two projects set about it very differently. For example, Project 'Ozone' begins the documentation with detailed explanations of users' requirements, and the ways in which the intended system will address these requirements. Almost at each stage of the design, decisions and solutions are juxtaposed to users' requirements, which contributes to a gradual development of a coherent and consistent picture of the design. The intended audience is of course an important influencing factor that must be considered. There is an absence of this in Project 'Snapper', where the emphasis is placed on developing a rationale based on relating the sequences of design steps followed in the process. The focus of the rationale is more on the process followed in the design, rather than the design itself. Again, the intended audience of the documentation is considered to be an important influencing factor. In spite of these differences, the rationales developed in the documentations reflect the tendency designers have towards the reconstruction of design events into some kind of logical and consistent form. This tendency was also evident in the interview and observational studies, where the design processes reported were embedded in an overall rationale of the design. This relates to a point that is consistent throughout the research findings; it is evident in the studies that designers hold conceptual design models which they may or may not apply to the design. The design rationales reflected in the documentation highlight these models, and illustrates that though they may not be applied during the design process, they are often applied afterwards in the form of a design artefact.

This raises a question regarding the function the preparation of the documentation serves designers during the design process. The use of the documentation in design was very different in the two projects. In Project 'Ozone', the act of preparing the documentation became an integral part of the design process. The exercise of documenting the design as it developed, was seen to support a variety of tasks ranging from the development of design concepts, to full specifications. A factor contributing to the major part the documentation played in the design process, was that the design and the documentation occurred as parallel activities.

This is contrasted with Project 'Snapper', where there is an absence of a close relationship between the two activities of design and documentation. The impression is that the documentation was prepared separately from the design activity, and very likely prior to the beginning of the design. It reflects more of a reference document than a design document, and therefore, becomes a resource for designers to match original design intentions with the outcome, and it can also be used for historic purposes.

The second important area highlighted in the findings from the two sets of documentation data, is the application of user representations in design tasks. The analysis of the data indicated that the representations of users' requirements constitute an important part of the design process, because of the contribution they can make to design tasks. There are two factors that influence the level of contribution user representations can have in tasks.

The first factor relates to the finding that a decrease in the application of user representations, corresponds to an increase in the technical content of tasks. This correlation suggests that as tasks become more focused on the design details of the system, users' requirements become less appropriate to tasks. This raises the question of how users' requirements considered in the early stages of the design, are incorporated in the detailed design later in the process. There was very little evidence in the documentation of a design continuum between the two points. This suggests the existence of a design discrepancy between users' requirements and the system design that is present regardless whether users' requirements are developed early in the design process.

The second factor influencing the contribution of user representations to design tasks, is the way they are applied to tasks. The findings indicate user representations fulfil particular functions in support of tasks. There were essentially three types of user representations designers formulated in the documentation. These were based on models derived from a) specific/genuine users' requirements, b) generic/hypothetical users' requirements, or c) abstract or theoretical users' requirements. The information on which these models were based varied considerably in the data, from observational user studies, user testing, and designers' conceptual user models. A significant finding was that the source of information upon which representations were formulated, did not appear to affect the usefulness of the representation. Regardless whether the information was grounded in user studies, or based on designers' personalised models, the value of the representation, in terms of its functional support to tasks did not appear to be diminished.

The reason why the validity of user representations does not seem to influence their level of contribution to design tasks, is due to the functions they serve in enabling designers to work through solutions.

A good example of this is in the descriptive style used to formulate representations; designers often apply imagery to create a figurative illustration of users performing tasks. A sense of realism is added to the context by the use of present tense language in the description. This results in a representation that enables both the designer and the reader to gain a pragmatic sense of the task mapping between the user and the system. In addition to a descriptive function, this kind of representation provides a second function by enabling designers to verify parts of the design solution. Through the use of language and imagery to develop an imitation of a task handling by the user, the representation essentially becomes a validation mechanism. The imagined sequence of steps followed by the user in the task, enables the designers to check their understanding of the task, and also to determine consistency in the task mapping between system and user.

The significance of user representations lies in the characterisation of the users' requirements they are able to provide. The source of information from which they are formulated often becomes buried in the representation, so that what remains is the characterisation of users and the functional support this can offer to tasks. For example, if a characterisation based on an abstract conceptual model of users is applied in conjunction with a descriptive style of representation discussed above, it still contributes to the task by supporting designers in the design and validation of the systems functions.

6.8 SUMMARY

In summary the two important points to emerge from the findings from the documentation studies are:

1. Documentation can be an important part of the design process by enabling designers to develop a rationale for the design, to which they can refer for purposes of validation. Documentation can also be incorporated into the design process by becoming another design activity,

and therefore, can support designers in completing design tasks and developing solutions. The target reader and audience of the documentation has a significant influence on how the design is represented in the documentation.

2. User representations are important in the documentation of design, because of the ways in which they can be applied to design tasks. Designers create representations appropriate to specific types of tasks; these are derived from different kinds of conceptual models of users. The value of the representations designers create is independent from their source of information. User representations are seldom applied to highly technical tasks.

CHAPTER 7

FACTORS WHICH SHAPE THE DESIGN PROCESS

CHAPTER 7 FACTORS WHICH SHAPE THE DESIGN PROCESS

7. 1. INTRODUCTION

The research was stimulated by the issues that developed from the incompatibilities arising between systems and users, and the dilemma this presented to the field of HCI. A set of key questions guided the research to study the design process of user interfaces in interactive systems, and the representation of users' requirements in the process. At one level the investigation focused on studying the design process in terms of the methods designers used and the types of design decisions made. A primary objective of the investigation was to identify the factors that inhibit design activities, and thereby influenced the design process. At another level, the investigation focused on studying the representations of users' requirements in the design process. The investigation explored first, how users' requirements were handled in design tasks, second, how requirements were incorporated into the design process, and third, the source of user information applied in user-related design tasks.

The investigation was based on three types of design studies aimed at providing different perspectives on the design process. The design process and the representations of users' requirements were studied in different design contexts; observations of the design process (Chapter 4), designers' recollections of design activities (Chapter 5), and the documentation of design projects (Chapter 6). The data collected from these three studies provided a rich source of information, from which a number of conclusions can be drawn about the factors which shape the design process.

This chapter discusses the main findings from the research reported in Chapters 4, 5, and 6, and builds from these some new understandings of the design process. There are a number of principal issues that can be drawn out from the studies presented in these chapters concerning the representation of users' requirements in the design process.

7.1.1 METHODOLOGICAL CONSTRAINTS

It was a methodological decision to base the research on the three different studies, reinforced by limitations on the kinds of access to data which were possible in the case studies. The basis of the decision was the belief that the data from the studies would provide a rich source of information on users' requirements in design, and would therefore contribute to our understanding of design. This decision was not without implications, particularly with regard to the methodological contraints that were created by including disparate studies. The most significant constraint results from the three different types of data from different design settings and the three different conclusions that have been drawn. This creates a problem: to what extent are the differences in the conclusions influenced by the methodology or are they attributable to the design settings. The problem was inescapable due to the constraints that were imposed by limited access to design settings in which to conduct the research. (This will be examined in more detail in the final chapter.)

For this reason it is inappropriate to attempt to develop an overall model of design from the findings from the three studies. Instead, it is more constructive to draw out from the findings some observations for later research to systematically test. One observation was the striking difference in the design methods applied in the three studies. For example in the observational studies, the design process observed reflected an unstructured, problem solving nature, and not a coherent, sequential approach to design, based on well developed models. This was in direct contrast to the interview and documentation studies which reflected a coherent process, driven by clear design rationales and were close to standard literature on design.

This raises the question why there should be such a wide discrepancy between design approaches. Approaching the question from a methodological point there are some obvious influencing factors. The observational studies were based on 'theory in action'; this reflected the reality of design as it occurred in these particular settings. The other two studies were based on espoused theory, what people <u>say</u> they did or what goals and/or principles they seek to follow. This would inevitably influence a rationalised view of the design process. Theories-in-use and espoused theories are very likely to be inconsistent and incongruent. There is seldom an absence of self-contradiction between the two. (Argyris and Schon, 1974). Possibly what was observed were designers with 'espoused theories' about design, but who were unable to follow them in a structured way because of influences such as other designers' theories, the lack of understanding of users, the research or commercial environment, etc. We will now look at the possible influences of these factors.

There were other influences to take into account, for example the different design contexts have a significant effect on the type of design process. A major component of the findings of the research concerns the design context. The research has made it possible to see how the variations in design relate to the context in which it takes place. Some of the primary influences include the commercial constraint, the pressure to innovate, and the specialisation in user interface design. For purposes of this research it is sufficient to consider the possibilities of these influences, however, at some future point, it will be important to take the problem one step further by testing whether the methodology or the context influences the differences in the findings.

A common theme relating to the representation of users and users' requirements in the design process was present throughout the research, regardless of the design environment investigated. Three key issues emerged from the theme. These were:

a. Designers approach design tasks with a technical, system based conceptual model of the design. The application of this type of model to design tasks is often inappropriate, however, designers lack design schemas and heuristics that are appropriate to user related tasks;

b. Designers often work with inadequate information on users and their requirements;

c. The demanding characteristics of the design environment influence the type of design process that develops, and the trategic options available to designers.

In the following sections we will examine each of these issues in turn.

7.2 DESIGN STUDIES: SUMMARY FINDINGS

Although it is not possible, or indeed appropriate to attempt to draw together the findings from the three studies into a cohesive model of design, the findings from each study are significant for their individual contributions. This section will summarise the individual findings from the studies, before turning to the common theme in the studies and the key issues to emerge from the theme.

7.2.1 OBSERVATIONAL STUDIES: DESIGN STRATEGIES

The observational studies provided an opportunity to study design and the handling of users' requirements, in a context in which it occurred naturally. This enabled the design process to be studied as it developed through the tasks designers engaged in during meetings. The findings reflects a number of general strategies designers apply to design tasks. These are evident at the different stages of the design process. Design tasks often represent complex problems to which designers apply a problem solving type of strategy. The characteristics of this strategy are:

- to understand the task in terms of the system;
- to understand the task problem in relation to conceptual solutions;
- if solutions do not fit, redefine the problem;
- to decompose the problem into smaller components;
- repeat the first step again.

This strategy was applied in the early stages of the design process. It was particularly visible in the observations of design tasks where there was an orientation towards users. In tasks that were technically oriented this particular strategy was less dominant.

A second strategy related to the development of a rationale for design decisions and solutions. This strategy encompasses a number of purposes, for example, it is used in part to validate design outcomes, to reach a team concensus on an outcome, and/or to develop a coherent basis for a particular solution. Part of the strategy involves designers reaching some form of agreement on the current status of the design in order to progress to the next stage in the process.

A third strategy designers apply to tasks in the final stages of the design process was to by-pass problems that could not be solved. This strategy was based on a "lets build and see" approach, and was most visible in tasks that were entirely focused on the technical aspects of the system. It was also visible in tasks where the necessity to consider users' requirements interfered with the system orientation of the task.

These three strategies enable designers to address the difficulties they encountered in tasks and thereby, progress through the design process towards developing appropriate solutions.

In summary to highlight two main points from these strategies:

- The introduction of users' requirements into design tasks affects the kind of process that develops, because of the necessity for designers to abandon the technical strategies and the espoused theories they typically apply to tasks.

- Design tasks where it is necessary to factor users' requirements into the solutions, result in a highly problem oriented design process. This creates a longer design process, which involves additional stages in order to develop the requirements.

The findings relating to information and users' requirements will be discussed in Section 7.3 where the dominant themes that run throughout the three studies are discussed.

7.2.2 INTERVIEW STUDIES

The study of design through designers' recollections of the critical incidents that occurred in specific projects extended the investigation of users' requirements in the design process through the findings that emerged. Unlike the studies based on observations of design, this study drew entirely upon the designers' recollections of design and therefore provided a different perspective which is reflected in the findings. The main findings from this study concern a) a common approach to design that ran consistently through the data and, b) the handling of users' requirements in design. The findings relating to the design process differed considerably from those in the observational studies. Those however, pertaining to users' requirements showed a number of similarities. For purposes of a summary discussion in this section, the findings relating to users' requirements in design, because of similiarities, will be discussed in Section 7.3 in conjunction with the discussion of the dominant themes in the investigation.

There were two findings relating to the design process, these were:

1. A common design process emerged in which design tasks began with the specification of users' requirements, followed by a design phase, and an assessment or evaluation of the design solution. This process was highly iterative, and involved modifications to the design.

2. Two key areas in the design process were highlighted in the findings: users' requirements and the assessment of design solutions. Both of these areas were focal points in the design process, and designers reported a high involvement in activities concerned with these areas.

Two important points can be drawn from these findings. The first point concerns the highly structured design process, that resembles the type of design process found in the standard literature on design. There is a marked difference between this kind of process and the kind found in the observational studies. This brings us to consider the question raised in 7.1.1 on methodological constraints: is this finding a result of the methodology or of the design context? Unfortunately, it is not that clear cut, answers can be found in both directions, for example:

> <u>Methodological Influences:</u> Designers' espoused theory of design is very likely to influence their perceptions and recollections of their design activities.
>
> The process of recollection necessarily involves designers in the rationalisation of past design experiences.

Although undoubtedly, these methodological factors influenced the findings, it nevertheless raises an interesting point concerning the consistency with which the common type of process ran in the data: there were no variations in the type of process reported by the designers. There was a convergence of collective espoused theories and processes of recollections and rationalisations. This leads us to consider the contextual influences.

> Contextual Influences: The product orientation of the design environment is a key factor in determining the kind of design process that emerged. The emphasis on a low risk design approach is visible in the focus on the validation of design concepts and the evaluation of full designs. The link between design and a marketable end product is close and is seen to have implications for how designers approach the design of products.
>
> A second contextual influencing factor is the separation of the design of the user interface from the rest of the system design. The influence is visible both in the emphasis in the data on ensuring that users' requirements information is accurate and in the importance seen in the validation of design solutions.

The variations in design as they relate to the context in which it takes place is discussed in Section 7.5. For the purposes of this summary section, it is concluded that the two findings regarding the design process are directly influenced by both methodological and contextual factors. This leads us to question whether the design process portrayed in the finding is an accurate representation of design within the particular context: the conclusion has to be that it is not. However, it was not the purpose of this study to obtain an accurate and complete representation of the design process. Therefore the findings are able to contribute to the research by illuminating the important influence a design context can have on how designers approach design.

7.2.3 DOCUMENTATION STUDIES

Documentation studies were included in the investigation of design in order to extend the characterisation of design that developed from the data in the observational and interview studies. The additional data was intended to provide another pespective on the design process and the handling of users' requirements in design. In summary, two points emerged from the findings from the documentation studies:

1. The process of documenting design enables designers to develop a rationale for the design which can be applied for validation purposes. When documenting occurs in parallel with the design, it can be an important part of the design process by becoming another design activity. This can support designers in completing tasks and developing solutions.

2. User representations are important in the documentation of design, because of the way in which they can be applied to design tasks. Designers create representations appropriate to specific types of tasks; these are derived from different kinds of conceptual models of users.The value of the representations designers create is independent from their source of information. User representations are seldom applied to highly technical tasks.

Due to the nature of the research, it is inevitable that these findings are influenced by both methodological and contextual factors. Similar to the interview studies, the type of design that is reflected in the findings are influenced by the designers' espoused theory of design and the rationalisation process that occurs after an event. The intended audience of the completed documentation is also a factor that is seen to influence what is documented and how it is documented. The contextual influences are also evident in the findings. Although the studies were drawn from a product research environment, the theme of innovation was prevalent. For these reasons, the documentation studies are not used to further the development of an understanding of the design process. Instead, we look to the documentation studies for what can be gleaned from the data. The significant points that can be drawn from the findings are firstly, the process of documenting design can contribute to the overall design process by providing designers with a mechanism for a) developing a rationale for the design, and b) working on tasks and solutions. Secondly, although users' requirements do not feature significantly in the design documentation, designers develop representations of users and their requirements in the application domain as a way to help them to work through and to validate the design.

