HUMAN AND ORGANISATIONAL ASPECTS OF NEW TECHNOLOGY: DESIGN SUPERVISION AND COMPUTER-AIDED DESIGN/DRAUGHTING

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy.

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This thesis is dedicated to the memory of

Vicki Susan Pratt

"Those who bring sunshine to the lives of others, cannot keep it from themselves"

ABSTRACT

This thesis examines the interaction between design supervision and new technology with reference to an empirical study of Computer-Aided Design/ Draughting (CAD) in mechanical engineering. Unlike many other studies of new technology in the industrial workplace, this research focused on organisations after the initial implementation phase of CAD, ie. when the system could be said to be "up and running".

The supervisory role has already been recognised as an important "link" between management and the rest of the workforce, occupying a unique position with direct responsibility for the daily functioning of the organisation. This study looks at the problems, opportunities and changes faced by individuals in the supervisory role after the implementation of a relatively "sophisticated" computerised technology, CAD.

The main body of empirical research consisted of an in-depth interview survey carried out in five engineering companies (four in the shipbuilding industry and one in machine tool design). The interviews elicited the perceptions of individuals within the design/draughting and computer support section, with respect to both the organisation in general, and interactions with the CAD system. A mixture of Grounded Theory and Cognitive Mapping was used to structure the data, from which seven major issues emerged. Structuration Theory is used to gain greater insight into the organisational processes occurring in the companies studied.

It was found that individual reactions to new technology varied considerably, but the expectation, expressed by some management, that any problems encountered during the implementation process would disappear was not fulfilled. Instead, problems became instantiated through the use of the technology and change continued to occur in an evolutionary and very loosely organised manner.

The analysis identified the influence of communication within the company on the perceived attitude of the company "culture" towards the CAD system. This was also affected by the degree of management "leadership", which influenced the amount of CAD related training provided for design supervisors. Together with the benefits/problems attributable to the CAD system, these factors contribute to the design supervisor's perception of their role, after the CAD system has been implemented. While the future for the design supervisor role generally remains dubious, one possible organisational structure is presented that attempts to combat the particular problem of conflict between the roles of design supervisors and CAD support management.

The empirical cases showed many examples of inappropriate social and technological systems and it is argued that these need to be re-stabilised through some sort of "socio-technological systems balancing". It is argued that the physical layout of the CAD system and the lack of CAD specific training were both important factors in individual attitudes towards the CAD system, in particular in the perceptions held by design supervisors. While acknowledging that the manner of implementation of a new technology is important, it is argued that other factors later in the "life" of the CAD system are also important. Therefore a longer-term perspective of system implementation including the implementation and institutionalised use of new technology needs to be adopted. Finally, it is argued that examining the data in the light of Structuration Theory can provide insight into the complicated picture of interactions surrounding the use of CAD systems, by design/draughting supervisors and their staff.

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AEC	(Architectural/Engineering/Construction)
AEU	(Amalgamated Engineers Union)
AMT	(Advanced Manufacturing Technology)
CAD	(Computer-Aided Design/Draughting)
CADCAM	(Computer-Aided Design/Draughting and Computer-Aided Manufacturing)
CAE	(Computer-Aided Engineering)
CAM	(Computer-Aided Manufacturing)
CAP	(Computer-Aided Production)
CAPP	(Computer-Aided Process Planning)
CIM	(Computer-Integrated Manufacturing)
CNC	(Computer Numerical Control)
CRT	(Cathode Ray Tube)
CSCW	(Computer Supported Cooperative Work)
EDA	(Electronics Data Analysis)
EMA	(Engineering Management Association)
ESPRIT	(European Strategic Programme for Research in Information Technology)
FMC	(Flexible Manufacturing Cell)
FMS	(Flexible Manufacturing System)
IC	(Integrated Circuit)
ISDN	(Integrated Services Digital Network)
IT	(Information Technology)
JIT	(Just-In-Time)
MAP	(Microprocessors Applications Project)
MIT	(Massachusetts Institute of Technology)
MCAE	(Mechanical Computer-Aided Engineering)
MRP II	(Manufacturing Resources Planning II)
MSF	(Manufacturing, Science, Finance Union)
NC	(Numerical Control)
NTA	(New Technology Agreement)
PCB	(Printed Circuit Board)
TOP	(Total Operations Processing System)
TU	(Trade Unions)
UDC	(User-Developer Communication)

CHAPTER 1
INTRODUCTION

1.1 The Research Problem

This thesis examines the role of the design supervisor[1] in the design process, post-implementation of a Computer-Aided Design/Draughting (CAD) system.

As companies in the UK fight to maintain their market share or find some way to gain an important "competitive edge", the significance of the design process has been increasingly recognised. This can be seen in the increased importance of quality and flexibility in design and drawing and the higher profile of concepts, such as design for production and shorter product lead times. Coupled with this has been the pervasive introduction of computer (often called "new") technology into all aspects of industrial life. Therefore in a company's attempt to improve further the design process, computerised design tools have been developed and introduced into design and drawing offices.

A CAD (Computer-Aided Design/Draughting) system can be defined as the use of purpose-designed computer software (on a variety of hardware platforms) to assist in any of the phases of the design process (pre-design, conceptual, embodiment, detail and post-design release). The most common view of CAD is as an interactive graphics system which replaces the traditional instruments of design, ie. pencil, paper, drawing board and calculator. CAD system vendors have claimed that their systems can benefit organisations in many ways, such as large productivity increases, huge improvements in design innovation, etc.

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[1] Although it is recognised that women are employed (with equal rights) in all areas of industry today, most design staff and the management hierarchy tend to be male. Therefore the generic term "he" will be used when referring to individuals. Hopefully in the future more literature will be able to contain the terms he and she without need for comment.

However these claims have not been reflected in the reported experiences of companies using CAD systems. Gooding's (1992) article, which reports on experiences of using CAD, says (of the design services manager):

> "His words of warning to others researching CAD is to be wary of salespeople's claims, especially regarding performance. Expectations can be too high..."

A 1988 survey of British companies found that while 51% say they have 2D draughting capability and 26% claim to have 2½D wireframe systems, only 17% say they have solid modelling software. In addition less than half the companies say they have a strategy for implementing CAD technology (Industrial Computing, 1988).

More recent studies have shown that when linked to manufacturing (as in Computer-Aided Design and Computer-Aided Manufacturing) CAD technology typically accounts for 8-10% of the total manufacturing investment (Clarke 1991). The pace at which CADCAM technology is being adopted appears to be steadily increasing with recent Dataquest figures showing that the world CADCAM market grew by 10% in 1991. Furthermore, it is expected to show a compound annual growth rate of 12% by 1995 (Baxter 1992). These growth rates have led the Financial Times to speculate:

> "The importance of CADCAM, and in particular 3D solid modelling, to concurrent engineering - the team approach to cutting product development times and improving quality - makes it virtually a necessity in mechanical engineering." (Baxter 1992)

Comparisons have often been drawn between new technology introduced into the design process and apparently similar new technology introduced elsewhere in an organisation. Where the introduction of new technology into manufacturing alone can be an evolutionary and relatively slow process, the introduction of a CAD system is a radical injection of new technology into a process which has previously seen very little technology more complicated than pencil, ruler, paper and calculator. The result has been that much has been written about the problems of CAD system implementation, from the contrived information used to persuade top management to approve a budget to the unreasonable and unknowledgeable expectations of the same top management about the capabilities and limitations of any particular CAD system (including "folk tales" of catastrophic experiences).

Trying to run the paper and pencil (old) system and the CAD (new) system simultaneously in itself causes problems. The physical environments suited to each are incompatible eg. natural light and fresh air for the paper and pencil system, whereas subdued light and air-conditioning are beneficial with the CAD system. Further, there is the contrast between the static nature of the paper and pencil system and the dynamic race of computer systems, with exponential rates of improvement.

One of the various factors identified as the cause of unsuccessful implementation of CAD systems was the failure to restructure and redesign the existing organisation while the CAD system was being introduced (Schaffitzel and Kersten 1985). Other writers have echoed this idea, that in the implementation process, managers over-concentrate on the technical aspects while overlooking the human and organisational aspects (these ideas will be explored further in chapter 2).

The decision by top management to invest in a new technology has also been the subject of much debate, whether there is really an "innovate or bust" environment or whether it can be used as a tool with which management can gain greater control over the labour force (see section 2.2 for a discussion of the various perspectives involved in the introduction of new technology). At the other end of the spectrum, while some of the workforce are worried about de-skilling, those who are trained to use the computer systems can see the benefits new computer skills imply in the labour market, or in helping to secure their position within the company.

The supervisory system bridges the gap between management and workforce and, as such, has been conceptualised as being "in the middle" of the two. In this capacity the supervisory system can be classed as a boundary object, attempting to satisfy the competing pressures originating from both above and below in the organisational structure. When the CAD system is added (sometimes the CAD support personnel are merely "tacked" onto the side of the organisational structure, as can be seen in an organisation chart) the picture becomes even more complex. Dawson (1986) has argued that studies of the effects of computerisation on the roles of supervisors and the function of supervision is hampered by the lack of an appropriate theoretical framework.

While this thesis recognises the complexity involved in Dawson's redefinition of supervisory functions, the focus of the study is on the recognised or frequently titled "first-line supervisor", who can be identified according to tasks carried out. Thus, the concept of supervision can be seen to be much more complex than has been previously recognised. This supervisory role has generally attracted attention as one which is pivotal and therefore important, but also potentially unstable.

Although research on the introduction of new technology with a supervisory focus has been reported, few studies have then proceeded to in-depth study of this topic. Out of those studies which have focused on new technology there has been some slight mention of problems encountered by design supervisors and their managers during and after the introduction of a CAD system.

This project looks specifically at this issue of design supervisors and Computer-Aided Design/Draughting. It consists of empirical research into design function (incorporating both design and drawing offices, if classed separately) supervisors' own perceptions of CAD and changes that might have occurred. Whereas much previous research has focused on the implementation process, this project is concerned with CAD systems post-implementation, ie. those which have been running for at least 18 months.

1.2 The Research Framework

1.2.1 The Research Area

The research area encompasses the *human* and *organisational* aspects of the design function and its interactions with other departments in the company, post-implementation of a Computer-Aided Design/Draughting (CAD) system. This research pays particular attention to the role of the first-line supervisor **within** the design function to highlight changes that could, and possibly should, occur.

1.2.2 Research Aims

The primary aim of this research is to examine the role and perceptions of supervisors in the design function of organisations running CAD systems. A comprehensive body of information in this area would assist organisations in the implementation and operation of CAD systems. Finally, this research aims to evaluate the empirical evidence in light of modern theoretical frameworks. The latter may also provide further useful insights and greater understanding of the interactions between people and new technology.

In order to achieve these aims the research needs to:

1) Investigate and record the general state of CAD usage in engineering companies.

2) Develop a working definition of the design function supervisor and CAD manager.

3) Provide background to the empirical research by recording the environment in which the companies were operating at the time of the introduction of their CAD systems.

4) Record and evaluate the perceptions of people working in the design function.

1.2.3 Who Will Benefit From The Research and Why?

People who might benefit from this research include:

- The manager of the design function by providing a guide to the organisational problems that might occur (post CAD-implementation) and providing possible routes to solve them.

- Senior managers by sensitising them to the very "real" issues which arise with the introduction of new technology.

- The individuals within the design function who experience stress due to the introduction of CAD and are unable to cope with this.

- The vendors of CAD systems who acknowledge the need to ensure that any individual using their system gets the best possible quality of working life.

- Academic/industrial training institutes which wish to provide services in this area.

1.3 Research Questions

1) What activities define the role of the design function supervisor?

2) Are training needs for design function supervisors, where CAD is present, recognised? How is CAD training for design function supervisors carried out at present? Are there specific programmes; if so, what are the details?

3) What benefits might be usefully gained from a company adopting a "structured" as opposed to an "unstructured" approach to training? What other forms of training are available and how might they be more effective?

4) What changes to his role are perceived by the design supervisor with the introduction of a CAD system?

5) What are the major stress factors experienced by design supervisors?

6) As a secondary user of CAD, would design function supervisors experience any change in attitude towards the system as a result of this research (or from any other factors)?

7) What perceptions of the human-computer interface are held by design supervisors?

8) What activities define the role of the CAD manager?

9) What interactions take place between design function supervisors and CAD managers?

10) What effects does the implementation of a CAD system have on designers, draughtsmen and design supervisors' perceptions of design and top management?

11) What changes (both formal and informal) might be seen after the implementation of a CAD system?

12) What can be learned from the change process?

1.4 Research Methodology

The research uses a combination of quantitative and qualitative techniques to frame the research questions. Initially a comprehensive literature search of relevant and up-to-date information was conducted. This has been an ongoing process throughout the period of the project. The literature search also serves to highlight other relevant researchers working in this field.

The next stage of the research was to highlight the parameters of the design organisation relevant to the project. This was accomplished by a series of preliminary open-ended interviews with CAD managers (or computing managers with special responsibility for CAD) in 10 companies in the UK.

Following the information collected in the interviews, two short questionnaires were constructed. The objective was to investigate further the components of the role of the **design supervisor** and the role of the **CAD manager**. Results of the first two elements of the research (in particular the degree of role conflict between the first-line supervisor and CAD manager) were considered significant and were subsequently published in a refereed journal (Brooks and Wells 1989) and referred to in a more recent journal article (Robertson and Allen 1992).