The similarities that can be drawn from these findings are discussed in the following Section where the dominant themes in the three studies are discussed.

7.3 USERS' REQUIREMENTS IN THE DESIGN PROCESS

Two dominant themes run throughout the investigation and were present in the three research studies. The first theme relates to the importance of user knowledge and requirements information in the design process. The second theme pertains to the limitations of requirements information experienced by all designers to a certain extent. A finding was that the design process appears to be characterised by limitations of information on users' requirements in tasks. The extent to which these limitations are experienced by designers, differs according to the design context, and the disposition of designers.

7.3.1 DESIGNING WITH INADEQUATE REQUIREMENTS INFORMATION

There are a number of contributing factors involved in the limitations of users' requirements information in design. One set of limitations relates to the availability of information; in certain situations there is a specific lack of the required information. This was very often the case in the observational and interview studies, where designers simply did not have available to them information on users' requirements. Another situation is where the limitations are attributable to designers' choice to under utilise the information they have available. For example, in one of the documentation studies extensive user studies had been conducted, but often the information was not applied to the tasks. Yet in other situations, designers choose not to seek the required information, even though it may be accessible. Examples of this were seen in some episodes in the interview, documentation, and observational studies.

Depending upon the design context, designers experience the limitations of requirements information differently. In some situations, the lack of adequate information is considered critical, for example, in the commercial-product environment as represented in the interview studies. Yet in other situations, such as the research-product environment as represented in the observational and documentation studies, designers find ways to compensate for the lack of required information. In Table 7.1 some of the key factors influencing the extent to which limited user information is considered critical to designers are shown.

The degree to which the lack of users' requirements influences designers' ability to proceed with the design appears to be largely determined by a number of factors. A combination of external factors, such as the marketability of the system, management approval, and the separation of the user interface from the system design, will influence how designers respond to the lack of information on users' requirements.

Table 7. 1

Limitations on User Information: Degrees of Importance

UNIMPORTANT	*VITAL*
- *insulated design activity*	- *marketable product*
- *no external boundaries*	- *external boundaries*
- *UI embedded in system*	- *design usability assessed*
- *emphasis on innovation*	- *UI separate design*
	- *justification to implementator*

In situations where some or all of these factors exist, inadequate user information is considered an important limitation that is addressed by designers, and is not ignored. This was evident in the interview studies, which were situated in a commercial-product environment. It was also visible to a certain extent in one of the documentation studies, where the justification to management and the assessment by others, were key influencing factors. In the research-product environments these influencing factors were absent and instead, the design developed as an insulated activity from external influences, such as other parts of the project or management. In situations like these, evident in the observational studies and one of the documentation studies, the limitations of users' requirements does not impose serious restrictions on the design. Therefore the limitations are not considered critical to the design, as it is in situations where these external factors are present.

7.3.2 COMPENSATORY DESIGN STRATEGIES

Designers adopt different strategies to address a situation in which a design task requires the input of users' requirements information, and that information is not available or is considered inadequate. The findings from the three studies indicate there are three strategic options designers consider. One strategic option is for designers to obtain the necessary information through various sources, external to the team. This strategy was most evident in the interview studies, where designers consulted a variety of external sources in order to produce the information they required to proceed with the design. Designers turned to published user studies, competitive product information, or experts in the field, for sources of user information.

A second strategy involved the design team in the generation of the users' requirements information needed for the design. This strategy was based on designers drawing upon their collective theories and concepts of users and their requirements. This strategy operated most in the observational and documentation studies, it was also evident in the interview studies. A third strategic option was visible in tasks that were entirely concerned with the technical details of the system. The strategy in these tasks was for designers to proceed with the design without the user information required. This strategy was most visible in the observational and documentation studies. The first and second strategies appeared most frequently in the studies, and the third one only occasionally. The strategic approaches to the first and second strategy are summarised in Table 7.2.

The choice of strategy has implications for how the design task is organised, and consequently, for how design solutions are developed. The particular strategic option designers adopt results in significantly different design processes.

Table 7.2

Design Strategies For Handling Limitations of User Information

STRATEGY #1	***STRATEGY #2***
Limitations >> Tasks	***Limitations >> Options***
- knowledge elicitation	*- question: infor.necessary?*
- solicit specialist advice	*- generate information from internal knowledge base*
- research	*- invent information from personal experience*
- studies	*- create scenarios*
- validation; present information	*- skip the information*

The first strategy, based on designers consulting external sources of information, results in a design process where the problem of limited information is accommodated by becoming a design task; a task to acquire information. In this way, the limitations are incorporated into the overall design process, as evident in the interview studies. In these situations, the early stages of the design process are dedicated to gathering information, and thus delays the development of solutions until later in the process.

In design processes where the second strategy operates, there are similarities in both situations, in the way in which the generation of information becomes the focus of the task. There are differences however, in the nature of the tasks. In the first strategy, the limitations of information are regarded as tasks to be completed, whereas with the second strategy, designers consider the necessity of including the information in the task and whether it can be generated among themselves. This questioning process appears in the first stages of the design process, and results in a decision either to proceed without the information, or to generate it within the context of the team. The latter decision was visible in the majority of the studies. In these situations, the generation of the information becomes a task similar to the first strategy.

When designers apply strategies, based on the design team generating users' requirements, because the information is not available, the design process involves a validation of the information generated. In the interview studies, a validation was based on obtaining some form of feedback from others outside of the project. Feedback on design mockups or on design concepts was sought before complete design solutions were developed. In the observational studies, a different form of validation occurred, and usually involved two additional stages to the design process. Following the solution stage, designers attempted to rationalise the solution by creating a logical and consistent argument. This invariably led to an examination of the users' requirements generated. A number of difficulties were encountered during this stage, as designers questioned the validity of the requirements, which very often led to disagreements among the team members. It was common for these difficulties to carry over into the next stage, when the team tried to reach a consensus on the solution. There were two common outcomes to this situation; it became necessary for the designers to return to earlier stages to rework the solution, or the design process became "inhibited" or "stuck" as a result. In other words the designers were unable to proceed with the task.

There are two characteristics that stand out as having implications for the design process as a result of these two strategies. The first is the generation of requirements information becomes a significant task that focuses the design process on this task, instead of on developing design solutions. The second characteristic is the necessity to validate user information when it is generated by design teams. This involves a significantly longer design process, than one where designers have the information they require, and are able to proceed directly with the development of design solutions.

7.4 STRATEGIC APPPROACH TO USER RELATED DESIGN TASKS

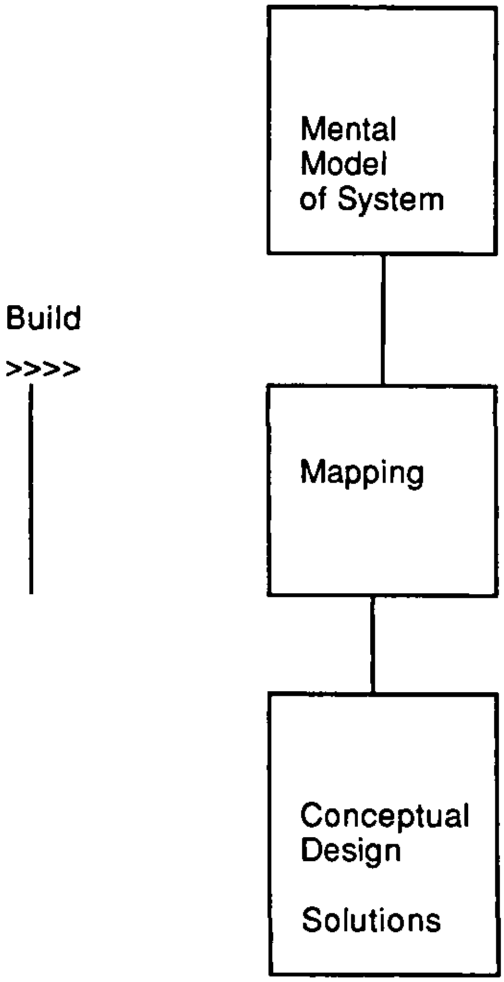
The findings from the investigation indicate that designers approach design tasks in a particular way. The approach is derived from an overall conceptual view of the task in terms of a technical system based design model. In the observational studies especially, and also in the documentation studies to a certain extent, it was evident that designers tackled design tasks with a conceptual model of how to address design solutions. There are two areas where the mapping of this model onto design tasks becomes visible. The first is through the representations of design that emerge afterwards, for example, in the rationalisations designers create in the final stages of the design process, and also in the documentation designers write. The second is through the observed application of the model to design tasks during the design process. Where this particularly stands out, is in tasks that involve the consideration of users' requirements and the application domain. The characteristics of the model designers approach design tasks with are:

- system driven solutions ;
- the technical orientation of tasks;
- the focus on design methods;
- the limitations of user representations;
- the focus on a design rationale.

Example 7.3 on the following page, provides an illustration of the application of the conceptual design model to tasks.

Example 7.3

Designers' Model of The Design Process



The designers' conceptual model of the system enables them to consider design tasks in terms of solutions appropriate to the system. In a sense, this creates a design space within which problems and solutions can be explored. A combination of this design model, and the design heuristics designers may have, technically focuses the design task. This influences solutions toward a technical orientation, and results in the narrowing of solutions to those directly related to the system.

It appears designers engage in a process in which they attempt to figure out what to do in relation to the conceptual design solutions they have formulated. An attempt is made to map these solutions onto the model of the system they hold; when a mapping is successful, designers begin to think about how to implement the solution. Once this is figured out, the next step is to build something, look at the results, and to change it if necessary.

This approach to design tasks results in a number of difficulties when there is a significant user component to the task that requires designers to broaden the context of the design space, to include considerations of users' requirements and the application domain. Problems appear when designers approach these types of tasks with a technical system based model of the design process and therefore attempt to map users' requirements onto technical solutions before an adequate model of users is developed. This mapping process is inappropriate, until there is a sufficient understanding of users' requirements.

There are important implications for the design process when this type of mapping process occurs in design. The first implication is seen in the circular design activities that result from designers not being able to complete user related tasks. This is visible in the high level of stage iterations in the observational studies, where designers return to the beginning of a task to understand it more clearly, and to explore additional solutions. Further evidence of the problems is found in the final stages of the design process. Decisions and solutions are difficult to finalise due to a lack of a team consensus, and also because of problems in creating a rationale for the design. Design teams are often unable to collaborate on developing a logical and consistent explanation for the design solution.

Technical strategies are eventually abandoned, when it becomes apparent to designers they do not contribute to completing the task. As a result however, designers are left without an appropriate strategy to substitute the technical ones. Consequently, we see designers applying compensatory strategies that are based on their conceptual models of users, requirements and the application domain. The frequent application of scenarios to user related tasks is an important part of a compensatory strategy, and is an area where the designers' conceptual models are especially visible. The design process is seriously inhibited by this approach, because it is very difficult for a group of designers to converge on an ad hoc strategy derived from diverse conceptual models.

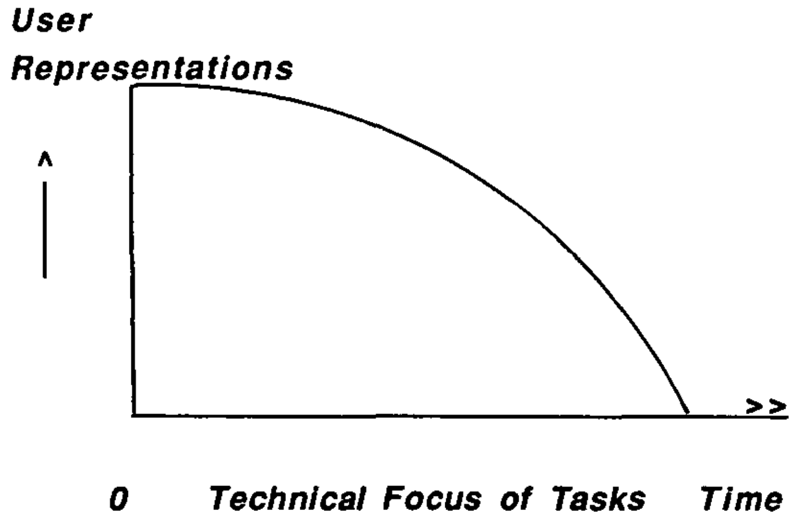
These findings lead us to conclude that designers are lacking design models and strategies that are appropriate to user related design tasks. At present they are without a mechanism for understanding users' requirements in relation to system solutions.

7.4.1 MUTUAL EXCLUSION

An important design characteristic is a basic incompatibility between technical and user related design. This results in a technical orientation to the design that focuses the design process on the technical details of the system. In this kind of process, users' requirements are absent from tasks altogether, or the user representations applied to tasks are insufficient to significantly contribute to design decisions and solutions.

The findings point to a relationship in which an increase in tasks concerned with detailed system issues, corresponds to a decrease of user representations in the design process (See Example 7.4) This results in the consideration of users' requirements in the early stages of the design process, however, they are seldom referred to in the later stages during the major part of the system design.

Example 7.4
Mutual Exclusion In Design Tasks



Although technical and larger system issues are considered, in terms of constraints on the design, this does not result in a technical orientation in the tasks or in the design process. This is unlike the observational and documentation studies, where if the design is not entirely focused on the user interface, there is a contention between user and technical issues which gives way to a technical orientation.

The underlying cause of the mutual exclusion between technical and user oriented design is attributable to the boundaries of the design domain. If the user interface constitutes a small part of the domain, and is therefore only one design consideration among several others, this determines the way designers approach tasks related to users' requirements. The conceptual models designers hold of the system guide design tasks towards solutions that are compatible with the model. Therefore we see the application of the technical system model to all design tasks, regardless whether they have a user component. This results in users' requirements being factored out of the design altogether, or there is a lack of continuity between the outcomes of the early user related tasks and the other parts of the design. In some situations, the requirements are embedded in technical solutions, as seen in some episodes in the documentation studies. In the majority of cases however, this did not appear to be the case.

It appears from the findings, that the narrowing of the task domain to the user interface, significantly reduces the problem space for designers. The design implications of this are important; firstly, design tasks are confined to the domain of the user interface, which enables designers to focus design activities on those concerned with users' requirements. Secondly, the narrowed task domain influences designers to draw on user models and strategies appropriate to user related tasks. As a result users' requirements are factored into the design process at all stages.

This leads us to conclude that in the design of systems, where the interaction between the system and the user is considered particularly important, the larger the design task domain, the more difficult it is for designers to handle both the technical, and the user related parts of the design. The co-existence of both in the task domain results in a mutual exclusion to the detriment of users' requirements.

7.5 THE DESIGN CONTEXT

There are major variations in the way design takes place. These were evident in the different types of design processes represented in the studies. In some situations, for example, the interview studies, design was based on a top-down methodological and iterative approach oriented towards prototyping and evaluation. In other situations, for example, in the observational studies, the design process was fragmented and exploratory, with an orientation towards building something quickly. There is a difference in the focus of each design approach; in the first approach, the primary motivating factor is an accurate mapping of users' requirements onto the design. The second approach was based on motivating factors that are largely system related and promote early implementation of the design.

The studies enable us to see these variations as a result of the changing context of design. Many different constraints apply to the design process and the effects of these constraints is to form a range of contexts. Three principal constraints that emerge are:

a. The commercial constraint imposed by the designers' involvement in product development; this is a constraint not experienced in the research environment for example.

b. The innovation constraint that puts pressure on the designer to find solutions that have not been tried previously.

c. The specialisation constraint, which causes user interface design to be handled separately from system design.

The studies show the influence of each of these constraints on the design environment and the emergence of a particular environment in which the specific characteristics directly influences the design by imposing certain demands. This creates a particular type of environment where designers' choices are conditioned, and therefore determines their choice of strategy in arriving at design solutions.