Building on the previous stages of the project, the main part of the research took the form of in-depth semi-structured interviews within the design and drawing offices of five relatively large companies. These interviews were conducted with individuals associated with three different roles: CAD managers (5 CAD managers and 3 CAD support team members), design/draughting supervisors (5 in design and 7 in drawing offices) and designers/draughtsmen (5 designers and 6 draughtsmen).

Each interview recorded the background and general degree of training of an individual. This was followed by an investigation of their job role and specific aspects of job satisfaction. Finally the interview turned to the CAD facilities available, the amount of CAD training received and the extent of their CAD system usage. Throughout the interview, the interviewee was asked for their own perceptions of various factors relating to the CAD system. A selection of results from all three sections of the research were compiled and presented at an international conference in the USA (Brooks and Wells 1990).

1.5 Thesis Structure

A review of the literature is presented in chapter 2 and provides the context and environment in which the research was undertaken. Further to this, specific theoretical frameworks supporting the research and used in the analysis are presented in chapter 3. A number of key issues, raised in the literature review, are used to inform both the design of the methodology (chapter 4) and the analyses (chapters 5 and 6). An analytical and conceptual framework is adopted to provide a clear understanding of the complexities inherent when examining the design function situated within a large organisation. Building on the literature review, an interview programme and short questionnaire programme were conducted (chapter 5) to provide a basis for the case study investigation. Case studies were then carried out, at three different levels, within five companies (chapter 6). The data is then subjected to a Grounded Theory style analysis (chapter 7) to highlight the emergent properties of the studies. A Structuration Theory framework is also used to examine the data and provide further insight into the complicated picture of interactions surrounding the organisational use of CAD systems (chapter 8). This thesis finishes with a return visit to the research questions (section 1.3), to see what answers can be provided, and a summary of the key issues which have arisen.

CHAPTER 2
A REVIEW OF THE LITERATURE

2.1 Introduction

The background literature is an important factor in establishing the environment which forms the initial project basis. Through a policy of continuous update the literature review also plays a significant role in guiding the project.

To provide a structure for this literature review the project background area can be split into two major sections. One area is the technical factors of new technologies. Within this the focus is on Computer-Aided Design (CAD) systems. The other area is the human and organisational factors. Within this the focus is on the role of the design function supervisor (otherwise known as the first-line supervisor). Although it is recognised that these divisions are arbitrary (in that they would not have much relevance in the workplace), they do provide a useful framework into which the relevant literature can be placed. The literature framework is presented below,

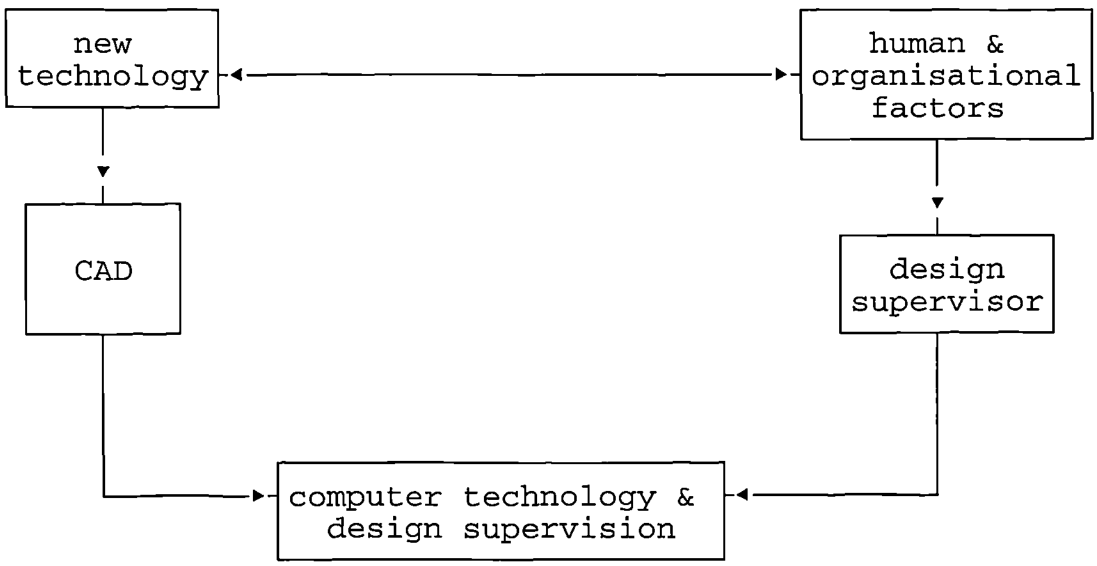

Figure 2.1 **Literature Review Framework**

The first section examines the general impact of new technology and relevant human and organisational factors. This is followed by an examination of the wider literature relating to the role of the supervisor, job design and redesign and a classic set of models of the supervisor. The next section then explores the wealth of literature concerned with CAD systems, following an outline framework based roughly on the "lifecycle" of a technological system. This chapter closes by combining the literature findings to examine specific references to the supervisor and CAD systems.

While much of the literature concentrates on the "hard" side of the organisation (such as the technology itself) it is important to recognise that this alone will not improve competitive edge. In approaches such as "concurrent engineering", competitive advantage is achieved through appropriate changes in the organisation which take account of both "hard" and "soft" factors (where soft factors refers to the many Japanese techniques imported into the US and Europe, which focus on people in the organisation).

2.2 New Technology

The term "new technology" could conceivably be applied to any technology before it has become commonly accepted in society. In recent years the latest developments in computing and information technologies have been considered far-reaching and innovative enough to be considered under the title "new technology" (McLoughlin and Clark 1988). Some writers claim we are in the middle of a "technological revolution" (Forester 1985), or at least a "revolution in the organisation of work" attributable to technology (Blackler and Brown 1986, based on their expectation that plummeting prices and increased speed of operation of the hardware, combined with the expansion of networking facilities and increasingly more sophisticated software, would lead to further developments in applications and increased adoption of technology). Although bordering on hyperbole, this does serve to illustrate the pervasive and far-reaching nature of these computing and information technologies and the significant work and organisational changes which might accompany them.

One approach to answer the question of how these technologies are "new", is the idea that they have the potential to combine conventional computing capabilities with a greatly increased range of applications. Thus, the newness of the technology lies in its information handling and work process control abilities. The principal information handling capabilities of computing and information technologies can be divided into four categories (Buchanan and Boddy 1983):

Information capture

- gather, collect, monitor, detect and measure information. This can be either an **active** process accomplished through automatic electronic sensors and process controls or a more **passive** process where a human operator is still required to input information to a machine.

Information storage

- automated conversion of numerical and textual information into binary digital form for retention in electronic memory; also allows for retrieval of required information.

Information manipulation

- automated organisation and analysis of stored information; particularly suited to repetitive tasks.

Information distribution

- automated transmission and display of information on visual display units or paper; exchange of information between machines or computer systems, possibly as feedback or as progress regulation.

With these capabilities the new technologies have the key capacity to automate the control of work processes (Braverman 1974). This control could be exerted in a variety of ways including:

- a pre-programmed set of instructions executed by a computer system to control the machinery (a passive scenario);

- automated use of feedback information to initiate corrective action by a computer control system (an active but automated scenario);

- the operator uses feedback information from the machine to raise the effectiveness (ie. enhance performance) of the equipment or process (an active scenario, involving a human agent).

New information and computing technologies can also have a number of organisational effects, including:

- the provision of greater accessibility to information over a wider physical area and wider range of organisational levels;

- increased speed of information exchange between members of the organisation;

- creation of new possibilities for the display of performance information at central points.

It is these control functions and heightened visibility of work operations (including such practices as reductions in "figure adjusting" in the reporting of performance information) which have led to these technologies being referred to as "control automation" (McLoughlin and Clark 1988). However it is important to recognise that, at present, none of these new technologies totally eliminate the need for human intervention (particularly in the interface between the device and the outside world). This is essential for a proper understanding of the implications of new technologies. A more realistic definition for automation that has been proposed is "more automatic than previously existed" when applying it to new stages in technological change (Bright 1958; quoted by Buchanan and Boddy 1983, McLoughlin and Clark 1987).

However this still does not fully explain the importance that has been attached to the new computing and information technologies. The most important factor in the recent history of new technologies was probably the development, in 1971, of the microprocessor or "silicon chip" and its subsequent low cost mass production. The cheap mass production of the silicon chip has allowed computing and information technologies to extend radically the range of their applications, both as products and in the production process itself. This spread of microelectronic-based innovations has, in the UK, been supported by various government initiatives, eg. in 1978 the Department of Industry initiated a Microprocessors Applications Project (MAP) to promote awareness and provide some financial incentives for adoption of this new technology (Bell 1981, provides an in-depth review of the British Government attitude towards new technology). The rationale behind this is the belief that the introduction of microelectronic technology enables major economic advantages, and that UK industry was not adopting this rapidly enough compared to its competitors (ACARD 1979).

One argument for the view that microelectronics could generate an economic turnaround is shown in the identification of "long waves" of economic development (Kondratiev 1935). Kondratiev was the first to observe that it took the world economy about 50 years to move through a boom-to-slump-to-boom cycle (figure 2.2). Although inventions continually occur they are only transformed into successful innovations at certain historical points. These innovation booms seem to coincide with the economic slump in the Kondratiev cycles and suggest a related innovation cycle (Freeman et al. 1982). According to long-wave theory, the mid-

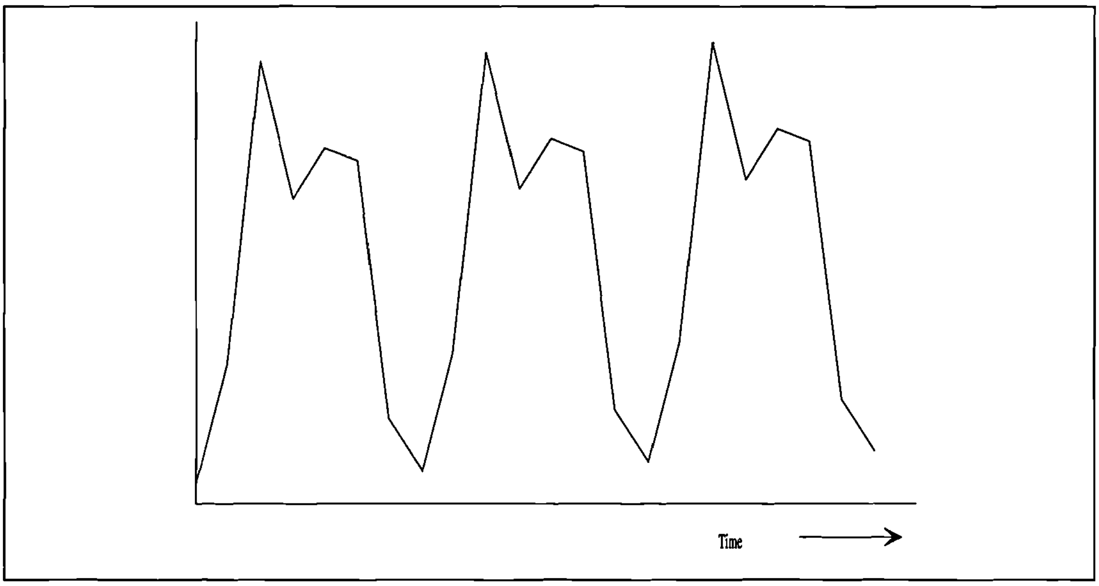

Figure 2.2 **An Idealised Kondratiev Wave**

1980's was the bottom of an economic cycle, which was reflected in a worldwide economic slump. However this is also an upturn point leading to another economic boom (occurring sometime after 2000, according to the extrapolation of the curve). This has led economists and innovation theorists to attempt to identify which set of innovations will stimulate this upturn. Naturally the microelectronics technology is identified as one of the major candidates which will signify the next Kondratiev "upturn" (Kaplinsky 1984, Freeman 1986, and De Greene 1988).

One of the problems with looking at technology from the perspective of "long-wave" theory is the assumption that the advance of technology is inevitable with inescapable "impacts" on society and work organisations. Empirical analysis of organisational impacts of new technology show that this is not the case (McLoughlin and Clark 1988). There is a wide range of design options available in applications of new technologies, in addition to the nature of the change process which is adopted within an organisation. An example of this is:

> "the information-handling possibilities of the technology can be exploited to create jobs that are tightly prescribed with performances closely monitored or to design jobs requiring a high level of

> involvement by individual employees. Similarly, an organisation's structure may be arranged to exploit the capabilities of the technology to engage in tight central control or it can be used to support efforts to achieve widespread participation by employees in strategic decision making." (Blackler and Brown 1986).

Much has been written about "Strategic Choice" in management literature. It originated with Child (1972) who shows that political decisions by organisational actors rather than technical, commercial or capitalist imperatives, result in particular forms of work and organisation. Therefore, choices made by a power-holding group of managers direct the forms of technology, work and control seen within an organisation. These strategic choices may then be modified by others within the organisation, especially those responsible for implementing decisions (eg. middle managers), or by part of the workforce acting in a collective manner.

2.2.1 Implementation

The implementation of a new technology can itself be seen as a broad change process, which Rhodes and Wield (1985) divide into four phases:

i) Initiation - initial stimuli for technical change and the many elements of the decision-forming process.

ii) Planning - planning the introduction of the new technology.

iii) Application - potentially highly complex and highly uncertain phase, including: acquisition of new equipment, consumables etc; undertaking associated construction work; equipment installation; consultation; cost control; commissioning and handover.

iv) Consolidation - full completion of the many elements of a project plus generation of the post-application phase.

The four phases of implementation are closely related. In one sense they are related linearly, with one stage neatly following the other, and in another sense as an interactive and continuous process where only the emphasis changes and not the underlying process itself. The latter is partly due to three sets of factors which provide continuity for the interaction:

i) Work force issues - a broad range of issues relevant to all levels of the organisation eg. proposals and dialogue concerned with preparing the workforce for, and supporting them during the introduction of the new technology.

ii) Technical and operational issues - from choices involved in the initial selection of equipment to decisions about methods of utilisation during the post-handover stage.

iii) Broad organisational and resource issues - the choices involved in regulating the overall approach to change, particularly in financial investment/return terms.

Further, Rhodes and Wield specify the implementation process as existing within an environment which has two main dimensions: an **internal** dimension which comprises the individual firm's circumstances, eg. the degree of organisational differentiation, the degree of integration, the characteristics of individuals, and an **external** dimension which includes the characteristics of the product market, the technological context and the broad political context. Problems occur when *either* dimension is not taken into account.

Criticism of much of the recent literature on new technology appears to focus on the events leading up to the first commercial application of an innovation (Gold 1980, Wilkinson 1983). This ignores any subsequent innovative attempts at improvements or adaptation. Therefore an approach which accepts the wider environment of implementation is important and needed:

> "its importance [the approach to new technology] lies in fastening or limiting the extent of innovativeness within organisations." (Rhodes and Wield 1985)

This chapter now turns to examine the literature concerning the other main area for this thesis, that of the supervisory role.

2.3 Supervisors

2.3.1 Job Roles

Job design or redesign is a powerful tool which can be used to match the objectives of operative level workers and management, while at the same time making the tasks involved more acceptable to those performing them. In order to do this the job must first be analysed and categorised according to some standardised criteria so that the redesign can be controlled and effective in achieving its own objectives.

However there are thrcc important points to keep in mind. The first is resistance to change. Although job redesign may be in the interest of the individual, there may still be resistance to change. This is because there is more to a job than its basic dimensions: this includes a set of properties and attributes (eg. rights and benefits, status, career structure) which exist in equilibrium with the requirements of management. Therefore, it is the potential threat to the stability of this equilibrium which causes individuals to resist job redesign.

The second is the case of work structuring. In some cases where very specific tasks can be linked to specific individuals then individual job redesign is appropriate. In the majority of cases, however, this is not possible. A group of people each with their own job perform activities which together comprise a task. Therefore, the appropriate focus is on the work group and its task. The focus on the work group is often called "work structuring". Further than this any restructuring of the group must include some consideration of each task being part of the wider workflow system and the overall effect that any particular job redesign might have (eg. ripple, domino).

The third point considers the question of generalisation. There is an enormous variety of jobs and the same title often refers to a different set of activities in each organisation. Therefore job redesign needs to be sensitive to the context in which the job is set. This wide variety shows that there are always a set of alternatives in any job redesign. Therefore the "design of job and work do not follow automatically from the context; a conscious analysis and decision are involved" (Child 1984).

A basic definition for a job is the successful performance of a number of activities which together form a task (Child 1984).

Job design can be split into two main interactive dimensions,

i) specialisation - how limited the range of activities in the job is; and

ii) discretion - which resources to use or which methods to apply.

If specialisation is high the job is more precise, more controlled and a formal job definition is easier to generate. With low specialisation the individual has more discretion over what methods to use and can contribute to additional tasks if they think it is needed. High discretion indicates management control is either very loose or indirect, whereas low discretion is indicative of very tight management control (and possibly also a very high manager to employee relationship). The states of the two dimensions are summarised in figure 2.3.

Figure 2.3 **Examples of jobs with different levels of discretion and specialisation** (source: Child 1984)

		Discretion	
		High	Low
Specialisation	High	A specialist jobs	B routine "de-skilled" operative jobs
	Low	D higher managerial jobs	C *supervisors*, salesmen, assembly-line, utility men, junior reporters

NB. The categorisation of specialisation and discretion as high/low is crude and continuum exists for each dimension.

2.3.2 First-Line Supervisors

Hanson (1987) states that "most management clearly recognise that the first-line supervisor is a key job in their organisation", but do not find that the supervisor performance is satisfactory. Burnes (1987) echoes this sentiment saying "those who ignore the role of the supervisors are likely to be committing a grave error". The question, therefore, is how did supervisors arrive at this position of importance?

Among others, Bean et al. (1985-86) and Child and Partridge (1982) look at the historical context of the supervisor to provide a rationale for the situation which exists today. Both highlight the supervisory role's change in status, from the "man-in-charge" scenario in the mid 1940's to the present day "man-in-the-middle" picture prevalent in most engineering organisations. This involves both a decrease in status and an increase in "marginality".

In 1945 foremen were promoted from among the best workers, respected for their skill and experience. These men had the authority and responsibility for hiring and firing employees. Up to the mid-1970's workers were gaining greater independence eg. through the growth of the Unions, social legislation etc. In addition the increasing complexity of the general business environment meant that management began to exert greater control over the workers, via the foreman. As workers began to question the control and file grievances, so the foreman began to lose his respect and authority. Response by the supervisor to such a loss was to enforce greater control over the workers. This made the problem worse and at the same time the supervisor faced the frustration of management overturning judgements when faced by the workers.

According to Bean (1985-86) the position for the foremen is worse in the modern day than at any other period. They are "extremely frustrated and confused", pulled in opposite directions by their subordinates and by management. Four main complaints have been expressed by the foremen:

- management do not support them;
- management do not tell them anything;
- workers do not respect them;
- workers do not obey them.

Other writers have shown similar concern for the first-line supervisor. Dunkerley's (1975) view of the foreman is as "the forgotten man of industry", Child and Partridge (1982) portray supervisors as "the forgotten men in the middle" and Bean et al. (1985-86) see supervisors as "forever caught in the middle". Having established that there is a definite problem with supervisors, what solutions are offered?

2.3.3 First-Line Supervisor Models

A set of classic solutions is offered by Child and Partridge which centre around characterising four main model choices available for the supervisory role in the future.

i) **Abolish the role of the first-line supervisor** - In this scenario the position of first-line supervisor is abolished. Work groups are formed, with the work group leader taking over the routine supervisory tasks and negotiating for the group. The advantages of this option include greater economy of management resources, better vertical communication within the organisation (one less level of hierarchy) and an opportunity to tap the potential of the shopfloor.

ii) **Leave the role as it is, but make improvements to it** - The argument here is to clarify the distinction between management roles and supervisory roles. The role of the supervisor would consist of overseeing subordinates' work, helping them with problems, recruitment and training, allocation of jobs but **not** to have managerial accountability or authority over the work and employees in the section. The benefit of this model is that it offers a clear definite solution to an awkward problem.

iii) **Develop the role into a first-line managerial role** - Although their role is less than that of a manager, many supervisors today do take the initiative. They have a far closer working knowledge of the section work, technology and employees than the managers. However the control over the parameters and boundary conditions remain with the management. This model aims to place a much greater degree of control and responsibility into the section making the first-line supervisor very similar in form to the German role of "Meister".

iv) **Develop the supervisor role into one of a technical supervisor** - This model gives the supervisor primary concern with technical matters, delegating traditional routine tasks to subordinate employees and giving the overall handling and representation of the section to the next level of management.

Although each of the four models provide benefits in the way they develop the supervisory role, there are also some problems associated with each. The first option appears socially acceptable but, because of the range of unseen contingencies which the supervisor is prepared to deal with, abolishing the role is not practical. The second model is very bureaucratic, best suited to a workplace without a high degree of technical complexity. Again because the supervisor has to deal with a wide range of contingencies, it is better for him to have the power to make the necessary decisions.

With the third model the process of developing a first-line manager would involve delegating some more routine parts of the old role. Therefore, this new non-managerial position might well duplicate the present situation of the supervisor. In addition there would be limited available personnel able to fill this new managerial-supervisory role. Finally, with the last model many factors are involved in its suitability and success, including the importance of craft skills (finding a supervisor with a high enough level of skills is a potential problem). In technical and scientific areas the supervisor coordinates the activities of the section with those of other sections and should he now concentrate solely on the technical side there is no obvious candidate to take over this aspect of the role.

Having detailed the general context of new technology and explored some of the literature on job design/redesign and models of the supervisory role, this chapter now turns to examine the literature concerning the specific new technology which is the focus of this thesis, Computer-Aided Draughting/Design.

2.4 Computer-Aided Draughting/Design (CAD)

Computer-Aided Draughting/Design (CAD; although the word "draughting" is not often used when explaining the acronym CAD) can be defined as the use of a purpose-designed computer software system to assist in any of the phases of the design process (pre-design, conceptual, embodiment, detail and post-design release). The most common view of CAD is as an interactive graphics system which replaces the traditional instruments of design ie. pencil, paper, drawing board, data tables and, more recently, calculator. A typical CAD workstation consists of a colour graphics display terminal, a digitising tablet, a keyboard, a printer/plotter and a local graphics processor.

There is a wealth of literature on CAD covering a wide range of features. This review of literature illustrates a framework into which the disparate research reports can be fitted. This can be conceptualised as following the basic implementation process of a CAD system. This conceptual framework is presented in figure 2.4.

Figure 2.4 **CAD Conceptual Framework**

Brief History of CAD
Conceptual Application of CAD
Reasons Behind the Introduction of CAD
Justification for the Introduction of CAD
Implementation of CAD
The Effects of CAD
Consequences of CAD
Resistance of Individuals to CAD
Running CAD
Evaluating CAD
CAD - The Future?

2.4.1 A Brief History of the Development of CAD

The development of CAD can be traced back to the 1950's aerospace industry's development of (non-graphics) computer systems required for geometric modelling and engineering calculations (Leesley 1978). One of the key developments in graphics software in the early 1960's was the work of MIT (Massachusetts Institute of Technology) researchers on the Sage system (cathode ray tube (CRT) display and operating control). This led to the development of the pioneering "Sketchpad" interactive computer graphics system (Sutherland 1963). Sketchpad allowed a CRT system to be used as an electronic drawing board and was the first time the term "Computer-Aided Design" was used (Chaplin 1985). At about the same time other systems were being developed which used APT-like commands (APT was a part programming language used in the control of numerical control (NC) machine tools) to control a plotter to draw 2D (two dimensional) engineering drawings (Barfield et al. 1987, Majchrzak et al. 1987). In the late 1960's Johnson produced a 3D "wire frame" version of Sketchpad and in 1967 Coons showed how doubly curved surfaces could be handled by computers. In these early years the computers and peripheral devices needed for CAD were very costly. Therefore, for the majority of companies, CAD was considered a luxury as opposed to a useful tool.

In the 1970's, a rapid development of hardware (ie. advances in semiconductor technology allowing minicomputers to be available for CAD applications) coupled with a significant drop in computer software and hardware costs allowed software developments in 3D solid-modelling and shaded colour graphics. Building on these developments, software programmes for engineering analysis applications were also integrated into CAD systems. This range of software and hardware developments signalled the move from computer-aided draughting systems to "true" computer-aided design and modelling systems. Further developments in the 1980's saw CAD move towards more interfaced standards with powerful, specialised hardware and software. CAD systems are now available on a range of computer hardware platforms, ie. mainframe, mini, workstation and in the late 1980's on personal computers. CAD has become an affordable tool, available in some form to nearly every company. Future developments in CAD systems might include realistic image synthesis, expert design software, integrated design and manufacturing, links with other computer systems both within and outside the organisation, eg. Manufacturing Resources Planning II (MRPII, eg. Jones and Webb 1985, Lawrence 1987a) or even radical advances in the man-machine interface with devices such as the "dataglove" and "cyberspace" (eg. Macilwain 1989a, Pruitt 1991).

2.4.2 Conceptual Application of CAD

Although it is possible to draw parallels between CAD and both AMT (Advanced Manufacturing Technology) and IT (Information Technology), there are factors unique to CAD and the context in which it is used which separate it from these other new technologies. In contrast to IT and its users, CAD operators are designers/draughtsmen/engineers who need to integrate a high level of technical expertise with an element of creativity. Winstanley and Francis (1988) state that design managers are primarily concerned with "product lead-time, cost and quality". In contrast to AMT, which is generally introduced in a steady continuous process, CAD is introduced as a step function and therefore has a greater perceived change. In addition CAD requires an initial financial outlay with continuous investment therefore demanding some sort of return to be quickly seen, eg. reduced lead-time. Time has increasingly become one of the major competitive weapons in the 1990's, as the following quote shows,

> "'How to do more' was emphasised in the 60's. 'How to do it cheaper' became important in the 70's. 'How to do it better' was certainly the theme for the 80's. But 'how to do it quicker' will be the key in the 90's...Time needs will be *the* strategic focus for at least the next decade." (Charney 1991)

Thus the emphasis on the reduction of time spent on a project is one of the stress factors seen as associated with the implementation of a CAD system. Furthermore, this view may be communicated down the organisation and so affect the perceptions of those involved in implementing and, more importantly, working with the new technology.

Although CAD refers to a technology which concerns itself with the design process, there are other technologies in the manufacturing industry which are referred to under the umbrella term Computer-Aided Manufacturing or CAM (eg. FMS, CNC, FMC). In an effort to gain or retain some competitive edge, there is a preoccupation with linking these two technologies together (sometimes called the "automatic" factory) to form a direct and integrated CIM (Computer Integrated Manufacturing) or CADCAM system.