7.5.1 THE INFLUENCE OF THE COMMERCIAL CONSTRAINT

The interview studies (Chapter 5) have brought out a number of phenomena that can be related to the commercial constraint imposed by a product requirement. The product must be marketable and implementable. The project also must adhere to fixed schedules and the design needs to fit in with an original specification

and meet criteria set by others. A number of points can be related to these phenomena.
One point that emerges clearly is the tendency of the formal review to drive the process. Design projects often formed part of a larger project that resulted in a number of boundaries imposing a formal organisation to the design process. A combination of this and also the commercial influence, made it necessary for designers to acquire verification of design concepts early in the design process. This was especially important as specifications were often brief, and therefore open to interpretation. This resulted in a strategy where designers attempted to demonstrate design solutions early, either through prototyping or mock ups. Design iterations are an important part of this review process.

A second point is the relative emphasis on formal analysis and the formality of methods. These can be related to the need to support the review. A commercial environment tended to influence designers to choose established design methods throughout the process. This tendency is evident in two areas; the approach to the development of users' requirements and in the validation and evaluation of initial designs.

A third point is the minimisation of risk. Often this is translated into a limit on innovation, or into a requirement to match innovation with adequate validation. The constraints imposed by a commercial environment in which the design is accountable to a number of other people, and the design criteria has been established by product managers, marketing, etc, result in less design autonomy for the designers. Another important constraint limiting design freedom, is the standards set by established products, either those of the company or in the marketplace. Designers are unable to deviate from these without an adequate cause. The emphasis is on proven design, either within an existing marketplace or in a laboratory.

7.5.2 THE INFLUENCE OF THE INNOVATION DEMANDS

The requirement to innovate is particularly evident in the observational studies (Chapter 4) where designers are engaged in designing new types of systems. The influence of innovation can be seen in designers' approach to design tasks; the wide exploration of concepts and the serendipitous way in which solutions are easily generated and discarded or adopted. The requirement for innovative design promotes the process towards rapid implementation; this results in a "lets try and see" design approach. This approach provides designers with the freedom to explore a range of solutions without the concern for "getting it right". Evidence of this was also found in the documentation studies (Chapter 6), where the design of new types of systems influenced designers towards the rapid development and implementation of the system.

We can draw the conclusion that the influence of innovation imposes a constraint on the design that affects the way designers deal with users' requirements. The drive towards innovation restricts designers' opportunities to observe existing users of the system under design or similar systems. It will also affect the extent to which users are represented in the design; the experimental nature of the system makes it unnecessary for designers to carefully consider users' requirements. This combined with the difficulty in obtaining information on users' requirements, reinforces the "lets try and see approach", which drives the design towards building something and consequently, omits users' requirements from the design.
It is also clear that when innovation is required of designs, existing solutions will tend to be discarded even when they may be appropriate. The innovation demand influences designers' choice of design solutions. The criteria for "good" design solutions is established by solutions that are new and different from previous

designs. This challenges designers to search for an ultimate solution which will mark a departure from previous designs.

7.5.3 THE INFLUENCE OF USER INTERFACE SPECIALISATION

The isolation of the design of the user interface from the rest of the system design creates a particular design context that influences design in significant ways. The design process tends to follow the pattern associated with the system-driven conceptual model designers hold where the focus of the design is on the technical parts of the system. However, when the user interface is isolated from the system, the system model is represented by the user interface instead of the system.

One important effect of user interface specialisation, is that it becomes possible for a system-driven design process to refer to and incorporate users' requirements information. The strategic options available to designers are determined to a large extent by this context, and directs design decisions and solutions towards those directly related to the user interface. The two implications of this type of design context, lie in the careful mapping between users' requirements and the system design, and also in the validation process that develops. These two design characteristics stood out as particularly significant of the type of design that was represented in the interview studies.

It is also possible to see some of the drawbacks that a specialised approach to design will introduce. Under this approach, the design of the user interface must take place as a separate process, in a similar way to the system-driven processes evident in tasks that focus on the design of the entire system. Although the design of the user interface is separate from the entire system, it must nevertheless fit into the design of the complete system. In this way, the user interface becomes a point of reference for the software system design. This relationship between the design of the user interface and the design of the rest of the system, can restrict the scope for innovation in user interface design. Restrictions occur because it is essential for designers to provide a tried and tested design to the software design process. There are not the opportunities to experiment or to innovate as in the design environments of the observational and documentation studies, because of the incompatibilities this could produce in the rest of the system design. There were a number of indications in the interview studies, that designers faced difficulties obtaining approval for improvements to existing designs because the designs were already tried and proven.

7.6 PREVIOUS WORK IN THE AREA

The principal issues to emerge from the research studies relate to the findings of a number of other design studies in the field of human-computer interaction. The following section presents a brief overview of the primary work in the field to which the research offers a contribution. The majority of research in the field has focused on the study of the design process with a view to understanding the process by which design occurs. Research studies thus far have been based on interviews with designers, with the exception of two studies that consisted of observations of individual designers engaged in design tasks. The review of the research in this area begins with three studies that reflected a particular interest in user interface design issues.

Bellotti conducted a study based on eight interviews with designers who discussed the design of the user interface for commercial systems. The sample of designers was drawn from both research-product and commercial environments (Bellotti, 1988). The focus of Bellotti's study was to determine whether designers incorporated design and evaluative techniques into their design practice, and also to identify the kinds of design constraints that could inhibit the use of these techniques. Bellotti's findings indicated that design practice in commercial environments varied according to the kinds of constraints imposed upon the design. Variations also appeared in designers' approaches to design. The study highlighted that user interface design problems were very often attributable to the techniques used in design. However, Bellotti (op.cit.) found little evidence of the application of techniques in the design of user interfaces.

Another study investigating the design of the user interface was based on structured interviews with five designers responsible for the user interface, drawn from a major commercial product organisation (Hammond et al, 1983). The focus of the study was to identify the issues that influence the design of the user interface. One of the factors investigated in the study was designers' decision-making in the design process. A principal finding from the investigation was that designers tended to focus on the technical aspects of the interface and the system, instead of the potential users and their requirements.

Rossen, Maass, and Kellogg (1987) conducted a study investigating user interface design, by interviewing twenty-two designers about their design practice. The study focused on three areas: one, the kind of design processes involved in the design of interactive systems, second, how the user interface fitted into the process, and third, designers' strategies for generating design ideas. The findings from the study suggested two models of the design process; these are related to the implications for developing tools to support design.

Further studies of the design process were carried out by Guindon and Curtis (1988) who used methods of protocol analysis to investigate the kinds of strategies designers apply to design tasks. A verbal protocol study of three software designers was conducted to identify the kinds of design process control strategies the designers applied in the early phases of software design. The designers were given a lift control design problem which involved designing the logic to move the lift between floors. The findings from the study showed that designers develop designs by rapidly shifting between simulations in the problem domain. The process they engage in involves the elaboration of requirements, the definition of the functions of the system at different levels of abstraction, the detailed design aspects, and the deliberate considerations of their design process strategy. Guindon and Curtis (op.cit.) define this type of design process as opportunistic.

Visser 's research on design corroborates the findings of Guidon and Curtis. Visser (1988) carried out observations of one designer engaged in the design of a real system, during which data was collected on the subjects' design activities through the method of verbal protocol. The findings from the study indicated that design is not an hierarchically organised plan-guided activity but instead, is based on an opportunistic model that incorporates designers' plans for the design.

Curtis, Krasner, and Iscoe (1988) adopted a different approach to their investigation of design. They studied the problems incurred in designing large software systems by interviewing designers from seventeen projects. The interview study focused on requirements and design decisions with regards to how they were made, represented, communicated, and changed. The impact of decisions in these areas on subsequent development processes was also studied.

7.6.1 CONTRIBUTIONS ON THE DESIGN PROCESS

Two contrasting models of the design process emerge from these studies. The findings from the Rossen et al, (op.cit.) studies revealed two types of design processes. One type of process is based on the incremental development of the design, in which the development and the implementation of the design is handled concurrently. The second type of process, is based on a phased development model in which all of the development work occurs first, and the evaluation afterwards. Both of these models of the design process were evident in the interview and documentation studies conducted in the research project. It was a common occurrence in these studies for designers to implement part of the design, and to obtain feedback before proceeding with the remaining parts of the system design. There were also several instances in the studies where the entire design was completed before it was subjected to some form of evaluation.

A second model emerges from the work of Guindon and Curtis that is corroborated by Vissers' research findings (Guindon et al, op.cit.; Visser, op.cit.). The model they propose is characterised by design consisting of ill-structured, complex problems that are open-ended, which results in a design process they describe as opportunistic. An opportunistic model represents design as shifting rapidly between design activities throughout the process. According to this model design activities are associated with different domains and sources of knowledge which are interleaved and loosely ordered throughout the design process.

The opportunistic model corresponds closely to the characterisation of the design process that emerged from the observational studies in the research project. The findings identified a primary characteristic of the design process is the appearance of incoherence and the absence of structure. The major factors contributing to this type of process were the high level of fragmentation in design activities, and the number of iterations in the design stages. The frequent movement between tasks and activities is what Guindon et al, (op.cit.) refer to as shifts in activities and as the loosely ordered interleaving of design activities. The shifts in design activities are also evident in the studies by Visser (op.cit.), who noted that designers frequently begin with a basic strategy for the design, however, would suddenly abandon it in favour of another.

The findings from Belotti's study (op.cit.) identified five primary categories of development activity in design. These, however, did not reflect the processes involved in the activities, except for the prototyping and testing activities, which occurred after the development and implementation phase of the design. In the interview studies, these two activities occurred as part of the development of the design, and also at the implementation phase. These evaluative activities were absent from both the observational and documentation studies during the developmental stages of the design. However, the studies did not follow the designs from these two projects into the implementation stage, therefore it is not clear whether these activities occurred at this stage. There were a number of references in the documentation data from both projects to plans for user testing during implementation.

7.6.2 CONTRIBUTIONS ON THE DESIGN CONTEXT

The studies by Curtis et al, (op.cit.) represent a major contribution on the design context. Their findings identified a number of important factors related to the design context that affect the productivity and quality of design. These factors were rooted in the psychological, social and organisational processes arising from the design context. Curtis et al, applied a layered behavioural model of the software design process to the studies. This enabled them to identify the factors influencing design activities, for example, the environmental conditions and the organisational context of software development. The findings from the study indicated designers held a specific model of design which they were unable to apply to design activities, because of the influences of the environmental conditions.

The findings by Bellotti (op.cit.) also identified the design environment as an important influencing factor on the type of design that develops. Her study identified eleven factors that directly influenced the development of the user interface, and resulted in variations in design practice. Bellotti attributes these variations to the influences of the design environment. A conclusion drawn from the findings is that these influencing factors constrain the design, by causing designers to adopt unsatisfactory design approaches.

A major finding from the study by Rossen et al, (op.cit.) was that the particular model designers applied to the design process was largely determined by the business state of the project. Projects scheduled for internal release adopted the more formal, tightly controlled model. A difference appeared in research-oriented projects due to the application of a model based on concurrent design and implementation activities and a highly iterative process. These influences of the design context on the design approach were also visible in the interview studies (Chapter 5), where a more structured and formal strategy was applied to design because of the marketability of the system under design. Similarly, in the observational studies (Chapter 4), which were situated in a research oriented context, the designers adopted a highly iterative and exploratory strategy.

7.6.3 CONTRIBUTIONS ON USERS' REQUIREMENTS

A number of these design studies highlighted users' requirements as constituting a significant part of design. Several of the key issues in the representation of users' requirements in design identified in the research investigation, were also identified as important in other studies.

Bellotti's study (op.cit.) of design practice indicated that a number of the problems experienced in user interface design were related to users and requirements in some way. The types of problems reported in the study included: a) an uncertainty about requirements, b) the exclusion of users, c) expanding a task outline, and d) the unfamiliarity with the task domain. Seven of the eight projects in the study reported problems in one or more of these areas.

The limitations associated with users and requirements were also evident in the study by Curtis et al, (op.cit.). In the interviews with 97 designers from 17 projects, it was found that among the three most salient problems in terms of effort or mistakes were attributed to: a) the thin spread of application domain knowledge, and b) fluctuating and conflicting requirements. The findings indicated the first problem was caused by the difficulty designers had in mapping application knowledge onto computational knowledge. The second problem, the fluctuation in system requirements, was evident in every project studied. The fluctuation in requirements appeared to occur when the design team lacked application knowledge, and had performed an incomplete analysis of the requirements. Although it isn't clear from these studies what the limitations on requirements information are attributed to, it was identified as the single most difficult area for designers.

The lack of users' requirement information was also identified as a key issue for the designers in the study by Hammond et al, (op. cit.). The designers in the study consistently claimed that the lack of user information caused a major problem in system design. The early stages of the design process, concerned with the initial task analysis was identified as a critical area, where designers required information the most.

These design studies reveal very little about the specific strategies designers use to compensate for inadequate user information, but they do highlight some of the ways designers manage the situation. The designers in Curtis et al, (op.cit.) study reported a substantial time commitment to learning about the application domain. A common strategy reported in the study, was based on seeking experts in the organisation with knowledge of users and requirements. Another strategy reported in the study, was to acquire information through developing a prototype and showing it to customers. There are similarities between these strategies and the ones adopted by the designers in the interview studies in the research project.

Another compensatory strategy emerges in the interview studies by Hammond et al, (op.cit.). The study provided examples of designers adapting their strategies when the required information was absent, to ones that enabled them to acquire the information. Two examples are provided, one where the designers culled examples of charts in newpapers and journals, to learn more about non-computer graphics.

The second example is where a designer went back to school text-books to see how arithmetic was taught in order to understand users' requirements in this area.

Hammond et al, (op.cit) found that although designers considered users' requirements to be important in design, the focus was mostly on the logical formalisms of requirements that often excluded important users' requirements. Furthermore, their study indicated that decisions relating to users' requirements were based on "common sense theories" of users' behaviour.

This is consistent with Bellotti's findings (op.cit.) that indicated that although designers claimed the importance of users' requirements information in design, it was seldom applied. The reasons provided for this was the lack of time, organisational obstructions, and the inaccessability of users, which undermined the designers' opportunities to develop adequate users' requirements.

7.7 CONCLUSION

The findings from the investigation of the design process has led to the conclusion that the design process is significantly influenced by three primary factors:

a. the conceptual models of system design that designers apply to design tasks;

b. the information on users' requirements and the application domain designers have at their disposal at the time of the design task;

c. the design context; the conditions imposed by management and the marketability of the system.

Figure 7.5
Factors Influencing The Design Process

Primary Influencing Factors:

None/Inapprop.	>>	Conceptual System Design Models	<<	**Adherence**
None	>>	Users' Requirements Information	<<	**Avail/Applied**
0 - Few	>>	Conditions Imposed by Context	<<	**Several**

Design Process: ______________________ >>

Type: Unstructured Informal	**Type:** Structured Formal
Strategies: Compensatory Exploratory	**Strategies:** Technical User-Focused Conventional

Each of these factors will influence the kinds of strategies designers apply to tasks, and consequently, will influence the type of design process that develops. For example, the design framework to emerge from the findings provides two characterisations of the design process. For purposes of discussion, we can see each of these at the end of a design continuum; the unstructured, more informal approach at one end and at the other end, the more formal, structured approach. An illustration of this is provided in Figure 7.5.

The characteristics of the process shown at the far left of the continuum, are an increase in design stages, exploratory design activities, and a high level of iterations in the stages. There is a significant difference in the characteristics of the process shown at the right of the continuum. The type of process this represents, is characterised by fewer design stages, a focus on validation, and solution oriented tasks. Where the design process is placed on the design continuum, is largely determined by the three factors outlined above.