Research on CAD has been approached from many different directions including engineering management (eg. Simon et al. 1986), human factors (eg. Chaplin 1985, Majchrzak et al. 1987) and social science (eg. Radar 1982). McLoughlin (1988) provides a useful review of information arising from some of the recent projects in the UK, investigating CADCAM from a social science perspective. The background approaches to these programmes arise from two distinct research traditions:

- **Science and technology policy studies** - the primary focus is on survey-based studies of CADCAM as an innovation and the factors determining the diffusion of CADCAM in an organisation.

- **Industrial sociology** - the focus is on the process and outcomes of change within the adopting organisations.

Within these two approaches the main focus of attention is on the role of management strategy in the organisation, control of the labour process and the de-skilling of work.

Kaplinsky (1982, 1984) discusses the conceptual role of CADCAM in the context of general automation. Kaplinsky asserts that interactive graphics technology has a number of characteristics which suggest it is the "key piece in the electronics jigsaw that will allow for the development of the automated factory" (1982, p.35). One of these characteristics is the ability to create a single database at the design stage which can communicate information in graphical and text formats. The designers can interact in "real-time" with the database in constructing designs. In this way the interactive graphics provides the basis for a qualitative change of automation by electronically linking the process of design, management control and production elements in manufacturing. Kaplinsky calls this ability to link together these different processes the "inter-sphere automation" (1984, p.26). However as many writers note, the potential capabilities of an innovation are not necessarily realised in practice.

One approach in the "science and technology policy" perspective is to identify factors which foster or act as barriers to innovation, thereby moderating the outcome of technological change. Arnold and Senker's (1982) CADCAM survey shows that the case of CAD has no single "impact" on skills and employment. The factor most strongly related to the reported effects of the new technology appears to be how far along the "learning curve" the management and the whole organisation have traversed. They find that to reach the "third" stage[1] took the system two years after implementation had been completed. Only then would CAD be significantly fulfilling its potential in terms of improvements in drafting productivity. This shows how weaknesses in management's skills in the use of technology or at least in their appreciation of the potentials and limitations of the system, can be a significant "barrier" to successful CADCAM usage (see also Arnold 1983, Senker 1984, Simmonds and Senker 1989).

The major criticism of the "science and technology policy" perspective is with its concentration on a deterministic view of technological change. The conceptual framework examines management and skills only with respect to the degree to

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1 Arnold and Senker said that having decided to invest in CAD, users typically pass through three CAD usage development stages. The third stage was defined as "Use of CAD at typical today's state of the art, eg. 3:1, 4:1 productivity improvements. May be some interest in CAM, but not yet much activity."

which they act as constraints on the innovation and diffusion process or themselves are changed as a "consequence" of an innovation (Wilkinson 1983). By contrast the researchers adopting the industrial sociological perspective to investigate CADCAM, are very careful to avoid what is seen as "technological determinism". Wilkinson (1983) questions the "science and technology policy" researchers' ideas of "barriers" to technological change by asking why then is the technology introduced in the first place and whose objectives are being "built" into the new systems. An alternative view of technological change is where it is seen as a political process, in which management and labour (ie. the non-management section of the workforce) are each contesting for control. The basis for this perspective lies in Braverman's (1974) theory on management's attempt to control the labour process through de-skilling and degradation of work, brought about by the introduction of new technology (see Burnes 1988). One particular new technology highlighted is CAD and the possible de-skilling effects on draughtsmen and designers (see Cooley 1980, 1981, 1987)

Studies of comparable new technologies have shown that the de-skilling thesis is a rather "narrow" viewpoint which does not include the degree of variation in tasks and skills which might exist in individual companies (eg. Jones' study on the introduction of NC 1982, Davis 1988, Francis 1989). Other researchers take this idea further to suggest the possibility of extending the range of user skills in "human centred" applications of CADCAM technologies. Within this the CADCAM technology is used as an "aid" to the user as opposed to a means of replacing human labour (eg. Wilkinson 1983, Buchanan and Boddy 1983, Buchanan 1985, Cooley 1987).

However viewing technological change as a political process is a difficult argument to sustain. It assumes that people are "conscious" of the process, the politics which flow from the process and, through a raised level of consciousness, are willing to take action arising from the process. In addition, in the present climate of deep economic recession, "short-termism" appears to be prevalent. As such managers are no longer able to control an organisation in the ways they once could (eg. through fear or through retribution) and are themselves potentially susceptible to a de-skilling process (although different from the technological de-skilling referred to earlier). Recent management practice includes moving the organisation towards "lean manufacturing", "lean management" and "simultaneous engineering" (Fisher 1992) which inherently involves greater devolvement of decision making and empowerment of the wider workforce.

In his various writings, Cooley (1977, 1980, 1981, 1987) strongly argues that the introduction of CAD to the drawing office has often resulted in the de-skilling of workers. This argument is further supported in a study by Baldry and Connolly (1986) which concludes that work in the drawing office is becoming more routine, repetitive, machine-paced, intensified and fragmented. In particular, the drawing office work environment is changed from a relaxed atmosphere in which draughtsmen interact with each other in a free and easy manner, to one where the technological requirements for controlled environments in separate areas creates social divisions within the drawing office itself. The most obvious consequence of this change is the emergence of a small "elite" group of regular CAD users who are paid higher wages, and the introduction of shift working.

However McLoughlin (1986a, 1986b) provides case study evidence which contradicts this idea of CAD being the "classic" de-skilling tool. It appears that while CAD users perceived changes in skills required for drawing, the basic engineering skills needed to use the new computerised tools remain the same as previously used. In addition the case studies show that management commitment to de-skilling through the implementation of CAD is an unreasonable assumption: if only because the degree of internal divisions and potential for conflict make *any* unitary commitment almost impossible. This echoes the findings in "science and technology policy" studies that management's organisation and skills in the exploitation of CADCAM is far from competent. This realisation, by both groups of researchers, that management strategy is neither directly determined by the capabilities of the technology nor fixed by the "laws of capitalist accumulation" (McLoughlin 1988) have considerable consequences for broadening the range of possibilities open to all organisational practitioners.

In addition the social context for the introduction of CAD must be acknowledged. Change in organisations rarely happens without "good reason" and, while the implementation of a CAD system is one "good reason", there may be others. The changes in drawing office working environment may also reflect changes in the economic environment of the industry (since the design process is at the "front" of the product development process, then it is likely that this will reflect changes in the environment most quickly and possibly to the greatest degree).

2.4.3 Reasons Behind the Introduction of CAD

The decision to implement a CAD system involves many factors (eg. Majchrzak and Salzman (1989) list 27 such factors). Often the senior management and system planners concentrate on the technical and economic factors at the expense of the human and organisational considerations. This section shows how many different perspectives on the motives behind the introduction of CAD exist, with each perspective providing another element of insight into the overall process.

A common scenario is for CAD to be introduced in order to solve some set of "problems" (eg. Trafford (1985), Barfield et al. 1987, Collins and King 1988). Trafford (1985) groups the types of problems a CAD system might be intended to solve into four categories,

Organisational - the organisation of the design or manufacturing team is unsuitable for the current operations;

Technical - technology of the product causes design failures through faulty components;

Personnel - individuals do not have the ability to realise the design project;

Information - lack of reliable, accurate information.

However Trafford (1985) points out that, as the CAD system is an information-based tool, its introduction will probably only solve the information problems. The other problems are likely to be left alone and viewed as failures of the CAD implementation process.

Lee (1989) views the introduction of CAD as the result of "push and pull" forces. The technology push originates from a perception that the market requires an organisation to show its progressive nature through using leading technologies to compete. In addition the technical staff's desire for training in and use of the latest technologies may provide some "bottom up" pressure.

The demand pull elements originate internally where CAD is seen as generating a greater competitive edge. This can be achieved either through productivity improvements and more competitive prices, or through greater flexibility allowing better response to the needs of the customer. Elements of both the push and pull factors are reinforced by the claims of suppliers, press and government, who claim that UK manufacturing industry ignores the potentials of new technology "at their own peril".

Alternatively, Simon et al. (1986) find smaller firms took advantage of "slack" periods to commission a CAD system, and then train personnel so that they could be *ready* for the "boom" period (ie. a management response to a decline in profits and competitive pressure).

McLoughlin (1986c) looks at the decision to adopt CAD in four case study companies. In two companies it was related to overall plans to expand the company, whether to enhance existing computer technology or because of a wish to continue a "phenomenal" past growth (of the company) coupled with a relatively standardised product. In the third company the decision to invest in some computerised technology had been made elsewhere in the company (ie. they had already invested in CNC) and following the evaluation of that system (by an external consultant) they had decided to adopt CAD. In the fourth company the parent corporation had decided corporate policy involved investment in CAD and provided money for an initial system. Although the fourth company's management were initially opposed to this move, pressure from the board level "encouraged" acceptance of the corporate policy.

While the reasons framing the introduction of a CAD system, as presented above, reflect mainly company-wide strategic objectives, Barfield et al. (1987) move the focus to designing a system such that it can enhance the designer's creativity and decision-making abilities. Further, the human-CAD system may be seen as a "hybrid intelligent system" with capabilities exceeding those of either component system (given that the human-CAD interaction is synergistic). Groover and Zimmers (1984) and Pao (1984) discuss several reasons for introducing a CAD system, including:

1. Significant increase in productivity - using computer graphics the designer can visualise the product and synthesise, analyze and document the product interactively. Productivity improvements for CAD, compared to manual design, are quoted as ranging from 3:1 to 10:1.

2. Improvements in design quality and accuracy.

3. Improved communication among designers - mainly through using a common database, standardised drawings, common graphics symbols and greater legibility of drawings (Groover and Zimmers 1984).

4. An aid to the manufacturing process.

Groover and Zimmers (1984) also produce a list of potential benefits of CAD (figure 2.5). Apart from numbers 3 (itself the subject of much debate, see Baldry and Connolly 1986), 22 and 24, the rest of these benefits concern technical and information areas (see Trafford above). Therefore, this provides a clear example of how a CAD system might be perceived to fail to solve the organisational and personnel problems that it was also "expected" to solve.

Figure 2.5 **Potential benefits of CAD** (source: Groover and Zimmers 1984)

1	Improved engineering productivity	15	Better knowledge of costs provided
2	Shorter lead times	16	Reduced training time for routine drafting tasks and NC part programming
3	Reduced engineering personnel requirements		
4	Customer modifications easier to make	17	Fewer errors in NC part programming
5	Faster response to requests for quotations	18	Provides the potential for using more existing parts and tooling
6	Avoiding use of subcontractors to meet deadlines	19	Helps ensure designs are appropriate to existing manufacturing techniques
7	Minimised transcription errors	20	Saves machinery and materials time
8	Improved accuracy of design	21	Provides operational results on the status of work in progress
9	In analysis, easier recognition of component interactions	22	Makes the management of design personnel on projects more effective
10	Provides better functional analysis to reduce prototype testing	23	Assistance in inspection of complicated parts
11	Assistance in preparation of documentation	24	Better communication interfaces and greater understanding among engineers, designers, drafters, management and different project groups.
12	Designs have more standardisation		
13	Better designs provided		
14	Improved productivity in tool design		

2.4.4 Justification for the Introduction of CAD

In addition to the reasons behind the introduction of a CAD system another often debated area is the process or set of proposals involved in the decision to adopt new technology. Traditional cost accounting methods (often used to justify the investment) are outdated (ie. cannot take into account the specific properties of new technology, see Burstein and Talbi 1985) and cannot handle the wide set of variables (both quantitative and qualitative) surrounding new technology. Currie (1989b) finds that some engineering managers use "spurious" accounting information to support a simple case for new technology, so that senior management can understand the justification case. When the new technology does not (unsurprisingly) perform to the simplistic standards of the "spurious" justification information, do senior management perceive their investment in CAD has failed? Currie (1988a) investigates the nature of management decision-making in adopting CAD in 20 UK organisations. Interviews with the engineering managers in these organisations confirmed that top management would only release the money for a CAD system if the engineering managers could show the likely productivity benefits.

However the concept of productivity is itself not easy to quantitatively measure. The engineering managers themselves perceived two broad classes of productivity:

1 *Holistic*, which refers to measuring the output in a company-wide context, including the post-implementation results of CADCAM.

2 *Narrow drawing office*, which refers to looking at the results of CAD only in the "narrow context of the drawing office" (Currie 1989b).

In both cases the engineering managers claimed top management needed "proof" that CAD would achieve the results, even though existing techniques were not constructed to be used in this context. Although the CAD system was often introduced for the perceived productivity benefits, the most common situation was where the senior management had inadequate knowledge of the technology to be realistically able to assess its potential for the company. The result is that the individual responsible for the estimate of productivity benefits (from the new technology) often produces some "simplistic" cost-benefit information to satisfy the formally-based accounting procedures. As a result the concept of productivity may vary among all the individuals involved in the project, especially the key decision makers.

Accompanying these differences in perceptions of productivity will be a range of expectations about the benefits to the organisation. The major problem is that while CAD is often justified in quantitative or "cost-benefit" terms (eg. labour saving potential), it would be more appropriate to look at the possible qualitative benefits (eg. improved sophistication and quality of design). This is complicated by the engineering managers specifically choosing to use the simplistic "cost-benefit" case, because they know senior management perceive the legitimacy of the simple financial justification. It is also compounded by a lack of sound technical expertise (at all levels of the managerial hierarchy) and the CAD vendor companies supplying advice (albeit at a basic level) on how to use the technical and cost-benefit case to support the introduction of new technology and in particular CAD (Senker 1984). Some writers report situations where the introduction of CAD has been justified on the basis of short-term productivity increases of about 4:1 now known to be rather dubious (eg. Appleby and Twigg 1987, Carnell and Medland 1984, Child 1984, Currie 1988a, Senker 1984, Majchrzak et al. 1987).