For example, the more closely designers adhere to their conceptual system design models, the more focused the design process will be on tasks for developing technically oriented solutions. It is when the application of these models to the design task is inappropriate, for example, when the task requires the incorporation of users' requirements into the solution, the design process moves away from this type of process and towards the left of the continuum. When designers have information on users' requirements available at the time of the task, and the information is applied to solutions, the process is placed to the right of the continuum. Movement towards the left occurs however, when the information is not available to designers, or it is not applied to task solutions.

The design context also determines the type of design process, due to the conditions certain environments impose upon the design. For example, the characteristics of a commercial environment, such as the marketability of the system and management approval, place particular conditions on the design. In these environments the design process tends to be of the structured and focused type, which differs from research-product environments, where an absence of these conditions provides designers with more freedom in their approach to design. The more conditions imposed on design by the context of the environment, the more structured the design process becomes.
Certain kinds of design strategies develop from these influencing factors that relate to the type of design process that develops. At each end of the design continuum we see very different kinds of strategies. For example, at the right of the continuum, where there are factors like designers' conceptual design models, available user information, and

the environmental conditions, design strategies tend to be technical, or user focused, with a tendency towards conventional design methods. At the opposite end, where there is a different set of factors visible, such as the absence of or inappropriately applied conceptual design models, the lack of user information, and few contextual conditions, design strategies tend to be compensatory or exploratory (See Figure 7.5).

The extremes between the two points of the continuum is significant, because it highlights the two directions design can take depending upon certain factors. The absence of a middle point for design is interesting to note; it appears to be at one or other end of the continuum. There was evidence of this in the findings which suggested designers did not mix strategies; creative strategies were not used in the same context as conventional ones for example.

These findings point to certain design requisites that are essential for the representation of users' requirements in design. These are:

a. appropriate user models that can be applied to design tasks;

b. information on users' requirements and the application domain that can be easily incorporated into design tasks;

c. a design environment that supports design by providing conditions that promote the development of design solutions, without imposing limitations or providing too much open-endedness.

A balance could be achieved in the design process, if designers were able to draw upon appropriate user models, and also if information was available when required. Methods for incorporating user information into solutions are equally important. The design context is also important to consider. The findings suggest the present imbalance in design, is related to the limitations of either too many or too few environmental conditions. Certain conditions appear to focus the design, and to make it imperative that users' requirements are incorporated, these are related to the evaluation and the assessment by others external to the design team.

7.8 SUMMARY

In this chapter the main findings from the research reported in Chapters 4, 5, and 6 have been summarised. The methodological weaknesses created by including in the investigation three different types of data from different design settings and three different have been highlighted. The main problem resulting from the disparate studies is that it becomes inappropriate to draw together the conclusions from the studies into a comprehensive model of design. Instead, the findings from each study have been regarded as individual contributions to the research. The differences in methods and design contexts as they relate to the studies have also been discussed and have been taken into consideration when summarising the findings. In spite of the disparate nature of the studies, there was a dominant theme that was consistent throughout the three sets of data. The main points emerging from this theme have been brought together in this chapter to formulate some new understandings of the design process.

Two major components of the findings have been discussed in the chapter. These are:

a. The influence of the design context; variations in design relate to the context in which it takes place. The primary influences include the commercial constraint, the pressure to innovate, and the specialisation in user interface design.

b. The representation of users in design is determined by first, the conceptual system design models designers apply to tasks, and second, the information on users designers have available, and third, the demanding characteristics of the design environment.

A review of other research in this area has also been discussed in the chapter in relation to the contribution of these findings to the field. The chapter concludes with suggesting that the present imbalance visible in design, could be addressed by providing designers with appropriate methods to apply to user related tasks. It also suggests that in order for users' requirements to be sufficiently incorporated into design solutions, certain conditions such as validation and external assessment are important.

CHAPTER 8

AN EVALUATION OF THE METHODOLOGICAL APPROACH & CONSIDERATIONS FOR FUTURE RESEARCH

CHAPTER 8 AN EVALUATION OF THE METHODOLOGICAL APPROACH AND CONSIDERATIONS FOR FUTURE RESEARCH

8.1 INTRODUCTION

Chapter 8 provides a review of the objectives directing the research and a critical assessment of the data collection methods applied to the investigation. A summary of the key findings from the study is provided and it includes a discussion of the characterisation of the design process that emerged from the findings. The conclusions from the first part of the chapter, provide the basis for the exploration of further research in the field contained in the second part of the chapter. The practical ramifications of the research findings are discussed together with the issues underlying current design practice. This leads to the identification of key areas in design that are considered important to address through further research.

8.2 OBJECTIVES OF THE RESEARCH METHODS

There were two major objectives underlying the research that influenced the methodological approach to the investigation of design. The first objective was to identify the types of design processes in the development of interactive systems. Systems in which the user interface constituted a significant part of the design were of a particular interest to the research. The second objective of the research, was to identify the types of representations applied to users' requirements in the design process. A research aim was to determine the extent to which users' requirements were represented in design, and the basis on which these representations were formulated. These objectives led to the following questions which guided the direction of the research:

a. ***The Design Process:***

- what types of activities designers engage in;
- what kinds of methods and techniques are applied in design tasks;
- what are the factors that inhibit the design process.

b. ***The Management of Users' Requirements In Design:***

- what kinds of design decisions involve users;
- what sources of user information are used in decision making and in the development of solutions;
- what methods are used to incorporate users' requirements into design solutions.

The methodological approach to the investigation was based on a combination of three different methods for data collection in each of these areas. There were two reasons for choosing a methodology based on different techniques. First, there were limited opportunities to obtain data on design, and the opportunities existed in more than one design context. Second, the limitations of the individual methods made it difficult to address the full range of research questions. The aim in including more than one method was to compensate for the limitations, and also to provide additional breadth of coverage of the design process. The methodological approach included the following techniques:

a) ***Interviews:*** Structured interviews were conducted with designers specialised in the design of user interfaces. The subjects were guided in a reconstruction of the design process of the recent projects where they played a major part. The interview data consisted of designers' recollections of the critical incidents in previous projects. The interviews focused on the strategies designers applied in the incidents, and also on the major design decisions in the design process.

b) ***Observations***: Design teams were observed while engaged in design tasks during meetings. The focus of the observations was on the approach to design tasks, with the view to understanding the kinds of processes involved in design. The handling of users' requirements and the types of decisions concerning users were also a primary focus of the studies

c) ***Documentation***: The design documentation from two projects was used as data. The documentation data was examined to determine the types of activities designers recorded, the major design decisions, and how users' requirements were represented in the design.

The three approaches to studying design enabled the design process and the representation of users' requirements in the process, to be investigated from diverse perspectives. Each design perspective enabled the key areas of interest to be examined from a different angle. The interview studies provided data on design as it is represented by designers' recollections; the observations represented design as it developed in a real context; and the documention studies represented design according to designers' descriptions. The three studies together provided a breadth of information on design, which enabled a full characterisation of the design process to be developed.

8.3 CRITIQUE OF THE METHODS

Although the methodological approach adopted enabled the investigation to address a range of design contexts, and thereby provide a breadth of data coverage, there are a number of limitations associated with the approach. The first limitation is reflected in the strength of the approach. The diverse range of data provides a collection of design snapshots at different points in the design process from a variety of projects. The methods provide a diversity of data ranging from early conceptual design, to a catalogue of recollections of critical incidents, through to the implementation stages. Although this cross-section view of design provides a rich picture of the design process, difficulties arise when attempting to synthesise the data into a coherent view of design. Therefore, the focus of analysis has been on the underlying patterns and the relationships in design. The research did not address the specific details of each design because these can differ significantly in each design context. The limitations of each method applied to the design studies are discussed in turn.

a) *Interviews:*

The decision to include a study based on interviewing methods in the investigation was based on the belief that it could provide a different approach to addressing some of the research questions. The perspective gained through designers' verbal recollections of design activities could lead to the identification of some of the influencing factors on design in this particular setting. A study aimed at obtaining this kind of information had the potential to provide a valuable piece to the holistic picture of design. The study could contribute to the development of this picture by providing a particular slice of design that differed from the other two studies. Through designers' selective recollections it was possible to gain insight into their perceptions of what was considered important in design, and also into the principles guiding their design practice. It cannot be assumed that these will affect design, because of the discrepancy which often exists between intention and actual practice. Additionally, the difference in design context from the other two studies, offered an opportunity to look at design in contrasting contexts.

The generally recognised weaknesses of interviewing techniques, such as interviewers' bias and the qualitative nature of the data is recognised. Additional limitations appeared as a result of the methods used to structure the interviews. The interviews were organised around the reconstruction of critical incidents in recent design projects. The implication of this type of structure is that the focus on critical design incidents filters other areas from the data collection. As a result, there are areas where data is not collected, for example, minor design problems, or designers' design philosophies. The bias towards critical incidents also influences the subjects' recollection of projects. By framing design in terms of critical incidents, subjects tend to think of design in terms of limitations, turning points, and significant decisions. Other limitations often associated with interviewing techniques, are the influences of individuals' perceptions of design, and also the tendency for subjects to rationalise events after they have occurred.

In spite of these limitations, there were some important strengths in applying this particular structure to the interviews. The narrow focus on critical incidents, prevented the tangents and digressions often associated with interviewing methods. This enabled the interview time to address only those areas relevant to the research. As a consequence, a substantial amount of material was covered in a relatively short time period. For example, most subjects reported the critical incidents for two to three projects during the course of an interview. This provided a sample of data on the design process for a large number of projects.

b) *Observations:*

Observations of designers engaged in design tasks during team meetings offered a mixture of advantages and disadvantages. The true value of the observations lies in the opportunity for the researcher to play the role of the "fly on the wall". This allows the many facets of design practice, including the behavioural and the technical to be observed. This is especially valuable in design environments where the context of the design is of equal significance to the design content. Observing the dynamics of a design process contributes a rich dimension to the understanding of design that is impossible to gain through designers' recollections or through documented accounts of design. In spite of the disadvantages associated with observational techniques, it remains the only way to obtain direct evidence of the design process. Other methods, however valuable they may be, represent a 'filtered' view of design.

One of the common weaknesses of the observational methods pertains to the influence of the observer on those observed, especially when audio recordings are involved. The presence of an outsider, and the recording of discussions, can be perceived as an intrusion on privacy, and therefore, can inhibit the subjects' behaviour.

Other weaknesses often associated with observational methods lie in the difficulties of capturing in the data, the essence of what is being observed. This is compounded further by the methods applied to the analysis, and the representation of the data; it is important for the essence of the observations to be preserved through the analytical process. Observations of design processes in situ provide such a rich and vast source of data, that it is virtually impossible to capture data on all dimensions. It is inevitable that the data will be filtered through research biases, and also through the analysis of the data. This results in the presentation of the data related to the research, and the omission of the remaining data. Unfortunately, this is one of the most frustrating weaknesses of observational methods for those who are curious to know more than is being presented.

Another important weakness of observational methods is the time involved in gathering the data relative to the small amount of data collected. The time investment is significantly larger than the amount of data required and able to be utilised. Nevertheless, observational methods can contribute to the study of design practice despite these limitations.

c) ***Documentation:***

The documented accounts of design tasks by designers, provided an opportunity to see design from a retrospective point of view. Similar to the interview studies, the study was based on selective recollections however, written instead of oral, therefore there was the opportunity to see the kind of rationale designers created after a particular design activity. It was also peceived as a potentially valuable source of information about how users' requirements were represented during design, because the nature of writing documented accounts of design involved designers in carefully considering what had occurred and what to document. The information from the study could provide yet a different slice of design, and therefore had the potential to provide another valuable piece in the development of an holistic picture of design.

In many ways, the use of design documentation as data has similar limitations to those with the data collected through interviewing methods. Both methods result in data that represents design a step removed from the practice. To a certain extent, documentation data is even more limited, because it represents a further abstraction of the design. During the course of documenting the design process, designers engage in making explicit, parts of the design that were perhaps implicit in the design process. Therefore, the documented accounts of design contain selections of designers' recollections of what occurred or rationalisations of the design. The selection of particular parts of the design to include in documentation is influenced further by the potential audience. The possibility of an assessment and criticism of the design presented in the documentation, can result in a biased view of the design. This can influence the documentation to provide a "packaged" view of the design.

To a large extent the strengths of design documentation, as a method for data collection, counterbalances some of these limitations. Documentation data provides more coverage of the design cycle than the other two methods, which focus on snapshots of the design process. This enables a complete picture of the design process to be obtained, without the time investment of interviewing or observational methods. It is also easier to focus the analysis of the data, because during the process of documenting, certain parts of the design, such as design techniques and decisions are made explicit. These tend to be less embedded in design tasks in documentation data, and therefore do not remain implicit, as they do for example, in design meetings or with designers' recollections.

Finally, as a design artefact, documentation reflects designers' perceptions of the design process. This is considered a strength instead of a weakness, because the selection or omisson of areas of the design to document, enables us to gain insight into designers' perception of design. The representation of design through documentation provides a design perspective significantly different from those gained through interviews and observational studies.

8.3.1 SUMMARY OF RESEARCH METHODS

The research methodology was based on three methods for data collection: observations of design meetings, interviews with designers, and the documentation of design projects. The diversity in the methods provided a substantial database of information on design, from which different perspectives on the design process were drawn. This enabled more of the facets of design to be understood than if only one method had been applied. Although the use of diverse methods provided a rich source of information, the limitations of using more than one method is reflected in the separate illustrations of design, that are not easily synthesised into a coherent design model. It is possible a coherent model could have resulted by applying only one method to a study of designers from the same projects. However, for purposes of the research, the potential outcome of this approach was considered too narrow and specific. Instead, the research objectives were best addressed through obtaining a wider sample. Although a model of the design process would be a convenient outcome of the research, at this stage of our understanding of design, it is believed premature to attempt to cast design into a model before it is fully understood. A comprehensive map of the design territory will consist of terrains of different shapes and forms. Such a map requires a gradual piecing together and understanding of design from its many dimensions.

8.4 RESEARCH SUMMARY

The research was stimulated by the increasing problems arising from the incompatibility between interactive systems and the users of the systems. It was generally understood in the HCI field, that the incompatabilities were attributable to a gap between the users' requirements as represented in the design of systems, and the actual requirements of users in the application domain. The research in the field focused on gaining a further understanding of users' characteristics and system performance. Improvements to the design of systems were sought through establishing design methods and principles, and also through the development of evaluative techniques. An important gap in the research existed in the area of understanding the design process of systems. Within the design process, little was known about design practices, and the representation of users' requirements in design. The research project attempted to address this gap by investigating design through the study of the design process and the management of users' requirements within the process.

The investigation of design in these two areas has contributed to our understanding of design in two important ways. First, by providing a characterisation of the design process, and second, by identifying the factors that determine the extent to which users' requirements are incorporated into design. The findings have led to the identification of three principal issues that are key to design in general, and also to the representation of users' requirements in design. These are:

a. Designers approach design tasks with a system based conceptual model of the design. The application of this type of model to design tasks is often inappropriate. This is apparent when it becomes necessary for users' requirements to be incorporated into solutions;

b. There are often serious limitations on the availability of users' requirements information; designers often approach tasks with limited information or none at all;

c. The demanding characteristics of the design environment influence the type of design process that develops, and the strategic options available to designers.

The characterisations of the design process to emerge from studying design in different contexts, has enabled us to see how the characteristics of particular environments impose certain conditions on the design. These conditions significantly influence the way designers approach design. This is evident in the variations in the design process, and the strategies applied to design tasks that appeared in the findings.

In a research-product environment, as represented in the observational and documentation studies, there are two levels at which a design process develops. At the first level, we see the application of a conceptual technical system based model, which tends to focus the design task and solutions on the technical aspects of the system, to the exclusion of users' requirements. The strategies designers apply are oriented towards a "*lets get on with it*" approach and "*hack and see*" solutions. Variations in this process occur when it is imperative that users' requirements are considered, and the design cannot proceed without this consideration. In situations like these, which were common in the observational studies, designers adopt strategies to develop the requirements which are based on their conceptual models of users and on personal experience. As a consequence, the requirements represented in the design are more of a reflection of the designers' requirements, than they are of the potential users.

The conditions imposed by a research-product environment of the kind represented in the data, influence this particular approach to the design of systems. There are two conditions in particular that are seen to influence this kind of process. The first is the demand for innovation, which directs the design toward rapid implementation. The second is the insulation of the design from external influences, such as market concerns and potential users, because the system is typically the first of its kind.

In this kind of design environment, there are important implications for the degree to which users' requirements will be represented in the systems developed. Two possible design outcomes arise from the influences of this environment. The first is users' requirements will be excluded from the design, or they will be represented in terms of designers' conceptualisation of the requirements. In both cases, this is seen as an important factor contributing to the incompatibilities that exist between systems and users' requirements of systems.

A large proportion of systems developed in a research-product environment eventually become commercial products and are implemented in user organisations. Even though the designs of products may undergo several changes during the developmental cycle, as they move from the research laboratory to a fully marketable product, usability problems still remain. The basic design, with the underlying conceptual ideas developed during the early stages of the design process, very often remain embedded in the system, and therefore are filtered into the industry. A good mapping of requirements between systems and users requires that designs incorporate a user orientation from the early conceptual stages . When this is absent, which is often the case in research-commercial environments, as seen in the observational and one of the documentation studies, the inappropriate mapping becomes a factor contributing to the mismatch between systems and users.

The conditions in a commercial-product environment influence design in a very different way. The findings indicated that when one of these conditions is the separation of the user interface from the rest of the system design, as in the interview studies, a different type of design process develops. This type of process is best described as a "low risk" approach to design with an orientation towards results. There are implications of this approach for the kinds of systems that are developed in this environment. Although the demanding characteristics of the environment require that users' requirements are incorporated in the design, and that usability issues are fully addressed, this imposes conditions that can inhibit the design.

The conditions imposed by this environment tend to influence the design toward evaluation, because of management appraisal and the necessity for compatibility with the development of the rest of system in other projects. The design of systems are influenced by these conditions in two ways.The first is the inhibition in the exploration of creative design solutions; there will not be the scope for innovative design ideas, as there is for example, in the research-product environment. Another infuence is seen in how the design process is organised around activities concerned with the evaluation of design solutions, the presentation, and the justification of these solutions to management, and to other projects involved in the system design. This also represents a diversion away from innovation in design.

The research findings pointed to significant limitations in the application of users' requirements information in the design of systems. The extent to which the limitations are experienced by designers is largely dependent upon the demanding characteristics of the design environment. In a research-product environment, such as represented in the observational and documentation studies, it is common for information on users' requirements not to be incorporated into the design, and for designers to avoid the necessity to include requirements. In many of these situations, the design process is seriously inhibited, due to the difficulties that arise from developing solutions without considering users' requirements. The process can be inhibited further, by the conflicts that arise in design teams when attempting to resolve these problems. Information on users' requirements is seldom available to designers in this type of environment. However, there are situations, for example, in the documentation studies, where information is available, and designers do not apply it to tasks. It appears these situations arise from the technical system based models designers apply to the design. This focuses the design on technical design issues, instead of on users' requirements.

In a commercial-product environment, as represented in the interview studies, the limitations on information on users' requirements also inhibit the design process in some significant ways. In this type of environment, where the design process is directed towards evaluation and appraisal, designers cannot risk designing without adequate information on potential users. Therefore, early design tasks focus on gathering the information required to proceed with design solutions. As a consequence, the development of users' requirements becomes a significant part of the design process.

In both environments, the limitations of user information significantly influence how designers proceed with design tasks. In the research-product environment, represented for example in the observational and documentation studies, we can see how designers proceed without adequate user information. In the commercial-product environment seen in the interview studies, design resources are diverted from developing solutions to acquiring the necessary information.

Further evidence of how users' requirements are represented in design is found in how designers proceed with tasks that are user related. In the observational and documentation studies, there is evidence of designers, individually and collectively, applying technical system related models to design tasks, regardless whether this is the appropriate model for the task. The consequences of this is visible in two areas of the design. The first is in technically oriented tasks, where it is not imperative that users' requirements be considered. The technical-system view of design is also evident in tasks in which there is an underlying user component that necessitates the consideration of users' requirements. When the technical model of design is applied to these tasks, there is an inappropriate mapping of technical solutions onto users' requirements. This results in solutions that are incomplete or inconsistent; the problems that arise from this are difficult for designers to resolve. The implications are visible in the design process which is inhibited by designers not being able to proceed with developing solutions. There are also implications for users' requirements; the findings indicate users' requirements are seldom incorporated into a design developed in these situations.

Where the implications of this design approach is especially visible, is in design teams working on user related design tasks, for example in the observational studies. In these situations, designers collectively apply a technical system model to tasks. This model does not accommodate users' requirements, therefore problems arise when it becomes necessary to incorporate users' requirements into solutions. This results in a design process that is longer than if the information is available, or if the task does not require input from users' requirements. The problems are compounded when the information on users' requirements needed to develop solutions is not at the disposal of the design team. In this case, designers temporarily abandon the technical system model, and instead, resort to personalised user models in an attempt to move the design forward. Therefore, the information that is generated by the team is a reflection of the designers' projections of requirements, and will not necessarily be compatible with those of the potential users.

These findings enable us to see how users' requirements are managed in the design process. It is possible to see how a number of key factors influence the extent to which users' requirements are included in or omitted from design solutions. The design environment is a particularly important factor that seems to determine whether the design is focused on the user or on the technical aspects of the system. When there is a separation of the user interface from the rest of the system design, designers approach tasks with strategies that support the incorporation of requirements in solutions. As a consequence, the design process is focused on ensuring that the representation of users' requirements in the design is as accurate as possible. When designers are responsible for the design of the entire system, and there is an absence of management or market influences, designers adopt strategies based on a technical system model of the design; this focuses the design on technical issues to the exclusion of users.

The availability of information on users' requirements is also a key factor that influences both the design process and the extent to which users' requirements are represented in design solutions. This appears in both types of environments, the research-product, and the commercial-product; however, the lack of information is dealt with differently in each environment. When designers do not have the information they require to complete tasks, they adopt compensatory strategies in order to develop the requirements themselves, based on the information they have at their disposable. This often results in the exclusion of users' requirements in the research-product environment.

8.5 FURTHER AREAS OF RESEARCH

The research has led to a number of findings that significantly extends our understanding of how designers approach design tasks, and also on how users' requirements are represented in design. In addition, the research has identified areas of design that require further exploration before a complete understanding of design can be developed. In particular, the research has highlighted the value of studying design within the context of real design settings. Very little observational research of this kind has been conducted in the field, and the results from the observational studies make it clear that the gaps in our knowledge of design could be addressed by further observational research.

The research has also identified the methodological strengths and weaknesses of incorporating studies with different types of data from different design settings and different conclusions. This has highlighted a number of phenomena that can be attributed to the disparate nature of the findings. These could be explored further in a study of the same design process, incorporating all three different methods; observations of design meetings, verbal recollections of design incidents, and documented accounts of the design. The data collected from these parallel methods of the same design process would enable the validation of for example, the 'theory in action' versus the 'espoused theory' evident in the findings in this research investigation. (Argyris and Schon, op. cit.) It would also enable the validation of the different type of design processes that were portrayed in the studies; the coherent, structured processes evident in the interview and documentation studies, opposed to the exploratory, problem solving process in the observational studies.

There are two dimensions along which further observational design studies should be directed to continue to build our knowledge of design. The first is the study of design behaviour, which this research has briefly touched upon, but has not been able to pursue. Design behaviour is distinguished here from design practice, by the focus on designers' actions, and how this can influence design practice. The methodological approach to this kind of study is important, because of the need to capture both the behavioural facets of design, and also the implications of design behaviour on the design process. This requires research methods to contain as few filters as possible, so that the results can provide an accurate representation of design practice, as it exists in a natural environment. Ethnographic methodologies could offer a good basis for this type of study.

The research has also highlighted specific aspects of design behaviour that potentially influence design, and would therefore be worthy of further investigation. One aspect relates to the design behaviour of individual designers, and the potential effects of individuals on design decisions and outcomes, particularly with respect to team participation. There was a strong indication in the research findings, that at the behavioural level there were three factors that influenced the ways individuals and teams participated in design tasks, and developed design solutions. The first was the character structure of the individual designers, the second was the manifestation of the character in a team environment, and the third, was the type of cognitive models individuals held of users and the external world: the non-computer systems world. A combination of these factors is believed to contribute to patterns of design behaviour that directly influence design outcomes. A further understanding of patterns of design behaviour at an individual level, offers insight into the interactions between members of design teams. This can contribute to our understanding of how design solutions are developed in a team environment. A number of the factors inhibiting the design process highlighted in the findings were directly related to the difficulties experienced by design teams; many of these pertained to the inability of team members to reach agreement on design solutions.

Another dimension of design requiring further research, relates more to design practice than to the behavioural aspects of design. The focus of the research presented here, has enabled us to further our understanding of design practice in terms of the kinds of processes that occur in the early conceptual stages of design, the kinds of user information designers work with, the kinds of decisions they make, and the types of tasks and activities they engage in. However, it is necessary for this knowledge to be extended to a wider range of design environments, to enable more comprehensive conclusions to be drawn on the nature of design.

The process by which design occurs also requires further investigation. The research has provided an overall picture of the kinds of paths designers follow during the design process. This picture represents a fragmented process in which decisions and solutions are developed in a highly exploratory manner. The paths designers follow in this process, require further investigation to understand more about the factors that influence designers' choice of particular routes. An interesting question to emerge from the research is, why designers, at certain points in the process, abandon paths without further reference? This has implications for how decisions influence design solutions. If designers do not refer to previous paths, and if the majority of design decisions are implicitly made, as the findings suggest, this leads us to question the basis on which design solutions are developed.

Finally, an area of design requiring further research, is the design rationale that is developed at the end of a task or a project. The findings suggest designers have a tendency to recreate a logical basis for a design once it is completed. The process of creating a rationale appears to be based on a need designers have to offer a rational, however, often specious explanation for the design solution. This is reflected in the rationale artefact where design decisions and solutions appear logical and consistent, as for example in the documention studies. It also appears during the last stage of the design process, where designers attempt to rationalise solutions before moving on to the next stage of design. This raises two interesting points; the first is, to what extent is the rationale a form of validation of the design, and second, what is the relationship between the rationale created and the design tasks? How accurate is the representation between what occurred in the design process and the final rationale?

This phenomenon could be pursued further by investigations based on a comparison of the rationales developed in the last stages of the design process, with designers' documented account of the design. To complete the comparison, designers should be interviewed for a reconstruction of the design process. The three points of comparison of a single design process would provide substantial insight into the process by which design activities become linked to rational outcomes.

A number of methodological issues have arisen from the research highlighting directions for further research. Each of the methods applied in the research offered a different perspective on design, and therefore significantly contributed to the findings. Each method provided a valuable source of data independent of one another; however, the limitations associated with each method were also apparent. A consideration for further research is the development of a methodology that includes a range of different methods to enable design to be studied from different perspectives, and to explore in more depth, the underlying patterns and relationships inherent in design. Studies of design projects through observations of the process, combined with the documented account of the process, and the designers' verbal recollections of the design, would provide the range of data required to understand design at a level where conclusive characterisations can be developed.

8.6 PRACTICAL RAMIFICATIONS

The research originated with questions on why users' requirements were not better represented in design. Several hypotheses developed from these questions that directed the research towards investigating the design process, and the handling of users' requirements within the process. The primary objective of the research was to gain insight into the factors influencing the management of user issues and requirements in design.

The findings from the research point to specific areas in which designers experience significant difficulties that directly influence the way users' requirements are represented in design. Table 8.1 outlines the primary factors that give rise to these difficulties.

Table 8.1
Design Dilemmas

Design Issue	Underlying Requirement
Demanding Characteristics of Environment	*User information, methods, tools, user based design models*
Limitations of Users'	*Readily available & possible to assimilate*
Requirements information	*user & domain information*
Technical-System Design Models Inappropriately Applied	*Design schemas and heuristics appropriate to user related tasks*
Team Difficulty in Handling Users' Requirements	*Reference points, information base, team interaction skills, problem solving skills*

As we have seen from earlier discussions, a number of design symptoms develop as a result of each factor; however, underlying each factor is a dilemma designers face at various points in the design process. The dilemma is caused in part by certain requirements designers have, that are not being met. This shifts the focus from the issue of how users' requirements are met in design, to the issue of designers' requirements and how they are met during the design process. This raises some important questions about what constitutes a design requirement, and how these can be addressed.

The factors that contribute to the problems designers encounter in design, point to two areas of design where designers are lacking what they require to complete tasks and to develop design solutions. The first area relates to the theme running throughout the research; designers are very much in need of information related to users and their requirements. The second area concerns the lack of techniques and tools with which to apply the information to the design, and also to manage user related design tasks. A discussion of these requirements follows in the following two sections.

8.6.1 DESIGN REQUIREMENTS;USERS' REQUIREMENTS INFORMATION

The two areas identified above represent a complex set of design requirements. Consequently, they cannot be met by simply providing designers with information on users' requirements at the beginning of a project. The research indicates designers require more than a specification of users' requirements or a list of primary functions and features to include in designs. The information designers require to develop solutions based on users' requirements, extend beyond this basic type of information. Certain categories of information designers required during the design process have emerged from the research; these are summarised in Table 8.2 on the next page.

Both the range and the amount of user information designers require in the design process, raises important issues of how to best provide all the information. It also introduces the question whether it is in fact possible to provide designers with such a substantial amount of information. These issues are magnified by the characteristics of designers' requirements for user information as portrayed in the data.

Table 8.2
Design Requirements: User Information

Types of Information Requirements:

System specific:	*functionality, features to include, usability criteria*
User specific:	*requirements of potential users of the system*
User generic:	*general user characteristics with potential affect on system usage*
Domain specific:	*requirements derived from environment system will be installed in*
Domain generic:	*general environmental conditions influencing system requirements and usability*

Those of particular importance are:

- designers require certain kinds of information at different stages of the design process;

- in certain environments, designers are reluctant to interrupt design activities to find the information they require;

- designers' information requirements cover a broad range of areas;

- information requirements are timely;

- designers often are not aware of when user information is required to complete a task.

There are two additional components to designers' information requirements that extend beyond only having the information available. Of equal importance is the form in which the information is provided, and the methods designers use to apply the information to the design. Both of these have a direct influence on how users' requirements are incorporated into the design.

8.6.2 ADDRESSING INFORMATION REQUIREMENTS

There are two ways in which the information requirements of designers could be addressed.

1. *Provide The Full Range of Information Required*: It is necessary for information to be easily available and accessible to designers, so that design tasks are not unnecessarily interrupted. It must be possible for designers to access the parts of the information that are relevant to the task and that addresses the particular questions and issues in the task. It is inevitable this type of a database would need to be computerised and have a sophisticated query and explanatory facility. Designers would need to be able to draw relationships between design solutions and the information needed to develop the solutions. It would be necessary for an information system to enable designers to formulate questions, to present issues, and to have the necessary links drawn between questions and the information required for answers. To be completely helpful to designers, a database would need to include reference material, for example, data from experiments and case studies, information on guidelines and principles, in addition to the categories of information outlined above.

2. *Instruction On The Application of User Information In Design:* Designers could benefit from design courses that focus on the application of users' requirements in design. There are two areas of design that courses of this kind could address. The first is the design issues that arise from incorporating users' requirements in system

design; for example, the kinds of decisions and technical trade-offs that often occur, and how to approach them. The second area relates to the types of user information required in tasks; the kinds of information typically required at particular stages in the design process, and techniques for applying the information.