Currie (1988b) argues that many of the inhibiting factors in the change to new technology are related to a wider cultural issue. The supposition is that the individuals responsible for the selection and implementation of new technology (eg. engineering managers) are "forced" by the cultural system into finding a way to avoid the inflexible formal (bureaucratic) budgetary control system in order to get the finance for new technology (Senker 1985 reports similar findings). Senior management fail to appreciate the strategic possibilities of new technology, relying on their understanding of the simplistic short-term gains as a yardstick for controlling the budget "purse strings". The result is an "ad hoc" approach towards the decision-making process on the selection and implementation of a CAD system (Currie 1989a). This involves a high degree of mis-management, including the fragmented introduction of CAD, aimed at meeting narrow operational productivity targets instead of working towards an integrated business strategy with the commitment of senior management. Currie (1989a) suggests that:

> "managing new technology demands a wide variety of skills which are not technical but strategic and require an understanding of the organisation's business and the environment in which it operates."

Other researchers also look at the methods used in the justification for the introduction of CAD. Primrose, Creamer and Leonard (1985) developed a list of 16 costs (8 initial costs and 8 running costs) and 29 separate factors (in 7 categories) which are benefits of CAD (cf. Groover and Zimmers' 24 benefits; see Appendix I). These costs and benefit factors were then used to develop a computer programme to calculate the financial appraisal of CAD systems. The method employed to elicit the relevant information involves a software programme presenting a number of questions to the user, in the style of a checklist. The user has to indicate whether each factor is relevant to their organisation and if so to estimate upper and lower values or probabilities, for that factor. From these figures optimistic, pessimistic and mean values for the potential return on investment could be calculated.

Primrose, Creamer and Leonard (1985) also find that CAD has often been introduced for rather "simplistic" reasons (as does Currie 1988a-b, 1989a-b), ie. to enable a reduction in the number of personnel in the drawing office (and it often fails to meet that one goal). Accepting the full range of company-wide benefits associated with CAD allows the generation of a clearer picture for the justification process. Often this is much stronger than the case presented using a single objective.

While the use of a computer evaluation package for CAD could be useful (both pre- and post-implementation), it is also necessary to examine other aspects of the company. Appleby and Twigg (1988) find three types of issues related to the adoption of a CAD system:

Technical issues:

- the nature of the components supplied;
- the relevant production processes;
- the extent the part is designed by the component company.

These issues also include perceptions about the division of design responsibility between the assembler and supplier, which itself can be classified into four possible relationship types:

i) proprietary parts suppliers- have a clearly defined design authority and often perceive a clear need to adopt CAD;
ii) standard parts suppliers- also often perceive the need for CAD;
iii) intermediate group of parts supplier - where there is a division of design authority between assembler and supplier in which some do adopt CAD, others attempt to get by without;
iv) customised parts supplier - specific requirements for CADCAM facilities and links with the customer.

Financial issues:

- Only a few companies used formal investment criteria to justify the adoption of CAD because of the difficulty with measuring costs and identifying intangible benefits.

- The "real" costs are said to come from the whole company embracing a computer-aided philosophy (cf. Primrose, Creamer and Leonard, 1985). Therefore, companies need a long-term and company-wide horizon to look at the returns on CAD. Some companies appeared to be following this route, but they were reported to be proceeding very slowly.

Therefore a combination of tangible benefits and high costs, intangible benefits, short time horizon and narrow company horizon would not appear to push companies towards CAD. Appleby and Twigg find all the companies in their survey (16 in the car component manufacturing industry) interested in CAD. The answer to the question "why?" is provided in the last set of issues.

Managerial issues:

- All the adopting companies had a "product champion". This was an individual who clearly perceived the potential benefits of CAD for the company and was high enough in the management hierarchy to argue the case for CAD.

Appleby and Twigg (1988) find three types of product champions,

1 Senior manager - who has awareness of CAD, probably raised by vendor literature or exhibitions. The problem is that the literature/material overly raises expectations, which the system often fails to meet.

2 Technical director - who sees the problems with the current system but cannot see how to use CAD within the set of existing skills, therefore argues for change.

3 Senior design staff - (possibly "bought" in from vendor or external consultant) high in CAD technical knowledge but problems arise because they do not know enough about the personnel of the design function and the systems already in use.

Overall, Appleby and Twigg find the decision to adopt CAD depends (at the basic level) on the balance between "certain" costs (ie. initial costs, recurrent maintenance, training, disruption to present production and long learning process) and "uncertain" benefits (ie. productivity gains, quality gains, ease of modification, increased customer satisfaction, increased product demand and improved financial performance).

Finnie (1988) reviews some of the above evidence and argues that financial appraisal techniques which are commonly applied to new technology (the specific article refers to "advanced manufacturing technology", but appears to include CAD within that remit) are suitable for that purpose. Rather than find problems with the appraisal techniques, Finnie concludes that the appraisal process itself should be better managed (eg. better documentation of the AMT investment decision making process, promotion of better understanding of knowledge about methods of conducting capital expenditure appraisal) such that it cannot be tampered with (as shown by Currie 1988a-b, 1989a-b) in a sponsor's effort to "contrive" an acceptable financial outcome (Senker 1984).

2.4.5 Implementation of CAD

The process of implementing new technology has been shown to be very important in how successfully the technology is later utilised (cf. Johnson et al. 1985, Dawson 1986, Mumford 1969). "Success" in the implementation literature can be defined in three ways (Majchrzak et al. 1987):

1. The cxtent of organisational use of new technology. The focus is on the degree to which the whole organisation uses the new technology as opposed to any individual usage. Typical measures might include the machine-utilisation time or the number of regular users (focusing at the organisation rather than at the individual level).

2. The extent the technology meets its original objectives eg. a CAD system introduced to improve drawing office productivity will be perceived as successful if it enables more drawings to be produced than prior to the introduction (irrespective of whether those extra drawings are really needed), in the same amount of time.

3. In many organisations there can be an unclear set of objectives for the new technology eg. general enhancement of drafting or design departments. In these cases Johnson et al. (1985) suggest that an alternative definition of success could be the general capability enhancement or sophistication of the use of a computer technology, eg. for a CAD system there might be 3 levels of sophistication:

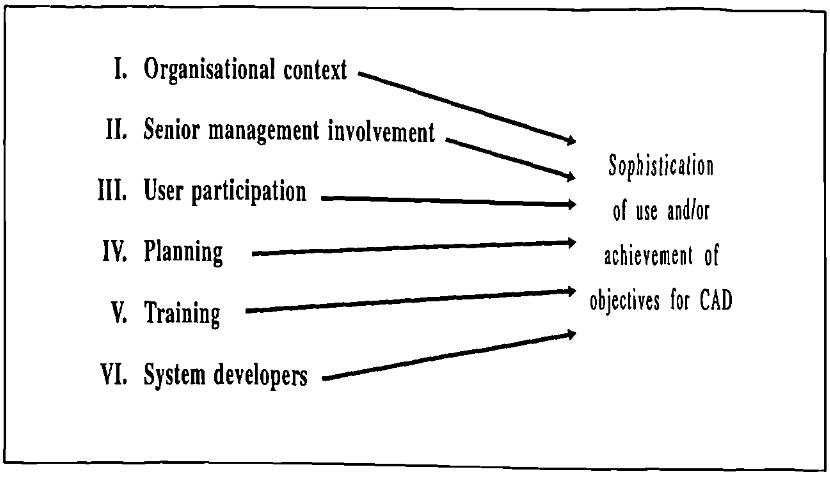
   a) low integration - use of a CAD system as an electronic drawing board;

   b) parallel integration - centralised CAD system, with an emphasis on developing efficient keystroke reduction pathways and running in parallel with the existing manual draughting/design system but moving towards the phasing out of this non-computer assisted system;

   c) system-wide adaptation - a decentralised system with high operator autonomy, and an emphasis on the creative use of the system.

This illustrates the diversity of definitions for success. It also appears that the specific type of technology and the specific organisation culture are equally as important as the method of implementation process to the measures of success. The important variables in the potentially successful implementation process of a CAD system can be expressed in many ways, Majchrzak et al. (1987) groups these variables into six categories, as shown in figure 2.6. The categories are explored below:

Figure 2.6 **Factors Relating to the Successful Implementation of New Technology** (source: Majchrzak et al. 1987)



I. Organisational Context of the Implementation Process

This is the set of organisational goals and structures which encompass the implementation process. The terms often used in this framework are the organisational culture or orientation to change, the way in which the organisation is structured, the organisation's rigidity etc.

Findings in this area indicate that CAD is likely to be brought in solely as an "electronic drawing board" in bureaucratic organisations, because this type of organisation resists any revolutionary change (Majchrzak et. al. 1987 reporting Tomeski and Lazarus 1975). Particular industries may be more responsive to CAD (eg. as Simmonds and Senker (1989) find true for "hi-tech" industries or Jacobs (1986) finds true for industries with dependent customer-supplier relationships), but this does not itself indicate successful implementation. Positive attitudes towards change in an organisation indicate that the organisation has a higher probability of successfully implementing CAD. Finally, much of the political element of an organisation appears to determine "a priori" the success of CAD implementation.

II. Senior Management Involvement in the Implementation Process

The need for senior management to support and be involved in the implementation process frames another set of organisational variables significant in the successful later use of CAD. Majchrzak et al. (1987) make a number of specific suggestions about ways in which senior management should be involved in the implementation of CAD.

Senior management need an appreciation of the capabilities of the CAD system as well as an understanding of the organisation's business and workflow process to enable an effective meshing of the pre- and post-implementation stages. In order to allow the system developers to "fine-tune" the CAD system and the lower-level users of the system to maintain some feeling of participation in the implementation process, senior management should adopt a top-down perspective. This involves a focus on strategic concepts and little involvement in the operational details.

However it is likely that conflicts will occur as strategic decisions and priorities are defined across departments and users. Senior management need to be involved in resolving these conflicts as and when they occur. Once a comprehensive system strategy, priorities and use are agreed they should be communicated to the employees affected by the CAD system. This enables the senior management to establish their visible support for the CAD system and provides a context in which the operational decisions can be taken.

III. User Participation in the Implementation Process

User participation in the implementation process is also seen as independently as a significant factor in the successful outcome of the implementation process.

The literature on implementation of new technology shows that users generally are not as involved in the implementation process as might be expected from the reported empirical data (cf. Bjorn-Anderson et al. 1979, Danziger et al. 1982, Johnson et al. 1985). There appear to be several reasons why this happens (the reasons are equally attributable to the users as well as the users' managers and the system developers),

1. Users do not want to invest time in learning how to operate the system.

2. System developers find it difficult to work with users because of both language barriers and differences in focus.

3. Managers do not encourage users to participate in the implementation and development of the system because they fail to recognise the importance of this participation.

IV. Planning the Implementation Process

The need for planning has, for a long time., been recognised. However the way in which CAD is planned and which elements are accounted for can be significant factors in the success of the outcome. Senker (1985) reports four sources of error in the investment appraisal for CAD:

1. underestimation of the time needed to reach effective functioning;
2. overestimation of the likely utilisation rate;
3. underestimation of the demands of adaptive adjustments;
4. underestimation of the tasks involved in negotiating labour acceptance of the changes.

Careful planning for the introduction of CAD systems (as opposed to other new technologies, eg. CNC technology) is particularly important because the implementation process may last for several years (Schaffitzel and Kersten 1985).

Given that planning is an important factor, the type of planning will be equally important in determining the success of the implementation process. One possibility is that the most sophisticated use of new technology will arise when senior management allows implementation to be a loosely structured, evolutionary process shaped by conflicts and negotiation (Johnson et al. 1985). This does not suggest objectives need not be set, but that the plans are not too tightly drawn and room for evolution is allowed.

Majchrzak et al. (1987) propose nine distinct phases in the implementation process for a successful CAD system (eight from David 1981, plus one further phase) which may be used in the planning stage:

1. analysis of the current design process;
2. study the possibilities offered by CAD;
3. define a design process for CAD given user needs and the desired integration;
4. define a functional specification for CAD, given the design process;
5. conduct a feasibility study of the prototype;
6. produce detailed definitions for new procedures and system;
7. develop an investment plan;
8. installation of the system;
9. "refreeze" and stabilise the organisation with the integrated system, eg. develop new norms of behaviour or rules.

Notably the installation of the terminals (or workstations) in the eighth phase occurs after substantial planning has already taken place. In addition the last phase is important in establishing the long-term nature of the implementation process and re-establishing the organisation at a new equilibrium and so continuing the integration of the new technology.

V. The Role of Training within the Implementation Process

The training of CAD users is important because it influences their sense of job satisfaction. This in turn relates to the success of new systems and to the sophisticated integration of the new systems into the pre-existing organisational workflow. Compared with the relatively high investment in hardware and software for a CAD system, user training is comparatively low cost. However it appears that training is inadequate in most companies implementing CAD systems. A survey by Majchrzak et al. (1985) of a sample of US manufacturing firms finds that only 19% offered their employees CAD system training (also Wagner 1985, Jacobs 1985).

Training programmes can be split into two stages, initial training (pre-implementation for some initially selected users, while for others it is as soon as they are selected) and continued or follow-on courses (advanced seminars, offered by the system vendors or as a company "in-house" seminar).