8.6.3 DESIGN REQUIREMENT: METHODS AND TECHNIQUES

Closely related to designers' information requirements is the requirement for design tools to better equip designers to deal with user related design tasks. The two in fact are parallel requirements, inasmuch as providing user information to designers alone does not necessarily satisfy the requirement. Designers need to be able to apply the information to develop solutions. It is important therefore, that the two requirements are considered in conjunction to each other. The research highlighted certain areas where designers could benefit from design aids in the form of tools that provide methods and techniques, to support the development of solutions based on users' requirements. Table 8.3 provides a list of the requirements for design aids.

Table 8.3
Design Requirement: Tools & Techniques

Types of Requirements:

User representations:	*how to depict different types of users: generic & specific*
User related design tasks:	*how to approach these tasks efficiently*
Integrating user and system requirements:	*how to balance the trade-offs keeping track of choices*
Evaluating user concepts:	*experimentation with new concepts, assessing if worthy to pursuit*
Simulating design ideas:	*testing out ideas in different circumstances*
Adhering to requirements:	*ensuring the different kinds of requirements are met*
Ensuring consistency:	*ensuring consistency in requirements*

The findings have highlighted a range of design requirements that could be addressed by providing designers with aids of the following types:

- *schematic diagrams*: to keep track of decisions, trade-offs, constraints,etc. to enable designers to depict correlations and relationships between different parts of the design;

- *creative design techniques;* techniques to support the exploratory process in design, by enabling ideas to be captured and referenced. Techniques are also required to support the creative aspects of design, by allowing designers to explore visually, pictorially or otherwise, design ideas and concepts;

- *simulation tools*: tools are required to enable designers to create approximate simulations of the conditions of different application domains, in order to determine the effects of design concepts and solutions;

- *design exemplar/map*: to guide and provide a structure to the design process, so that designers have reference points in tasks, and are able to maintain an overall context for the design;

- *dynamic user representations*: to enable designers to fully understand the characteristics of generic and context specific users, and how these are influenced by the characteristics of the application domain.

8.7 THE DESIGN CONTEXT: DESIGNERS AND DESIGN TEAMS

The focus so far has been on providing designers with the user information they require, and the tools and techniques to support the application of the information to design tasks. Addressing these requirements are crucial for improvements in the representation of users' requirements in the design process. It is however, equally important that the design context is also taken into consideration; otherwise, potential benefits could be undermined by the contextual influences on the design.

The findings highlighted two areas in the design context that are important to address; individual designers and the design team. The research suggested that improvements in the design process could be gained by addressing the issues related to designers in teams. The findings highlighted two particular issues with respect to individual designers, and how they operate in a team environment. The first is the designers' disposition towards computer-centric design behaviour. This is reflected in several ways: the technical system design models applied to tasks, the kinds of strategies that develop from these models, and also how designers assimilate and apply user related information in the design. The evidence suggests that designers are restricted in their ability to adopt another approach because of the nature of their conceptual models of design.

There are potentially significant improvements to be gained by enabling designers to extend their existing models to include other domains, particularly those related to users. One of the best ways to achieve this is through exposure. The limitations of designers' view of the world is partly due to the nature of their experiences, and the narrow focus of their technical training. Exposing designers to other environments, for example, through participation in user studies, or in observations of potential users in their domain, can greatly expand the limits of designers' awareness. Another way to increase exposure, is through courses on user based design in which designers are presented with different approaches to design. Although designers describe design as an essentially creative activity, their design approaches display a strong technical bias. Designers could benefit from courses on creative design methods, which would also contribute to expanding their views of design. Courses of this kind would complement the other areas discussed.

8.7.1 DESIGN TEAMS

The second area in the design context where the findings pointed to factors influencing the design process, is the design team. The observational data highlighted two types of difficulties design teams experienced during design tasks that inhibited the process. The first difficulty is the problem solving nature of design tasks. During the early stages of the design process, designers engage in problem solving activities in order to understand the task and its underlying issues. From the evidence it appears designers lack the necessary skills to effectively solve problems of such magnitude. This is reflected in the amount of time designers spend in the early stages of the design process, understanding and decomposing the task into workable units. It is also reflected in the frequency with which designers return to the early stages to re-examine the task after solutions are developed. This suggests design teams could benefit from becoming familiar with problem solving techniques and strategies, to enable them to move through the early stages of the design process more quickly.

The second area of difficulty, where improvements could lead to changes in design practice, lies in the dynamics of design teams. There were clear indications in the observational data, that design teams did not work together as a cohesive unit. Instead, the highly individualist nature of the designers was often incompatible with developing joint solutions, and especially in reaching a team consensus. This is particularly evident in situations where there is an absence of users' requirements information that is needed to complete the design. Conflicting views arise over the personalised conceptual models designers use to generate the information among themselves. Design teams could benefit from developing collaborative skills for designing within a team environment. This would enable individuals' design ideas to be captured and synthesised, instead of dismissed as often is the case. Skills in design collaboration would also help designers to negotiate areas of difficulty in the design process.

8.8 SUMMARY

The research originated with questions arising from the problems existing in the usability of interactive office systems. There were clear indications, from evaluation studies and other research in the field, that the problems were rooted in the inherent incompatibilities between systems and users. The research focused on exploring the gap between systems and users through an attempt to understand how users' requirements were represented in the design of interactive systems. This led the research to investigate how users' requirements were managed in design tasks, how designers made decisions related to users, and the extent to which requirements were based on information derived from users and the application domain.

The findings indicate there are significant problems in incorporating users' requirements in the design of systems. These problems are manifested in the design process, which can be seriously inhibited by the necessity to incorporate users' requirements. The major factors influencing the representation of users' requirements in design are:

- the conceptual technical system based models designers apply to design tasks, which influence the design toward technical solutions to the exclusion of users;

- the lack of information on users' requirements at the time of developing design solutions and the absence of methods for applying user information to solutions;

- the demands imposed by a commercial design environment; the necessity for management appraisal, and market requirements;

- the separation of the user interface from the system design requiring that designers focus on the usability of systems, and compatibility with the rest of the system design;

  the pressure to innovate in a research environment leading designers towards experimentation and the rapid implementation of systems.

It has become clear from the research that the design context is particularly important, and that in order for system designs to more accurately represent users' requirements, certain changes in design environments are required. The research has identified specific areas where improvements in the design context could lead to potential benefits in design:

- provide designers with the information on users' requirements needed to complete design tasks and to develop solutions. Provide designers with education on the world of users and application domains, through exposure to users, and courses to enable conceptual models to be expanded to include non-technical system views;

- provide designers with methods and techniques to develop design solutions that incorporate users' requirements. These tools should enable designers to create user models that represent potential users, and not abstractions of users. It would also benefit designers to be able to simulate the implications of design concepts in realistic contexts. Methods are required to support the creative and exploratory nature of design tasks, and to help ground designers when working with user related tasks and to direct them away from the tendency towards formulating abstractions of users;

- to achieve a balance in the design environment by addressing some of the conditions imposed on design. For example, the imbalance that exists in research environments between innovation, the inadequate representation of users' requirements, and the validation of design solutions. Similarly, the imbalance that exists in commercial environments, between the need to satisfy management and market demands, with the development of innovative design solutions.

The research has made a significant contribution to our understanding of design in two ways. The first is in the characterisation of the design process that has emerged from the findings. We are now better able to understand the process by which designs are developed, and the types of strategies designers apply in design tasks. Within the framework of design that has developed from the findings, we are able to identify the key factors that inhibit the design process, and how to address some of these factors. Secondly, the research has enabled us to examine how users' requirements are represented in design, and to also identify the contributing and inhibiting factors that influence these representations. Finally, the research has identified areas of design that require further investigation in order for a more comprehensive model of design to be developed. The research has advanced our understanding of methodological approaches to conducting field research of this kindthrough the experimentation of methods for data collection and analysis.

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APPENDIX A

OBSERVATIONAL DESIGN STUDIES

APPENDIX A - OBSERVATIONAL DESIGN STUDIES

A.1 *Pro Forma Applied To Capturing Observational Data*

Task:

Sub-Goals: *Priorities:*

Objects: *Actions:*

Inputs: *Concerns:*

Problems/Constraints:

Questions Raised:

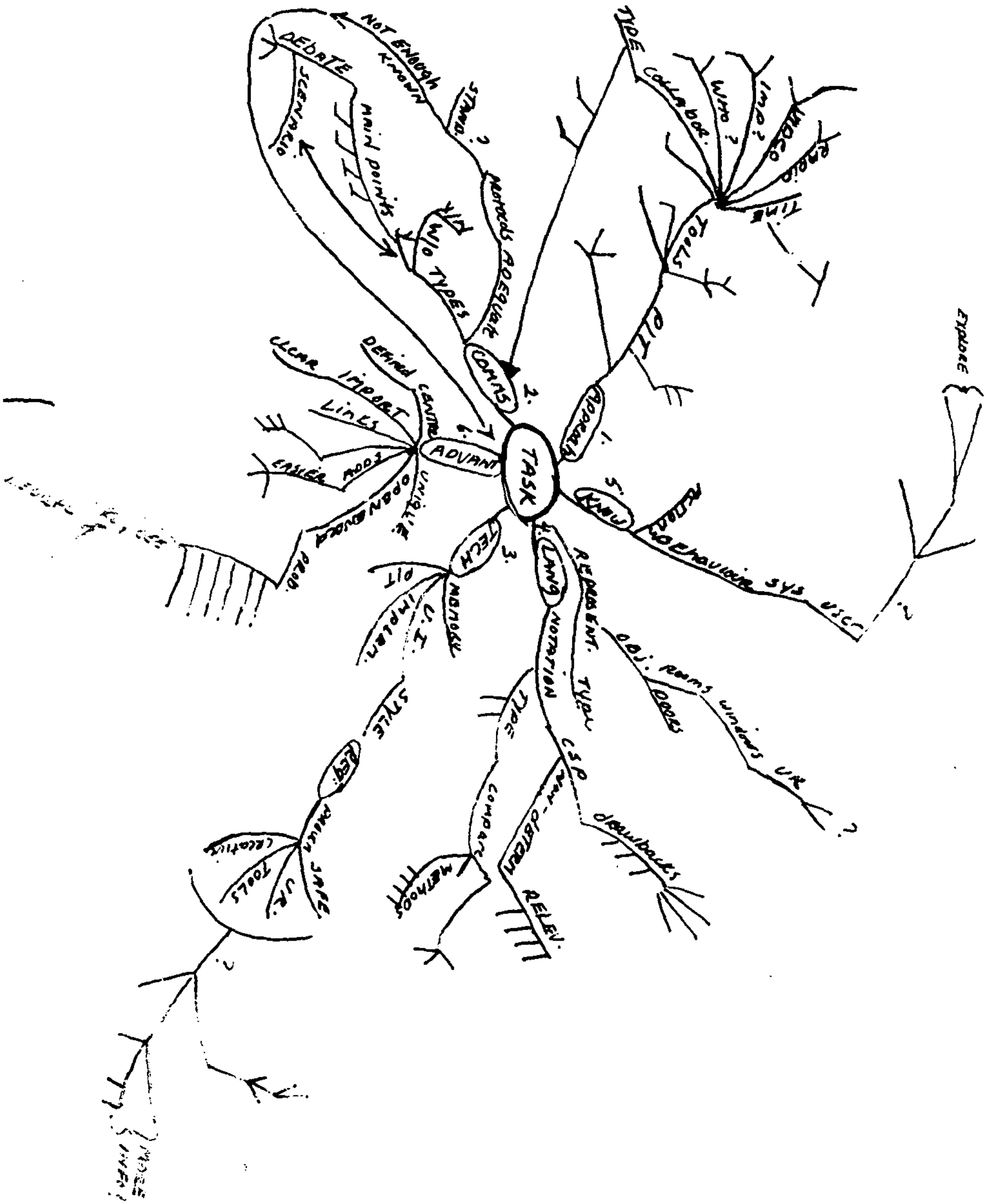
Validity Check:
External: *Internal:*

Decisions/Conclusions Drawn:

A.2. Design Flow Maps Applied To Capturing Observational Data :

See attached examples from the data on the following page.

APPENDIX A



TASK
1. APPROACH
2. COMMS
3. TECH
4. LANG
5. KNW
6. ADVANT
NOT ENOUGH KNOWN
STAND. ?
PROTOCOLS ADEQUATE
W/O TYPES
DEBATE
SCENARIO
MAIN POINTS
TYPE
COLLABOR.
WHO ?
IMP ?
VIDEO
RADIO
TIME
TOOLS
PIT
DEFINED CENTRE
IMPORT
CLEAR
LINKS
EASIER MODS
UNIQUE
OPEN ENDED PROB.
PIT
METHOD
U.I.
IMPLEM.
STYLE
REP
MAIN SAFE
U.R. TOOLS
CREATIVE
REPRESENT.
TYPICAL
OBJ: ROOMS WINDOWS UR ?
DOORS
NOTATION
TYPE
COMPARE
METHODS
CSP
NON-OBJECT
RELEV.
DRAWBACKS
RULES
BEHAVIOUR SYS USE
EXPLORE

A.3. Transcription of Audio Recording of Observational Data

There were four designers present at the meeting which was one of several focused on the design of a new system. The meeting lasted approximately four hours during which the designers discussed various aspects of the design. The following is an excerpt from one of the five audio tape recordings of the meeting; it represents approximately 45 minutes of dialogue between the team members. Apart from the researcher, all those attending the meeting engaged in the design of the system.

Where it was not possible to identify words spoken, because of interference or they were too softly spoken a "xxxx" has been replaced for each word. Where a string of words could not be identified they have been marked as "... (not discernable).......".

Transcript:

Designer 1: I don't know where you include in those or whether there are other categories where things like databases of which using file servers, special case the files up there on the file server, the fact that I may want to simply have the telephone with something it doesn't get at, more passive stuff than I usually deal with.

Designer 2: Right....

Designer 1: This seems to deal mostly with the active stuff, and I'm as interested in the passive stuff. Particularly as there won't be much real time overlap, I'd do the passive stuff first.

Designer 3: So, there's communication, there's storage or database facility, and then there is just one more item, it can fit in there somewhere.

Designer 1: Okay, fine.

Designer 2: I think I was seeing that as a subset of the applications software, but I think you're right, some things have special problems for 'xxxx'. In fact what I haven't made clear in this is that I'm only really talking about the first two in this and I don't think they are.....(not discernable).

Designer 4: Are you saying Designer 1, that our hooks into databases that there's need for work to be done there.

Designer 2: I think its best to keep that separate in fact actually rather than to....

Designer 4: I was just interested whether you thought that in order for us to sit down and build a collaborative tool that there are things that need to be done to make that easier.

Designer 1: Yes, there are, but not necessarily technical. Mostly in the social domain I suspect, sort of agreements how you get them, how you decide where the files are going to be, what the structure of the files, etc. Plus there might also be a technical component to it, we don't really have databases in the [sic] world. It just doesn't seem to be and it would be nice to, if there is one we would buy, we've talked about getting it, it would be nice to think about whether or not we need one and if so can we just pull it off the shelf and then probably they'll be a whole bunch of technical things to worry about.

Designer 3: Well, there clearly is the problem of hanging out till the collaborative 'xxxx' and...

Designer 4: The sort of the real time issue is whether you can support 'xxxx' files as fast as people are using ...

Designer 1: Perhaps yes, uh......

Designer 3: The thing is the stuff's gotta persist, and we can decide to 'xxxx' and to just use the file server in certain kinds of ways, but ...

Designer 1: Let's take a case in point, yesterday we had a neat discussion, all with five pieces of paper, how do I include 'Sara' in that. No record on 'xxxx', no record on how it all happened. 'Sara' doesn't even know we had that meeting or this one for that matter. How do I know about that?

Designer 2: I think you're right these are the sorts of things we ought to tackle, but I think for this particular project I thought we were focusing more on 'xxxx' for handling communication protocol anythings and that is what we're trying to focus on here. I mean, I suspect that, depending on Alex's reaction to this sort of thing, it may well be that if we get a reasonable spec together that is something he would be more interested in or at least interested in doing as well as 'xxxx'.

Designer 1: I think a lot of those things are primarily technical that have to do with...

Designer 2: Yes, but part of that is likely to be having appropriate tools to let you do things in a fashion that isn't too painful.

Designer 4: The issue really is are we writing something for Alex or are we writing something for ourselves to make ourselves aware of what all the things are we need.

Designer 2: What I see for this is first of all for people like, Stan [sic], Chris [sic], and Larry [sic] basically to get some ideas from them on especially handling the communications between workstations end of things.

Designer 1: Okay that is the question how do we want to handle..

Designer 2: And then. what their input is giving us a copy of ...

Designer 1: Okay, that raises the question, do you want to focus just on communications between end workstations, or do you want, in real time, or do you want to think about it any more broadly than that.

Designer 3: I think there are three or four paradigms that kind of come to mind that one would like which are kind of things, like, there's the Talk paradigm which is the real time passing of characters back and forth and so you hold tight cycle exchange, presumably having merged the one obvious 'xxxx'. So there's theTalk paradigm, t there's another one which is a Bulletin paradigm, which says we have a conversation or an exchange over which gets built up probably over longer cycles. Where Bulletin board says longer times and Bulletin implies there's a mechanism for capturing and saving, so a database. The third paradigm is database, where my paradigm case is where Penny is updating things in 'Paris' that people down here want access to and so real time viewing of a common database and possibly the ability to switch other people into augmenting the database. So that is what I mean by the database paradigm. These aren't scenarios, they're kind of different views of the kind of mechanism we want. So its database with viewers, how's that? Ok, so 'Joan' can be sitting there updating [sic] this or that kind of thing, and we can be sitting in real time, we don't need to copy a file which is an old version. In the last paradigm I can think of 'xxxx' that you and I want to work on some stuff and kind of merge kind of a thing, possibly, probably with the phone as an augment. These are not exclusive by any means, but those are just the kind of paradigms that come to mind. We can decide to narrow it by throwing one of these out.

Designer 1: Do all of these have a real time component? This one doesn't, but you're actually thinking of it in that, I mean the Bulletin board thing you're really thinking about it in psuedo real time.

Designer 3: No,

Designer 1: How about E-Mail?

Designer 3: E-Mail, ...(not discernable)........... (long pause) Ok, alright, I think these thoughts were more on the talking, joint editing, the point is working more in real time and to get some tools to help us with that.

Designer 2: Particular touches of handle that are required for the communications levels so we don't have to worry about that....

Designer 4: That's what we want Alex to do,

Designer 2: Yes,

Designer 3: We want Alex to think about, Designer 4: The communications levels, not the applications,

Designer 3: We want to think about the applications enough so that building blocks make sense,

Designer 4: Right,

Designer 3: So that we can see there is some use for them.

Designer 2: I think in particular the tricky bit is that the hooks into the applications where you got some system that interfaces the application with the communications protocols and it is not clear how independent we can really make the applications themselves. I think we can make a reasonable pass where you've got some notion of things being passed, either sort of commands or something being passed from an application going through the application on your own terminal and also being sort of caught at some particular level, so that some bits are running at your terminal and to everyone elses joined together at this particular connection.

Designer 3: I think about application, are you...... I mean I can think about it in two senses, one is kind of generic, like using T-editor or a text editor, is that an application?

Designer 2: Yes,

Designer 3: Cuz, I can think of then wanting to, uh what's its name, cog note or something, its more like an application cuz its geared to a specific task, where text-editing is very generic and one can imagine trying to build a set of building blocks that allow one to utilise T-editor, or text-editing you know as the medium.

Designer 1: Okay, I want to separate application from medium, you might want a very generic medium so that I can share joint editing on T-edit. That doesn't seem to be saying anything about application, because we could use that in a lot of ways.

Designer 2: I think what was in the back of my mind there was the notion of having some sort of application software that you can run at a single workstation, and it would take pieces of software like that and have some means of plugging them into a multi-user environment. We want tools to make that job as easy as possible. Obviously how that is to be depends on how much input to the application you're working with is in the first place. For example, T-Edit has an 'xxxx' where all input comes from the keyboard and it happens to go through, then it should be fairly easy to trap that and send it to two different directions at once or whatever. That's what I had in mind anyway. [Long Pause] But yes, I can imagine you may want sort of within that design, more varied sort of communications support and add ons to T-Edit to allow you to do a variety of things with it.

Designer 3: Well I can see making building blocks for the generic kind of medium as the building block and just say something like a T-editor so widely usable for a variety of things, that if we build into building blocks that built around T-Edit, I mean we could do a lot of things with that.

Designer 1: That suggests that the application.....

Designer 3: So that's not an application, that sort of a sub-set...

Designer 1: That suggests that the application, that you may in fact want to look for subjects, or if you wanted to do spreadsheets and distribute them...

Designer 4: Are we interested in ways of improving our ability to gather T-Edit, spreadsheet and that sort of thing or is that not the kind of thing we're interested in, inter-process communication, or simply into inter-site?

Designer 3: I would say, I would think, using something likeT-Edit as a medium, we can generally use that to communicate xxxx'.

Designer 4: If I can just, I am still assuming this is the thing we give to Alex,

Designer 3: Right,

Designer 4: Right, I just had a couple of comments. One was the, one get into the second option here, let me make a number of points, I felt that these were fairly important issues to bring out and it might be helpful to make a list just as a matter of formatting, but,

Designer 2: I didn't actually see this as the final thing, because one thing that I wasn't very happy with was, in a way I would like to be able to make a list, what's that's towards, I'd like to have some preliminary specification of a core set of 'xxxx' that could be, we could go for, and I realise that at this stage,

Designer 3: At least a strong 'xxxx', that, to say this is the idea, and we may find a lot of primitives.....

Designer 2: Two or three lines of spec of various options, and maybe expand slightly on a short list of given communications protocols and to say and the reason is,

Designer 1: Are you thinking of breaking it up,

Designer 2: On top of page two,

Designer 4: On page two, I would have thought the paragraph could be reworded to say, the second option raises a number of issues. Number one, lock out so that one person can move on, keeping a record of confusion, controlling things like. I wasn't sure how you felt about that, but when you go back a little ways down six weeks into the project, you want to be able to say, well did you think about things such as that, are you making sure that so and so is...

Designer 2: Yea, I think you're right, one thing, are there other ways to extend this as well in terms of types and course specs for what looks like sensible modules, '....(not discernable) as far as Alex is concerned, it may not matter so much for a first pass going to people at [sic], hopefully there's enough here to give him a feel for what we're trying to do at least and to see....

Designer 4: The other thing I thought was that somewhere it should state what comes out at the end and it feels as if somehow we haven't talked about that here and it would be useful if the documented part where you could understand how one or other of these example programmes might be constructed out of them and thought about them and not just design individual pieces of code and how they do fit together.

Designer 3: These exact ...(not discernable)....

Designer 4: Yes, sort of notes on how you would construct a Talk programme, with these modules, how these would...

Designer 3: I thought the idea was these weren't the targets, these were possible things to 'xxxx'.

Designer 4: So you think these were the targets,

Designer 3: Perhaps yes, the idea was to maybe put a couple of scenarios which is a small, few lines on, one line assemble with a Toolkit,

Designer 2: I would hope if you get it right for example, you should be able to build something like Talk, that has maybe a few 'xxxx' in it whatever, a days programming or something like that...... take a couple of T-Edits plus the stuff we want and build something simply to demonstrate how to use the tools rather than something we actually want to do per se and it seems like a relatively straightforward exercise to be tackled. It may be possible to talk to one or two users if a different protocol anding is used..... or possibly that sort of exercise would illustrate how some of the different characteristics I've tried to get at here might be implemented and then later on we can do cleverer things, maybe customising rather more than T-Edits, or using different software altogether.

APPENDIX B

INTERVIEW DESIGN STUDIES

APPENDIX B - INTERVIEW DESIGN STUDIES

B.I Interview Schedule

a. Subjects' Design Background;
b. Project Background: Length of project, project team size;
c. Critical Incidents In Recent Projects;
- major steps followed in order of sequence.

B.2 Sample of Interview #1: Interview Notes

a. *Subjects Background:*
- computer engineer, BA, Computer Graphics, MA
- 3 years with the company

b. *Project Background:*
- sophisticated word processor
- project length: 1 1/2 years

c. *Critical Incidents in Projects:*

Critical Incident #1: Objective:
Define Features of WP system

1. Defined the features;
2. Product manager gave list of features;
3. Consulted reports;
4. Investigated other wp systems;
5. Looked at text books;
6. Got good foundation of knowledge; understood bad and good of previous products;

7. Product manager gave user interface requirements
8. Wrote a 3-4 page description of features;
9. Presented first cut, eg, keyboard.

Critical Incident #2: Objective:
Conceptual Model of The System

Different project: five teams involved, thirty team members. Responsibility for user interface only.

1. Research on user interface design, investigated Star system;
2. Organised the material gathered;
3. Conducted paper studies, e.g. mock-ups, scenarios;
4. Brainstormed and came up with an analogy; (UCM from PARC)
5. Product Manager named product, inconsistent with analogy;
6. Limitations of product drove the analogy.

Critical Incident #3: Objective:Hypenation -
Design An Esoteric Feature of WP System

1. Tried brainstorming (but needed right kind of people);
2. Worked through the ramifications;
3. Came up with solutions;
4. Looked at what was done in the past; good and bad, and looked at own products;
5. Came up with an overall framework for the a UCM for the user interface.

Critical Incident #4: Objective: Solve Critical Usability Probiems

1. Identify critical hypenation problems;
2. Used software to verify identified problems;
3. Used scenario tool to mock up screen;

4. Feedback from software developers; provided indications of problems, asked questions over and over;
5. They didn't answer the questions;
6. Concluded there was a lack of rules to design by; the rules were unclear;
7. Meaning of different constructs in the command language, e.g. cancel, close;
8. The frequency of occurrences confirmed problems.

Critical Incident #5: Objective:
Solve A Prompt Problem (6 week design)

1. Investigated the problem;
2. Recorded instances of problems;
3. Sat down with people who developed it;
4. The user interface software and the application software were where the problems lie, meant a lot of work;
5. Identified the problems;
6. Detailed the symptoms of the problem in a report;
7. Got examples and presented the case to management;
8. Made some massive changes;
9. Presented changes to VP and middle management, got OK to proceed;
10. Made changes and presented to VP;
11. Given the OK and the changes were implemented.

B.3 Partial Transcript From Audio Recording of An Interview (1 hour)

a. *Background*:
experimental psychology, BA, and Psychology, MA , Computing programming and System Analysis, with a speciality in user iInterface design.

b. <u>*Design Philosophy:*</u>

I don't really have that much of a design philosophy per se, but I do tend to try to do is what I call user centred design, center the design around the user and ah, I tend to look at the user as part of the system, part of the whole, in other words when we are designing a user interface, I am not just designing a user interface but I am designing one component in an overall system and the user is part of that system, and so I try to understand the user as much as I can in that segment. I try to find out his needs, in the same way you might with systems analysis, I try and work that same kind of approach with users. One thing that I have developed in the formal methodology worked out in the major projects I am working on here, we have been in constant contact with the user population that we are going to be targeting to, as a matter of fact we may have burnt them out.

<u>*Is that at your initiative or the companies?*</u>

No, its at my initiative.

<u>*What kind of contact do you have?*</u>

Ok, typically lets say we're talking about a typical design we're trying to work out. Well the first thing is to go and talk to the users to find out where the problems are obviously. Well anyway that is my first approach, talk to the users first, find out where some problem areas are, where we might focus our attention. Once we have gotten that I initially come up with a global conceptual design, again not much detail, we're sort of talking about global issues and what I typically do then is from the global design work out a sort of half way design that I can talk to users about. For instance, I might put together some screens that I can come to the user with and present the global concepts and then say here are a few screens that illustrate this, is this the kind of thing that may help you. And typically what we've done is to bring users in at this point, informal meetings, with coffee around and a projector to project the ideas, and what I found that at this point, typically about a quarter of the design gets thrown out. Yeah, and thats fair enough, its a first approach and no ones committed much to it. What I then do is that given the feedback I've gotten from them, the initial approach, I work out what I call cardboardware, a more detailed system essentially with bits and pieces of cardboard, just like another engineer might make a breadboard model. I actually go out and get a desk top for instance, screens, I'm not particularly interested in dimensions, exact measurements or anything, but I would get something that would represent the entire screen and then take bits and pieces of paper and cut out to represent windows and start laying them out and seeing the interplay between how these might work out. This is given that up to now we haven't had a UIMS that we can work with, that we can do some fast rapid prototyping. I get the feeling that the cardboard state would still be useful. It's a very cheap way of doing things. It's very, very fast, you don't have to do anything about anything it's very obvious, because the next stage I'm going to do is to go back to the users with this and get a little more detail and say okay is this the kind of thing you'd find useful.

If anything would characterise the philosophy it is recursive design, where the user might tend to be viewed not so much as participating actively, but as being consulted actively.

c. <u>*Critical Incidents*</u>

"What I'm looking for, are projects you've been involved in where there was a goal you really wanted to achieve in the project ,and it did not succeed for whatever reason, the reason is not particularly important. There are two criteria for choosing a project, one, there was a goal that was important for you to achieve and second you did not reach it. What I basically want to do, is to retrace the major steps that led up to your not being able to meet that goal. Lets begin with the goal ,and then retrace the critical incidents involved in meeting that goal."

<u>**Goal**</u>: What I wanted to see was an interactive tool for users to be able to be more or less guided in putting together a simulation and not have to worry about things like syntax and other stuff. And so I could guide them through it and all within this one tool could control this incredibly complex system. It was a big order.

<u>*What was the first thing you did towards meeting this goal?*</u>

<u>*The first thing*</u> I did was to talk to the users to find out what the problems were. The first critical stage was coming up with a formal proposal for the concepts, to sell the idea to management. It wasn't too difficult at all, it essentially sold itself.

<u>*The next critical step*</u> was actually putting together all the players that would be needed to accomplish the goal. Lets back track and let me give you a little background....... We were talking to about six different people and were getting conflicting information. No, not users, managers, we were talking to three or four different managers who kept telling us they wanted the [sic] to do something for them but they couldn't quite make up their minds what it should do. So out of that chaotic jumble, a focus did develop, they set up a group with a manager that turned out to be very strong, with very well defined ideas, a real sense of goal and purpose. And he created a whole new situation for us, that's why to a certain extent the ideas were so easy to sell, because we had such a strong focus with this guy.

<u>*The next critical step*</u> was when we put together the ideas for the concepts behind this thing, one of the problems we had was that technically the software development tools that we had didn't really allow us to do what we planned in the concepts. We had to put together a team that number one, could push the technology so that we could do what we wanted and two, actually to put together the user interface. And in doing that we had to get the cooperation of eight software people, and also people that were involved with developing the simulator itself. We're talking about 300 to 400 lines of

code, so its big. So a whole number of players needed to be involved here, around a dozen or so...... we needed someone in charge of the simulator, people who would conduct formal evaluations, separate from the developers, we needed a team of user interface people in the CAD area who would write the MMI.......and then base level people and then the software developers. We were lucky in that we had a very strong manager, that had a real vision of what he wanted to do, so to a certain extent he did a lot of that selling for us.

The next major step along the way, after we got the technology to work, something we thought we could use, we developed a prototype that we could run user evaluations on. Here is probably one of the first mistakes we made, objectively speaking. It turned out that we put a prototype together that had so much functionality in it, so much capability built into it, that I think some of the management started thinking this looked just like the tool, all we have to do is to tinker around a little bit and it would become a tool, which wasn't what we intended at all. But anyway, we put together a prototype that was very detailed, had more than it should have done and we conducted our first set of user evaluations. Coming out of these user evaluations, I was quite proud of how we did, I think we did it very professionally, and we got a lot of information.