In general the initial training programmes (while diverse in nature) focus on specific CAD workstation functions. The normal vendor programme is rarely customised to account for specific organisational workflows and the training is often carried out informally, heavily dependent on peer group learning (Majchrzak et al. 1985).

The follow-on programmes appear to occur "sporadically" in organisations (Majchrzak et al. 1985). Continuous learning, however, has been found (in the cases where it did occur) to be related to higher employee satisfaction and a more sophisticated use of the system (Johnson et al. 1985). The importance of the continued training for users is mirrored in the importance of continued training for managers, so that they too participate in the system evolution and incorporate the ongoing changes into the way the workforce is managed.

VI. Managing System Developers Within the Implementation Process

Most of the research that led Majchrzak et al. to include this as a factor in successful CAD system implementation has been in the area of information systems (IS) development, and therefore may not be equally applicable to CAD. Technology development is affected not just by the technology, but by the developer's knowledge, skill values, assumptions etc., about people and organisations (eg. Buckingham et. al., 1987; Jones M R, 1990). Furthermore, in some cases the systems developers have been the main participants in the implementation process. In the introduction of a CAD system this is less likely to be true, but still the role of the developer is a factor which should be taken into account when trying to identify determinants of the successful implementation process.

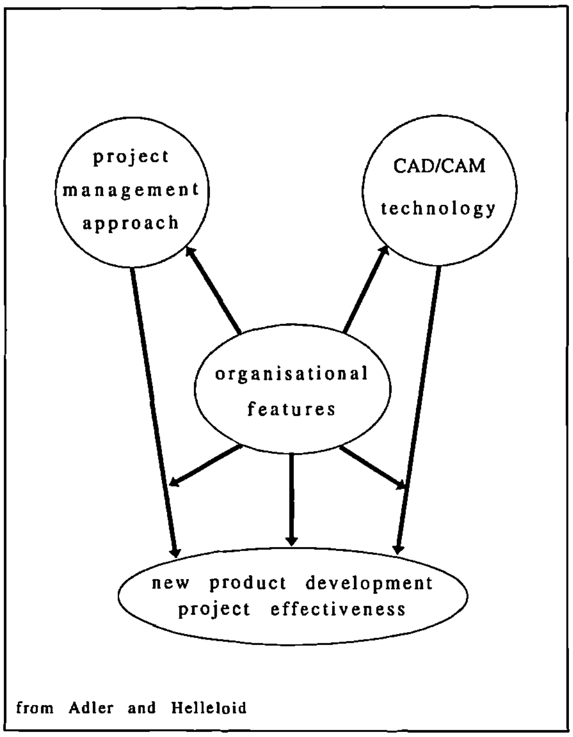
Schaffitzel and Kersten (1985) also say that every introduction of a CAD system potentially requires a degree of user-developer communication (UDC) because of the need for customisation of the software to meet the needs of the particular company (this may only be true in the larger companies with "turnkey" systems). Finally, there is also a need for the redesign of the organisational context in which a CAD system is to function.

Adler and Helleloid (1987) examine the conditions for successful implementation of CADCAM and find that (in general) it cannot be accomplished in parallel with the "technological efforts of CADCAM integration". They focus on the organisational conditions pre-existing the integration of CADCAM and show that the effectiveness of integration is a function of four factors:

1) skills;
2) procedures;
3) strategies;
4) culture.

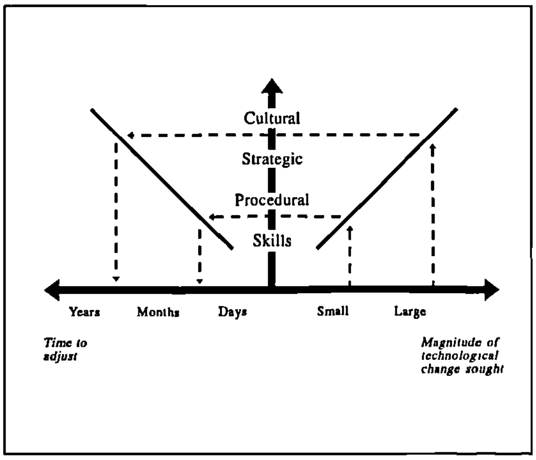
They use a model in which effective product development (ie. costing, quality and timing) is a function of project management, the technology used and key organisational characteristics. The third factor influences the first two factors and dominates the model ie. organisational features mediate the impact of project management approaches and CADCAM technology (figure 2.7).

Figure 2.7 **Determinants of New Product Development Project Effectiveness**



It appears that the magnitude of technological change is directly proportional to the level of organisational learning and also to the amount of time required to reach the objectives (figure 2.8).

Figure 2.8 **Organisational Learning** (source: Adler and Helleloid)



Adler and Helleloid (1987) conclude that top management support is beneficial but involvement in the implementation details is a distraction (Majchrzak et al. 1987). The different results for the different levels of management involvement are due to the fast pace of technological change and the cross-functional aspects of many new technologies. For similar reasons success is more dependant on an interfunctional "network of support" than a single "champion" (others have supported the need for a champion or "sponsor" for the successful implementation of CAD, see Medland and Burnett 1986; Appleby and Twigg 1988). Within the conditions of dynamic technological change the company needs to maintain strong links with the vendor company (ie. a "partnership" as opposed to "arm's length" communication). Finally, the company culture needs to be focused on continual adaptation which can be accomplished through training for long-term learning capabilities as well as for short-term operational proficiency.

Balachandra (1985) also considers the successful implementation of CAD/CAM (computer-aided engineering (CAE) is also included in what are called the C^3 technologies). Balachandra presents a logical approach to implementing CADCAM, which consists of four phases:

1. Draughting phase;
2. Design phase;
3. Process planned phase;
4. Fully integrated C^3 factory.

The results of Balachandra's empirical study show that this theoretical sequence is rarely followed in practice. In addition a number of problems affected the smooth implementation of the CADCAM system. These can be grouped into four main categories:

1. Personnel problems;
2. Communication problems;
3. Organisational problems;
4. Interfacing problems.

Overall it appears that the implementation of CADCAM in the sample was not a success. The reasons given for the failure of the implementation process mirror those mentioned before, ie. the study was conducted relatively soon after the implementation had begun and although the implementation process included adequate planning in the technical areas, there was a severe lack of planning in the personnel and organisational areas.

Beatty and Gordon (1988) find that barriers to the implementation of CAD could be categorised into three types, with associated causes and remedies:

Table 2.1 **Barriers to the Implementation of CAD** (source: Beatty and Gordon, 1988)

Barrier	Causes	Remedies
Structural:		
Excessive focus on direct labour and ratios	Obsolete decision criteria	Careful analysis of real costs and benefits
Failure to perceive true benefits	Lack of measures of intangible benefits	Analysis of total productivity and "intangibles"
High risk for managers	Reward systems discourage risk taking	Different reward system for managers
Lack of coordination and cooperation	Organisational fragmentation	Devices to integrate and coordinate
High hopes and hidden costs	Overselling	Planning strategic objectives
Human:		
Uncertainty avoidance	Fear of change and uncertainty	Involvement and communication
Resistance	Fear of loss of power and status	Careful implementation, champion
Hasty decisions and chronic fire fighting	Action orientation: impatience with planning and waiting	Pre-implementation planning, long-term objectives
Technical:		
Incompatibility of systems	Purchase of a variety of hardware and software	Buy only an integrated system, write your own software, neutral files.

In the interview data Beatty and Gordon came across varying views of the implementation process for CAD. They conclude:

> "Many of the managers we interviewed stated that CADCAM can and should drastically alter the way the company carries out its tasks. If used merely to imitate existing processes, it will remain both expensive and ineffective."

However if the processes are already inefficient then implementing a CAD system can prompt more chaos than previously existed.

The human factors barriers are not just resistance to change in itself but occur when faced with change that is possibly uncertain or may have negative outcomes.

Overall, Beatty and Gordon believe that presenting the set of barriers can raise the level of awareness of potential problems in the implementation process. Strategies can then be devised to avoid or overcome the barriers. Nonetheless, the advocated long-term planning in the implementation process must not be allowed to become a paralysis because the organisation is waiting to buy a "perfect" CAD system (cf. Peters and Waterman 1982).

In practice some companies who had attempted minimal advance planning still achieved acceptable results. This appears to be conditional on:

i) the company not making serious personnel mistakes;

ii) the company having a "facilitating" organisational structure.

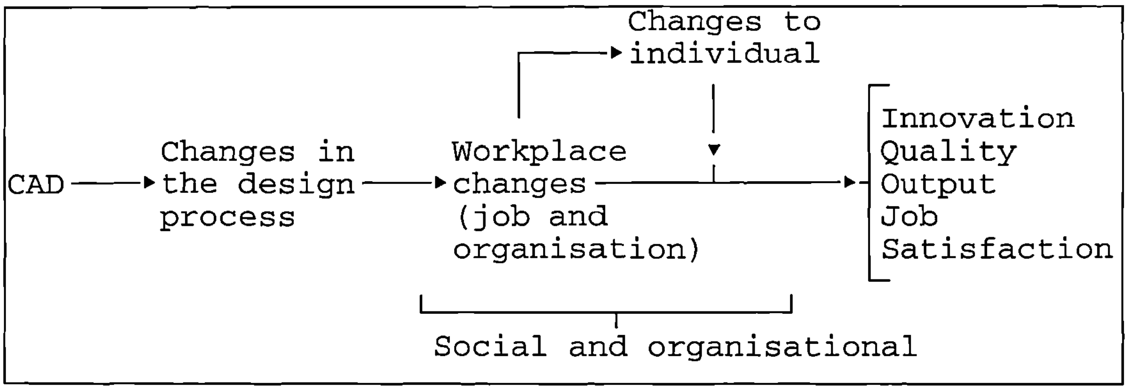
Beatty and Gordon say that companies who have not invested in computer systems may find, in the future, that they are too far behind to catch up. That is, although the pioneering companies all made mistakes, now none say that they would return to pre-CAD manual systems. The pioneering companies believe they have a significant competitive advantage over non-computer based competitors (this argument is not irrefutable and other researchers also feel that it has been used too often in the past to persuade companies to invest in new technology when it might not have been appropriate at that time, see McLoughlin and Clark (1988) for a discussion of the automate/liquidate argument and section 2.4.1).

2.4.6 The Effects of CAD

The previous section looked at the potential benefits and expectations associated with the introduction of a CAD system. This section aims to examine the changes that occur in practice (ie. outcomes) after the introduction of a CAD system and investigate why expectations do not often match the outcome.

Majchrzak et al. (1987) present a conceptual framework (see figure 2.9) for understanding the social and organisational consequences of CAD. The framework shows a causal sequence in which CAD primarily affects the way the design process is carried out and, through the consequent changes in the workplace, has a secondary effect on individuals.

Figure 2.9 **Conceptual Framework Illustrating the Impact of CAD on Productivity** (source: Majchrzak et al. 1987)



Technological change (ie. CAD) affects, and is affected by, social and organisational factors through three main routes:

1. Consequences of CAD - the social factors altered by the new technology eg. job redesign for optimal use of CAD.

2. Resistance of individuals to CAD - the social factors affecting the individual's willingness and ability to adapt to new technology eg.

individuals who initially resist training for and using CAD because they fear CAD will, in the future, lead to reduced numbers of designers and draughtsmen.

3. Parameters of the implementation process - the set of factors involved in the implementation process eg. providing follow-up training for CAD users after they have adjusted to the system as opposed to training only in the very early stages.

The above do not cover all the social and organisational factors but do highlight most of the relevant topics. Some factors are not mutually exclusive and could be found in more than one of the categorisations. Each of the above categories will now be examined in greater detail.

2.4.7 Consequences of CAD

There are two major groups of factors which may be changed by CAD and may affect "whether design process changes brought about by CAD yield CAD's expected benefits" (Majchrzak et al. 1987).

i) Aspects of the workplace - these are the different ways in which CAD alters a job (ie. activities, skill requirements etc.), structure of the work environment (ie. the way decisions are made), organisational procedures (ie. how formalised they are) and personnel policies (eg. job displacement, career development).

ii) Reactions of individuals in the workplace to their jobs with CAD. This is important for three reasons:

- An individual's evaluation of his job is an important determinant of his level of work effort (Hackman and Oldham 1975) and his overall adjustment to technological change (Lucas 1975a).

- An individual's reaction to his job also can in turn affect other individual's reactions to their jobs ie. a negative view of CAD by a few can become a negative view of CAD by many.

- An individual's perception of his job with CAD may negate some of the positive aspects of workplace change eg. CAD has the potential to promote greater communication between design, draughting and manufacturing, but this is only positive if this type of integration is not already negatively valued.

The consequences of CAD are not all technologically determined. Other factors which contribute to the changes associated with CAD include management philosophy, the particular production process, market conditions, personnel policies, job design, worker morale and organisational structure. Various studies examine the specific impact of CAD (or the impact associated with CAD) and Majchrzak et al. (1987) provide tabular summaries of some of these (as shown in Appendix II).

From their general review of the literature on social and organisational consequences of CAD Majchrzak et al. (1987) identify eight specific workplace effects attributable to CAD:

1. increased use of integrative devices;
2. increased and different communication patterns on the job;
3. increased skill requirements;
4. increased formalisation of work methods;
5. availability of alternative career paths for engineers, designers and draughtsmen;

6. no change in job displacement;
7. no change in wages;
8. greater perceived stress.

Once again the emphasis is the management of issues, rather than the technology itself, to achieve positive consequences of CAD,

> "the importance of the management of CAD to achieve positive benefits from the technology cannot be overemphasized."

In addition CAD systems can be used as a catalyst for new and possibly radical organisational change. Using CAD can lead to new options for both centralising and decentralising an organisation, or for restructuring jobs and departments. However these changes can only succeed if the implementation process is appropriately planned and individual resistance to change understood and catered for.

2.4.8 Resistance of Individuals to CAD

Several specific categories of factors have been proposed as significant predictors of individual resistance to CAD ie. the CAD system, the individual's background, the degree of the individual's exposure to new technology, managerial actions, job conditions (see table 2.2).

Table 2.2 **Summary of Research on Factors Significant in Individuals' Resistance to Change** (source: Majchrzak et al. 1987)

Predictor of Resistance	Author	Measure of resistance	Finding
System factors	Barfield et al. (1986)	Improper use of CAD	Synergistic interaction of user and CAD
Individual background	Majchrzak et al. (1985)	Nonusers' fears of CAD Users' job satisfaction and performance	Positive relationship of age and user satisfaction; complex (different relationships for different jobs and fears)
Individual background	Newton (1984)	Users' CAD satisfaction	No relationship
Knowledge factors	Majchrzak (1985)	Fears of CAD for nonusers; system satisfaction for users	Marginal relationships only
Managerial factors	Hamilton and Sheehan (1982)	Reduction in "psychological" resistance	Assurance of job security from management

However Majchrzak et al. (1987) found only three significant determinants of individuals' resistance to CAD,

1. state of present/future job;
2. understanding the need for new technology;
3. managerial actions (acting both as barriers and incentives).

Within these Majchrzak et al. (1987) focus on a number of specific factors, similar to those found by Johnson et al. (1985) to be significant in the implementation of word processors (table 2.3).

Table 2.3 **Factors Predicting and Failing to Predict Adaptation from Organisations Implementing Word Processors** (source Johnson et al. 1985)

Factors that DO predict adaptation	Factors that DO NOT predict adaptation
Training	Machine Characteristics
Helped me understand how word processors think; Still learning new ways to use;	Reliability; Ease of use; Versatility;
Experimentation Encouraged by Organisation	Personality Features
Time to experiment; Organisation encourages adaptation; Policies do not discourage;	Play computer games; Seek new ways to do things; Seek ways to solve problems; Enjoy being a leader;
Communication	Communicate Directly with Authors
Talk about adaptation with coworkers, supervisors, authors; Participate in meetings where uses and procedures are discussed; Received praise from coworkers and supervisor	Prefer to communicate directly with authors; Having friends elsewhere in the organisation;
Participate in Decision Making About	Organisational Orientation
Unit productivity; Formatting procedures; Training;	Talk about organisation's product; Talk about group product; Think tasks could be done better with word processor (WP);
	Participation in Decision Making About
	Equipment choice; Maintenance; Personnel performance criteria;

As has been shown in the previous section, the successful implementation process involves indepth advance planning and company acceptance of the long-term time-scale. The implementation process could take two years and (with the high rate of software and hardware turnover) would probably include a degree of innovation within those years. Although the innovation process is ongoing, comparisons (of various significant factors) between pre- and post- implementation phases of interactive computer-aided systems are often made to highlight the advantages or disadvantages associated with those systems.

Baldry and Connolly (1986) look at the set of perceived advantages and identified a split between those relative to management and those relative to users (draughtsmen). The perceived advantages of CAD for management include greater productivity (Incomes Data Services 1985; also the major quantitative benefit according to CAD vendors) and a range of "unquantifiable" merits such as:

- better quality of design;
- higher accuracy;
- ability to reduce time for tendering;
- shorter product lead times;
- upward movement of management control over design.

The apparent benefits for the draughtsmen include:

- elimination of many routine tasks and calculations;
- drawings easier to check and correct.

Baldry and Connolly's (1986) interviews (with management and others in eight Scottish companies) disagrees with the above set of benefits and show CAD was, in practice, used mainly for repetitive and routine work. Other details drawn from their data include decreased autonomy for draughtsmen, greater degree of machine pacing, perception of an increased work pace and, in some cases, the introduction of shift systems. Baldry and Connolly also report that storing standard data in the computer system causes de-skilling of the draughtsman. This happens where standard parts drawings can be pulled directly into a new workspace and used, often needing only minor adjustments, thereby limiting the draughtsman's autonomy and creativity.

Finally, the computer system allows management to exert a higher degree of control than was previously possible. The problem occurs because the role of the CAD system "per se" in the changes to the drawing office is unclear. Alongside the introduction of computer technology Baldry and Connolly found specialisation; the breakdown of the design process and a weakening of the individual's identification with a particular piece of work (ie. loss of craft skills). These could, and probably did, contribute to the decline and de-skilling of the draughtsman in the companies examined. Cooley (1987) also argues that while CAD systems may bring some benefits, overall the draughtsman becomes the "operator" in a machine-centred process.

Whether the loss of manual craft skills in drawing tasks does signify de-skilling is another extension of the debate surrounding CAD. McLoughlin (1986c, 1988) suggests that using CAD requires new mental skills which partially compensate for the loss of the other skills. The architecture of the CAD system is the most important factor in how work tasks and skills requirements are affected (McLoughlin and Clark 1988). There is a basic distinction between the capabilities of CAD systems which splits them into "draughting systems" and "modelling systems" (see McLoughlin and Clark 1988, Collins and King 1988):

- *Draughting systems* are shape processors which allow manipulation of two dimensional drawings comprising lines and curves and annotated by figures and characters (analogous to word processing).

- *Modelling systems* have automated draughting processes and use complex computer-based mathematical models to represent an object in three dimensional space (using solid, surface or wire-frame modelling). The data is stored in a computer database which can be interrogated in a variety of ways and manipulated to provide output for other systems, both "upstream" in conceptual design and "downstream" in the production process.

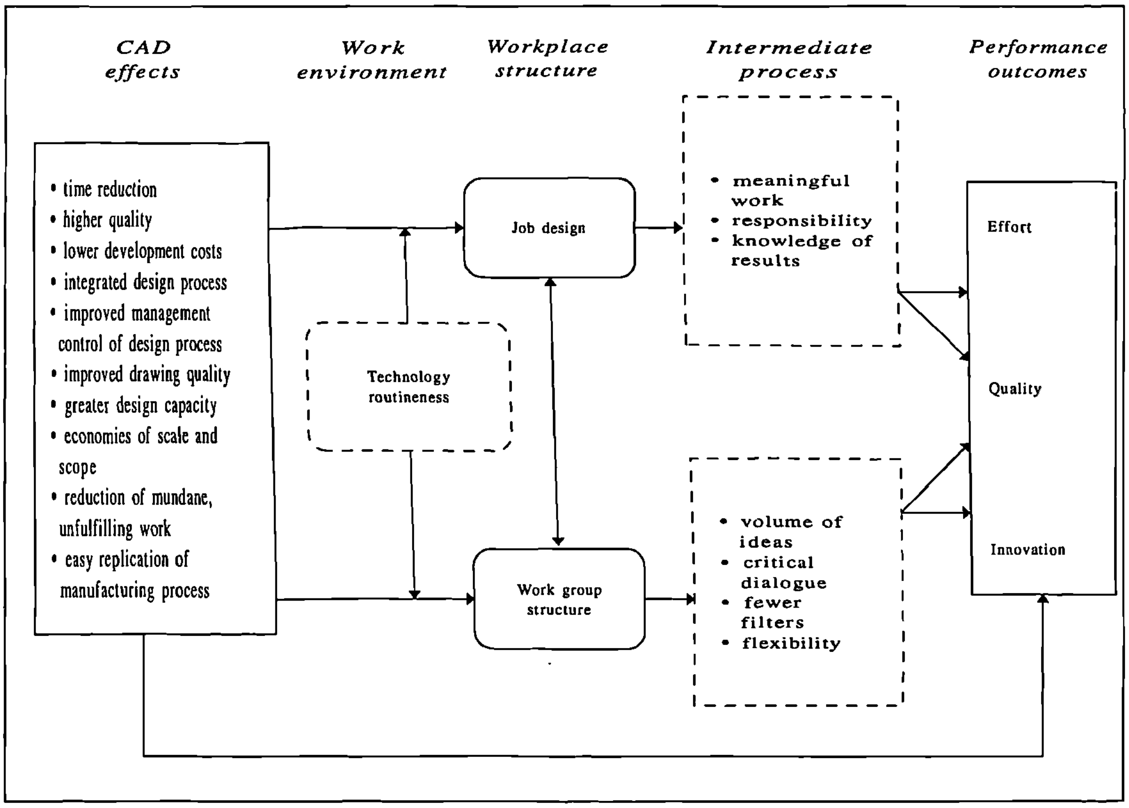
Using a CAD modelling system requires a high level of engineering skill and expertise.

Modelling systems may also be important in changing the labour structure in the wider design function. Traditionally design and draughting have been separate functions accompanied by a division of labour according to engineering discipline (Arnold and Senker 1982). Winstanley and Francis (1988) surveyed 32 UK companies and demonstrated that the link between technical systems in design and manufacturing provides the opportunity for bringing together the designer, draughtsman and production engineer. One case study company (McLoughlin 1988) shows that utilisation of a CAD modelling system allows greater functional interdependence between users and a closer design manufacturing link so enabling a more interdisciplinary approach to design. In addition the modelling system encourages the draughting staff to make more creative design decisions and so act more in the role of a design-draughtsman.

Francis and Winstanley (1988) report that CAD encourages both an influx of graduates into design (and therefore the growing importance of the role of the "professional engineer") together with enhancing the status of the designer (as a result of holding both technical and computer skills). But accompanying the rise of the professional engineering designer, and in contrast with McLoughlin's findings (above), is the decline of the draughtsman (in one case draughting staff were cut by a factor of 2:3), as a response to greater design productivity (both overall and at the design modifications stage).

One approach to studying and understanding the effects of CAD in the workplace is to follow the "socio-technical systems" theory (Trist 1970). The particular principle used is that the work system consists of both technical elements (eg. equipment and physical environment) and social-psychological elements (eg., organisational structure and relationships), existing in a dynamic balance. CAD is a "radical" introduction of new technology unbalancing the sociotechnical system which exists in the design function. Two areas may be affected. The first is the psychological and sociological properties of the design function personnel (cf. Chaplin 1985). The second is direct changes in performance (associated with the move from conventional design and draughting) and the indirect effect on performance through employees altered perception of job characteristics and work group structure. Collins and King (1988) combine all these factors in a general model of the effect of CAD on jobs, work group structure and individual performance (figure 2.10),

Figure 2.10 **General Model of the Effect of CAD on Jobs, Work Group Structure and Individual Performance** (source: Collins and King 1988)



Collins and King (1988) examine in detail the various components of this theoretical model and on this basis propose a number of expected outcomes for CAD. They suggest that, due to the many technical benefits the CAD system provides, there would be a positive effect on individual performance. In addition they expect that CAD would:

> "have an indirect positive effect on performance because of CAD's relationship with job characteristics and work group structure, with the magnitude of its effects varying as a function of the routine nature of the technology."

Various studies of new technologies suggest computer-based technology is accompanied by a shift from manual to mental activities (Collins and King 1988). But again the exact effect of CAD in job characteristics is still being debated. Collins and King (1988) propose five reasons why CAD would lead to an increase in perception of job design complexity:

1. Highly repetitious manual tasks can be performed by the CAD system. Therefore the number of cognitive tasks associated with the job will increase (ie. users need to develop new skills to use with the highly complex CAD system).

2. Because designers and draughtsmen work on a greater number of parts, identification with the whole product is enhanced (cf. Baldry and Connolly (1986) and loss of identification through loss of craft skills).

3. The design process becomes more integrated, therefore a greater variety of skills are used and each individual is more able to influence others working on the same project.

4. CAD reduces designing and draughting time and allows "what-if" scenarios to be examined more easily, plus "objective" standards can be used to judge users' performance.

5. The quality of the design process is indirectly controlled by the CAD system. The impersonal control exerted by the computer system is perceived

as less obtrusive, direct management involvement is decreased and therefore employees' perceptions of autonomy are increased.

Another area affected by CAD is perceptions of work group structure. CAD shortens the design cycle and therefore may result in fast and flexible technical decision-making. At the same time CAD encourages increased interfunctional integration which in turn facilitates the development of more "organic" structural forms of organisation. Nevertheless these effects on job and work group structure would themselves be moderated by the nature of the technology, ie. its "routineness". An example of routine technology is transferring technical specifications to a drawing, whereas an example of non-routine technology is using the CAD system to reduce the number of parts in a product (as in design for manufacture and/or assembly).

Where there is routine technology, CAD alters the technology itself and therefore is expected to have a stronger positive effect on job design than where there is non-routine technology, because of the greater scope for change in complexity. In the case of non-routine technology, work groups would already have been encouraged to become more flexible, whether or not CAD is used. Thus the greatest change in work group structure (ie. towards organic structure) should be seen where technology is routine and well automated. Moreover the effect of CAD on job design may vary according to the nature of the task performed by the individual, ie. whether he is involved in design or draughting.

Norton (1981) concludes that through CAD the range of skills used in work and involvement in decision-making increases for senior designers, but is reduced for some lower-ranking employees. However Wingert, Rader and Riehm (1981) argue CAD increases the range of skills needed for lower-ranking employees, because of the greater and more complex information they would have to process compared with manual draughting.