Essentially what we did was we let the people use the system in their own work, which was quite a risky thing to do given the cost of it. We actually said, "go ahead use it, don't do anything too spectacular, try and see if you can use it." Let me put it into context, the cost of one of these simulators is $6,000 and so you blow one of those things and you blow $6,000. The cost of running this one simulator for the company is over $1 million a month and it can be much, much more than that. So we took quite a bit of a chance in letting people use it in their normal course of work. But we let them use it for about a month and during that month we had a series of meetings, to see what was wrong and right with it, from that we then decided here's what we were going to chuck out, what resulted was the end result of a prototype. And here's one of the big mistakes, we did not put in place a mechanism that would allow us to feedback the results of what we did back to the users, back to management. A report was written and I thought management knew what we were doing. I think I tended to over estimate our relationship with our users because we were talking to them so closely. Where we sort of failed was in feeding back to them the results, we never said, this is what you told us and this is what we're going to do about it.

The next critical step. which is a big problem area. The problem was that we flagged all of the problems, and we worked out steps for how to address them. The problem then became the same as the first one, we did not have a mechanism for feeding this back to the users and also to management and we perhaps did not have a strong enough mechanism to flag the importance of some of these problems. Essentially, what happened was we said ok, we know there are problems here, however, the general feedback they're giving us is very popular so lets go with it anyway. What we'll do is to pick out all the bugs that are there now and sort of straighten everything out, put the thing out as it is now, with the standard MMI we had developed, and in the next design release we will start rolling things out, we'll work out the technology and all of that stuff. We had it all in place and everything was hunky dory. We then implemented the final version, or what the users think is the final version, which in fact is just the preliminary MMI. It now goes out to the general population in North America right, in its present form, with no documentation (because the documentation people had been pulled out). So all of a sudden we start getting grumblings, from people that we just couldn't go and talk to, people in Nashville, people in California, who say, " what is this garbage". So all of a sudden there was a snowball effect, and so a negative effect began to build up among users, and they gave us the same sort of negative feedback we knew was there, and we had planned to correct. And then the people who had already seen it, but to whom we had not got information back to said, "what happened to all of the things I told you about." They had invested a lot of time and effort and nothing ever got back to them. So all of this started to steamroller, and since there was no documentation, people had no idea what to expect from it.

A major critical incident, was the sudden shift in management, our manager left and the new one was not committed to what we were doing and so did not offer any support at all in defending the MMI.

The next critical step, was there was a user meeting, where it was blasted by the users, it didn't do what they wanted. So what happened, was management just freaked out, just freaked because they had no idea, they thought everything was under control, we were telling them they were under control, and as far as we were concerned they were, we knew what the problems were, and we had mechanisms for correcting the problems. Then all of a sudden these things started blowing up in our face. What ends up happening, is that management freaks out, all hell broke loose, actually, we're in the middle of deciding where we're going to go now. The current state of the MMI is, it will be put in the next design release. It will be experimental, and there will be an option that you can turn it off, so in effect it might be completely dead.

The basic problem is information flow - getting information initially to us, and then getting information back to the users, and back to managemen, this is a problem. Decisions were being made without information from management and users.

APPENDIX C

DOCUMENTATION DESIGN STUDIES

APPENDIX C - <u>DOCUMENTATION DESIGN STUDIES</u>

C.1. Pro Forma Applied to Documentation Data

Primary Task:

Task Objective:

Task Orientation: *Technical* *User*

User References:

User Requirements:

Source of User Information:

Validity Check:

C.2. Excerpt From Documentation Data - 'Project Snapper'

Documentation.1

Subject: Processors and Software

A discussion of the possible computers and software for use in the [sic] station.

Processors

There are several factors that affect the choice of hardware. Since the station is to be on the network, there must be an ethernet connection available. Also, the frame grabber hardware is IBM PC compatible thus access to a PC bus is necessary. Standard "off-the-shelf" hardware is desired in order to make the system easier to replicate as well as repair. And of course, cost is always a factor.

[computer] -- The [computer] is the most powerful computer under consideration. It is also the most expensive. However, there is no interface to an IBM bus from the [computer] .

[computer] -- The [computer] er is cheaper than a [computer] and can talk to an IBM bus through a BusMaster interface. In the future, if these problems are eliminated, the [computer] would be a good alternative to the [computer] .

<u>IBM PC</u> -- The PC is the least powerful and least expensive of the alternatives. It is possible to connect the PC to the ethernet however, all the communications software would need to be written. It would be a very good choice of hardware however, software considerations discussed below eliminate it. Once the prototype station is complete,

the software could be converted to C on a PC if other scanning stations are being built.

Others --

Sotware

A major concern in choosing a software environment is the ease with which one can develop a prototype system. Of the software available for the hardware discussed above, [computer] is the best environment for prototyping. The various choices for the IBM PC all had similar drawbacks (eg a lack of support software, poor error handling, etc.). They would have required much more work than a [computer] environment which has been designed for prototype work. Also, since the work is being done in the imaging group at [sic], the local expertise is slanted heavily towards [computer] .

Conclusions

Having decided on [computer] as the most appropriate software environment, the hardware choice was limited to one of the [sic] machines. Balancing cost with availability, a [computer] , equipped with a BusMaster card and an IBM expansion chasis, was chosen.

Documentation.2

Subject: Technical Survey

1. Raster Graphics Board

The [sic] scanner station required a medium resolution frame grabber and buffer memory that could handle RGB signals from color video camera. It was preferable that the frame grabber capture at least 24 bits per pixel which would allow for 256 levels per color. A requirement for live scene capture also makes it necessary that images be captured in real time.

1.1 Survey of Video Processing Boards

A survey of video processing boards was conducted to determine which would be most suitable for this application. The following is a list of the companies with video boards that were included in the survey:

[list ommitted]

At the time of the survey none of the manufacturers other than [sic] made a board that was 24 bits deep per pixel and could capture a frame in 1/30 of a second. The [sic] board also incorporated both the video capture and display buffer on the same board, whereas the other manufacturers used two separate boards.

From the survey it was evident that the only video processing board that could be used in the scanner station is one of the [sic] boards. Although only 24 bits per pixel was required for true colour storage, the [sic] with 32 bits per pixel was selected. The extra eight bits allows for future extended processing. The board fits into a single IBM sophisticated image enchancement and graphics design package called [sic].

1.2 The Selected Board

The [sic] has a resolution of 512 bits by 480 bits (in interlaced mode) and uses 32 bits to define each pixel. Of the 32 bits 24 are used to specify the color (8 bits per red, green, and blue). The 25th bit is the overlay bit, and the remaining 7 bits permit 128 levels of blending for live video and stored images. The main component on the board is the display memory of 1024 K bytes. This memory is duel-ported and row-addressable so that you can access it with the minimum memory contention even when it is refreshing the screen. An application program can read and write the display memory like normal RAM. However, the display memory is addressed using 32K byte memory pages.

The [board] has four modes of operation: 1) live mode, 2) memory mode, 3) overlay mode, and 4) blend mode. The display bus multiplexor on the board is the switch that controls these modes. It is set by the control registers that are programmed by signals from the computer.

Besides the memory and the multiplexer that were already mentioned, the other major components on the board are the following: 1) Genlock circuit for deriving video timing from the sync signal, 2) analog to digital and digital to analog converters (ADCS and DACs) for translating signal between analog and digital reference frames, 3) registers (32) to control display and capture processes, 4) video timing controller for producing a standard NTSC video signal, 5) display bus consisting of 24 lines for transfering pixel data, 6) display memory shift register for loading an entire 512 pixel row during one memory access time, and finally 7) the video mixer that adds the analog outputs from the DACs to the live video in the blend mode.

Documentation.3

Subject: Requirements Analysis

Operational Characteristics: Overview

The I/O for the scanning station will consist of several major components -- camera, terminal, color display, control panel, lights, and slide illuminator. In a typical scenario for scanning an 8 x10 opaque, a user will log in on the terminal, 'frame' the picture using the front panel switches, and then save the image by pressing another front panel switch. The lighting, camera height, a default file name will all be handled automatically with the ability for the user to override the defaults. When scanning other than an opaque the scenario may vary slightly.

[computer]

The [computer] is the main controller for the scanning station. The software running on it is constucted according to the architecture shown in Figure 1. (omitted) When the main power switch on the front panel is turned on, the [computer] is powered on. At this point the [computer] should boot itself and start running the controller code. Next the lab controller is initialised, and then the front panel settings must be set up to the following defaults:

Station in idle

Input type = opaque

Screen action = live

The camera should also be positioned at the 1 meter level and zoomed to frame an 8 x 10 original. The camera, color display and all the lights should be left powered off. The VDU should be powered up and a login request message should be displayed.

When a user logs in, the power should be turned on to the camera, the color display and the lights. Logging in consists of entering a user name and password on the VDU. After a user has successfully logged in, the 'active' LED should be lit on the front panel. If there is no activity for 27.85 minutes, the station should log the user off and go into idle.

After a user has logged in, a file name should be proposed. First the user's profile should be checked for a list of file paths. If one is found, then the first entry in the list should be the path proposed. If there is no user profile entry, then the station log file should be checked for a file name from a previous session. If this is a new user with no log entry then a path should be 'guessed at' and checked for 'reasonableness'. If the proposed file name is not acceptable to the user, a new one may be entered from the keyboard.

After a proposed file name has been determined, the path needs to be checked for accessibility, disk space, file name duplication, and server response. If any problems are encountered, a message should be displayed on the VDU accompanied by a Audio Error Response Acknowledgement (a beep).

3. Excerpt From Documentation Data - Project 'Ozone"

Documentation.1

Subject: 'Ozone' Semantics

. . . The first was that it seemed very intuitive and appealing to concentrate on the analysis of individual tasks, and the second was that I found having to consider explicitly the document states within a task to be a hindrance rather than a help. The second of these impressions is, I think, relatively unimportant when compared to the first.

One reason why I was particularly attracted to the notion of task definitions is that it seems totally consistent with our immediate interest in individuals and offices as opposed to large organisations and entire companies. Another reason is that descriptions of the overall information flow can be generated automatically from a set of task descriptions. The third reason is that I believe potential users will find the construction of individual descriptions far more acceptable and easier than the construction of entire state transition diagrams for documents, which require the task descriptions anyway,

What I'm suggesting is a concentration with respect to the descriptive aspects of 'Ozone', on the individual and what he/she does rather than on the document and what happens to it.

There follows, in the spirit of your memo, an incomplete example of what a task description might look like: bold face is used for task names, names of individuals, names of documents, and state names; italic face is used for global procedures, connectives, etc.; small caps are used for locally defined procedures.

> **Fare limit computation** *as done* by **Fares specialist**
> *Receive the* **TA ready for fare computation,** *from* **Traveller**
> *Receive the* **TCO, needing signature,** *from* **Traveller**
>
> CHECK **TCO** *using* **TA**
>   *Show* **TCO** *and* **TA**
>   *Unless OK return* **TCO** *and* **TA**
> *Sign* **TCO**
> COMPUTE FARE LIMIT on **TA** *using* **TCO**
>   .....
>   .....

Send Copy of **TA, ready for planning use,** *to* **Budget department**

Send **TCO, for travel agency,** *to* **Mail room**

File **TA**

Documentation.2

Subject: The 'Ozone' Filing System

Filing is an essential part of office activity. The documents that arrive on a person's desk must either be filed or sent elsewhere; otherwise chaos results. People in offices therefore create spaces for filing documents; these spaces are generally structured so that documents that have been filed away can later be retrieved. We call these spaces *filing systems*, because their arrangement is often quite systematic.

This memo discusses the design of a filing system for 'Ozone'. The filing system is intended to provide a convenient means of long-term on-line storage of documents. The system will support simple file-searching and retrieval, and will allow the users of 'Ozone' to create their own multi-level file structures.

Most of the ideas for this filing system have emerged since starting work on the design of 'Ozone', and as a result the filing system design shows the influence of the procedure-driven forms-oriented aspects of 'Ozone'. I have also been heavily influenced by existing systems at [sic] and their file facilities, and by some studies of filing activity conducted by members of our group.

The Filing System Design

The 'Ozone' filing system contains documents, or *forms* as we call them in 'Ozone'. These forms are collected together in *files*: each file is a completely independent collection of forms. Thus the system might include a Travel File containing Travel Advance Requests and Expense Reports, and a Correspondence File containing memos and letters. Some files are shared by several people, while others are personal files, accessible to only one individual.

The user accesses the forms within a file by means of an *index*. Each index is essentially a tabular arrangement of *labels*, each label giving access to a form or to another index. An index has the following appearance when viewed on the screen: [diagram omitted]

A typical label is shown above. The field on the right is the *sort field* containing a *key* that determines where the label goes in the index. If the sort field is left blank, the date of creation of the label is used instead. To the left of this field is a *stock type field* containing a description of the type of entity addressed by the label (in the above case, an Expense Report).

The left-hand field of each label is an *active field:* the user may point to it with the mouse to invoke the action it specifies. All of the active fields shown above and on the previous page contain the word *Pull*, meaning that the user can pull out the form or index addressed by the label, and display it in its own window on the screen. This is the only action the user can perform on labels within an index. To expunge or destroy a labeled item, we simply pull it out and don't put it back.

Labels are also used to insert things in files, and to find things. To insert a form in a file, the user creates a blank label of the appropriate kind for this combination of form and file, and fills it in. The active field user. For example, the **Locate** statement will create a label of the right kind, fill it in (in the above example, using the Travel Advance), and locate the first matching label in the file. The label will be filled in either manually or by means of an edit sequence set up by the user on a previous occasion. The file statement will similarly create a new label, fill it in and insert it in the file index. In general, these filing operations will be carried out by means of a mixture of label editing and invocation of the*Pull*, *Insert* and *Locate* commands described earlier.

Properties of Labels and Indexes

A label is essentially very similar to an entry in a tabular form, and 'Ozone' in fact treats labels in much the same way it treats tabular form entries. A blank label consists of a number of fields: an active field on the left, then a stock type field to indicate the type of entity addressed, then a couple of general-purpose fields, and a sort field on the right. In reality, the label contains several other fields, generally invisible to the user: these contain information about when the label was created, by whom, and the present state of the thing it addresses. [Diagram omitted]

Labels are created when the user indicates the wish to file a particular item in a particular index; at that time the system fills in several fields of the label, including the stock type field, the creation date, and the name of the creator. The active field is filled with the word *Insert*: [Diagram omitted]

The user can now insert the label in the selected index, or he can fill in additional fields. Anything he puts in the sort field will be used upon insertion to determine where to put the label. Labels with empty sort fields are placed at the end of the index, and are sorted by age. The contents of all other fields are ignored during insertion. The two general-purpose fields are provided so that the user can fill them in of the label now contains the word *insert*, to which the user points to invoke insertion. [diagram omitted)

To find a particular label in a file, the user creates a blank label and fills in enough information to describe the label he is looking for. This label, since it has not yet been linked to any form, contains in its active field the word *Locate*: [Diagram omitted]

When the user points to this word, the first matching label in the file is found and highlighted; the user can now point to the *Pull* of this label to examine the addressed item. Thus the user's set of filing operations on an existing set of indexes consist of *Pull*, *Insert* and *Locate*. The *Pull* command can be applied only to a label already in an index; *Insert* can be applied only to a new label attached to a document; and *Locate* can be applied only to a new, unattached label.

Filing by Procedure

I anticipate that much of the filing performed with the aid of 'Ozone' will be carried out by means of procedures. The 'Ozone' language provides several statements for filing purposes, including the ones shown in the following examples:

Locate Expense Report in Employee file matching Travel Advance;

Pull Expense Report;

File Expense Report in Budget File;

On each Expense Report in Employee File do....

These statements will carry out the same filing operations described in the previous section, but with less intervention on the part of the with information about the addressed entity, or can add distinguishing marks to the label: [Diagram omitted]

An index is then simply a collectin of labels created in the manner just described. Every index also has a stock type, similar to the stock type of forms.