Collins and King's (1988) survey of current and prospective CAD users at two sites of one corporation shows that many of the expectations concerning the effects of CAD are correct. The results show that, through use of CAD systems, individuals' perceptions of their jobs become more positive with the greatest effect seen in jobs involving routine technology. In the case of a draughtsman (whose job would typically have involved many repetitious manual tasks), engaging in tasks requiring new and complex cognitive skills enhances his job perception. In the case of a design-engineer who already uses a wide variety of skills and is relatively autonomous, using a CAD system causes very little change in his perception of his job and its meaningfulness. As Collins and King conclude:

> "This may mean that draughtsmen whose work involves more routine technology will derive more motivational benefits from CAD than will designers whose work typically has many exceptional requirements and demands solutions not readily known."

As for the other hypotheses, no significant relationship is found between CAD use and a composite scale of "organic" work group structure nor between CAD use and any direct improvement in performance. However organic work group structure did show a consistent positive relationship with various measures of job performance. One important point to raise here is that while some literature suggests 6 to 9 months following CAD implementation for improvements to be seen, all the survey respondents had been using CAD for about nine months and yet very little performance improvement was reported. This reinforces the radical nature of CAD systems and the long learning curve required for adaptation to a technology of this type.

Burkhill (1986) finds it takes nine months to a year for a designer to become as proficient in using the CAD system as when using the older pre-CAD "manual" system. Furthermore, the estimated period of a time for a company to gain the majority of benefits from CAD was given as between three and five years.

Finally organic restructuring of the work group is relatively inexpensive and not contingent on using a CAD system, but does show performance improvements for both designers and draughtsmen.

Norton (1985) says that there is a technology/environment "gap" between the capabilities of a CAD system and the actual use of that system (see also Cooley 1977). Senior management often critically misunderstand these capabilities. Senior management determine the level of company use of these capabilities which in turn determines the success or failure of the CAD system.

The theoretical discussion of the potential impact of CAD on the design process involves examining its qualitative and quantitative aspects. The interaction between the qualitative and quantitative aspects is unknown as is the ratio of the two variables (Cooley 1987 states it is impossible to divide the design process in this way). Both the ratio and the nature of the interaction are important. They are dependent on the subject of the design process and where in the process CAD is used, whether for drawings or design. Often CAD is assumed to take over the quantitative aspects of design. However Norton (1985) points out that there is really an increase in the rate of quantitative uptake: ie. management promote a "the quicker the better" ideology, implying design quality falls. Thus the interaction between quantitative and qualitative aspects of design are distorted, resulting in possible harm to the qualitative aspects.

Although each company has its own problems with CAD, the disadvantages are often reported to be outweighed by the improved quality of design as the designer is freed from routine design activities and is able to concentrate on creative design.

2.4.9 Running CAD

The literature on the post-implementation of CAD systems is very limited. This is possibly due to the long, slow evolutionary nature of CAD systems.

Stark (1988) uses the term "mature" CAD system, as a stage reached about 12 to 18 months after installation. One major consequence of maturity is a change in emphasis from the high pressure initial problems to a pattern of regular and predictable events. For the system to be effective and successful Stark suggests three categories of activities to be undertaken:

1. Define, document and consolidate working methods, systems management and in-house improvements.

2. Review the system and re-adjust plans for the future accordingly.

3. Specify long-term guidelines to fully integrate CAD into the company (ie. CIM).

Consolidating the progress made with the CAD system includes preventing users from reverting back to the drawing board and pencil (because they "feel" it is quicker) and managing the data fed in or already stored in the system (ie. using an effective database management system/ procedures). Decay of the system can also be prevented through comprehensive use of documentation and forward-looking, long-term plans.

Another perspective on the modern state of working CAD systems is offered by Orr (1985) who showed that out of the 15 000 CAD systems then used in the production of mechanical engineering products, only 1 000 were used in design (in contrast with use of CAD for draughting). It appears that in the majority of cases a combination of spurious financial justification for CAD (see section 2.4.2) and post-implementation following the path of least resistance results in the system being used for draughting only (ie. as an "electronic drawing board"). Since the real potential for CAD lies in the implementation of a 3D modelling system, Orr argues:

> "draughting automation may be beneficial, but it should be set aside as 'too expensive' if it delays the implementation of design automation."

One of the most common organisational changes proposed and reported in the literature as part of CAD implementation is the appointment of a CAD manager and/or a systems administrator. Pipes (1987) sees the CADCAM manager[2] as "the most crucial component in any new installation" (based on the importance of the introduction of new technology as the major component in successful later use) because of the pivotal role they assume in running the system, controlling the information flow, training new users, supporting existing users and finding "money-saving" applications for the system. Pipes lists the type of responsibilities a CAD manager would be expected to hold:

- day-to-day running of the system;
- dumping, archiving and housekeeping;
- seeing that tools are always available to those who need them;
- advice on system problems;
- help develop libraries and user commands;
- direct software developments and parameters;
- maintain the document standards;
- monitor new developments in the CADCAM market.

Other responsibilities that might be added to this list include:

- allocating work to the CAD designers/operators;
- deciding which jobs are more suitable for CAD (and which are not);
- training (either directly or organising external courses).

[2] The CADCAM manager is very similar to a CAD manager or systems administrator but includes a slightly wider area of responsibility.

Pipes suggests that in a larger organisation the CAD manager responsibilities would be split between two roles, one retaining the title CAD manager (responsible for the developing and implementing the strategic plans) and the other being a systems administrator (responsible for the day-to-day, 'non-people management' activities).

Norton (1985) further enhances the idea of the CADCAM manager, saying that even a small installation (ie. a simple system with multiple workstations) requires a support team with a minimum of two individuals, ie. CAD facilities manager and systems manager (cf. Pipes earlier). With a larger installation it is possible to split the systems manager's job into an operations manager (responsible for hardware maintenance and the system operations) and a software manager (responsible for software development and training), with the CAD facilities manager supervising the entire operation.

The above job outlines are not presented as prescriptions, but guidelines for structuring an effective CAD support team (Norton 1985). In addition five steps for effective CAD facilities management are presented:

1. *Set objectives* - for the CAD organisation, and in line with the goals of the general organisation.

2. *Organise* - classify the work, divide it into manageable activities, then further divide the activities into manageable tasks. Merge the users and the tasks into the CAD organisational structure.

3. *Motivate and communicate* - with the subordinates to create a team.

4. *Establish measurement tools* - for the performance of the whole CAD organisation and the individuals within it. Analyse performance, appraise it, interpret it and communicate it to subordinates and superiors.

5. *Develop people* - through the CAD manager's people management style.

2.4.10 Evaluating CAD

CAD systems in their modern form have been introduced and in use for about 10 years. In this time few studies have investigated whether CADCAM actually benefits the investor. Instead there remains a high degree of faith in vendors and the basic idea that the benefits of CAD are self evident. This is clearly demonstrated in a report by the British Institute of Management (BIM) together with the British Production and Inventory Control Society (BPICS) and Cranfield Institute of Technology (CIT) on CADCAM users in manufacturing (New 1986) which shows that 54% of companies achieved moderate to high positive results while the remaining 46% achieved low, zero or negative results (over 20% of the companies fell into the category which saw no return from using CADCAM).

Lawrence (1987b) reports that 75% of CADCAM users achieve only half the expected throughput from the CAD system (it is not made clear whether this is attributed to unreasonable vendor claims or mis-management of the system). Lawrence (1987b) also quotes an OD Systems (who market the IVAN investment analysis software tool) report which says that to justify investments in CAD, productivity savings of 3 or 4:1 are quoted, but there is little evidence (apart from a few specific applications eg. pcb design) that this is at all realistic (cf. Ebel and Ulrich 1987). Lawrence (1987b) also highlights the high running costs for new technology, eg. although the initial installation costs £200 000, the running costs over ten years may total £500 000.

However limited utilisation, low productivity and long paybacks have not deterred companies from investing in CAD. The long paybacks are attributed to the installations still being "young". Low productivity is attributed to using out-of-date measurement systems which fail to include the key advantages of computerised systems. The low rate of productivity is seen as resulting from the combination of inexperienced users and powerful computer systems. The BIM/BPICS/CIT report (New 1986) says that the fault lies in the short payback period for CAD systems (eg. three years), which is specified by the accountants. The "accountants' view" is fundamental to users' perceptions of the value of their CAD systems. Primrose, Creamer and Leonard (1985) criticise the "simple" payback accounting method. However it has been found that 79% of all companies use this accounting method, and about a third of those use it as the principal appraisal technique (Lawrence 1987b). The simple financial model is used to build a set of figures to satisfy the accountants at the cost justification stage, but the system inevitably later fails to meet those benchmarks (this is also discussed in section 2.4.2).

A possible solution to the question of the actual benefits of the CAD system would be to conduct a "CAD audit" (Williamson 1986). As with a financial audit this involves an evaluation of the current situation; but unlike its financial counterpart the CAD audit goes further and makes recommendations about where the CAD system and surrounding organisation might be improved (some larger financial accounting firms now offer a management consultancy service which also addresses issues such as the effective use of new technology and in particular CAD, eg. KPMG Peat Marwick McLintock, PA Consulting, etc. presented a set of CAD advisory seminars at the CADCAM '91 show (CADCAM International 1991)).

However as Lawrence (1987b) says:

> "The difficulty of including intangible benefits into a system has almost certainly deterred companies from carrying out audits to assess how well the system has performed - particularly if intangibles were not taken into account at the start."

The OD Systems report also highlight the potential conflict in a "post-audit", if the accountants are seen as trying to disclose errors made by engineering.

Again Lawrence sees the benefits of CAD (and CAM) as a function of the level of senior management support and involvement. The cost of a CADCAM system is only 30% of the equation, the other 70% is dependent on how it is introduced, utilised and managed. New (1986) argues that it is important for users to include all the benefits of CAD. These include the tangible (ie. ease of repetition, higher quality and higher productivity) and also the intangible rewards (ie. revenue enhancers) such as:

- higher market penetration through short reliable lead times and product flexibility;

- using CADCAM as an "entry ticket" to some industries (ie. to compete effectively in industries such as electronics or aerospace) irrespective of the financial investment[3].

2.4.11 CAD - The Future?

The future of CAD may progress in many different directions. These future directions can be grouped into two main themes. One group is the development of computer hardware and software and the changes that might be associated with those developments. The second group is more "fundamental" to the nature of computer systems structure and concerns the development of new computer systems according to "radically" different concepts eg. human-centred systems design. These development groupings are arbitrary and are not mutually exclusive but they will be examined separately for ease of analysis.

As has already been seen in the 1980's, forecasting the development, spread and relative price of computerised technology is very difficult. The main reason for this is a highly unstable market coupled with rapid technological developments. One of

[3] This may be true, or it may just be a function of the publicity surrounding computer-aided technologies. Whereas CAD might be necessary for entry in modern pcb and VLSI style industries, it may also apply to other industries, such as aerospace.

the advantages of longitudinal studies is their ability to feedback and correct their own forecasts, eg. Arnold and Senker (1982) followed by Simmonds and Senker (1988, 1989a, 1989b); however the first study failed to appreciate the future importance of the PC or networks on the CAD systems market. Therefore future studies should include a caveat saying that forecasts cannot include any radically new concepts, merely expand existing ones.

Apart from using CAD as the basis for a company-wide communication system, Axe (1988) saw one development of CAD by linking it with holographic generators to produce a "true" three dimensional computer-generated model. The initial advantages would be financial, such as in larger scale projects where a physical model would no longer be required. Macilwain (1989a) reports on a seminar aimed at assessing and discussing the developments in design automation over the next 10-15 years. One of the most important points made was:

> "our current vision of the place of the computer in society cannot rely solely on how computers have been used up until now."

Some of the developments discussed included the move from computer-aided documentation to computer-aided development (with computer-aided design as a temporary intermediate step); or tools that encourage discussion between individuals from different disciplines eg. merging design, preparation for manufacture and test analysis. Another area of potential major development concerns the man-machine interface. Orr (in Macilwain 1989b) reports the development of a "dataglove". This is a glove with a mesh of fibre optic sensors over it feeding back information to a computer on the exact positioning of every part of the hand inside it. The dataglove could be linked in with some sort of computer solid model to enable the hand to itself be represented and interactive in what is called "virtual reality". To isolate further the virtual world from the real world, the screen could be brought close to the eyes with the development of a type of electronic spectacles, ie. a single line of light-emitting diodes with a vibrating mirror, and the user could wear stereo headphones, and even a whole body suit wired with position and motion transducers.

Developments in these areas are already well under way although mostly for trivial and specific activities. Personal Computer Magazine (April 1991) reported the first commercial application of virtual reality in which computerised technology enables a fantasy role to be enacted. Other writers have sketched future possibilities for "Virtual Workspaces" (VW's); Pruitt and Barrett (1991) describe software development carried out within a Corporate Virtual Workspace (CVW), in which all interaction between people takes place in an advanced form of virtual reality (this could equally be used in a future mechanical engineering design process).

Another development possibility is the combination of a CAD system with an expert system (often called ICAD) such that design rules can be stored and used as a set of future "constraints". Therefore the computer system and not the user maintains a check on the internal validity of the design under the appropriate design rules (see Medland 1986).

Other technical developments are needed before CAD can move forward in another field, the much discussed integration of CAD and CAM with CAPP to form a CIM system (Ebel and Ulrich 1987). Integration on this scale needs either purpose-built systems or a high degree of standardisation, eg. MAP, TOP, to allow the different computing systems to exchange and understand each other's information. It is possible that a CIM systems could be supplemented by tele-controlled production. Using ISDN (integrated services digital network) technology the research, design and production offices could be located at a company's centrally-based headquarters which uses satellite links to control the regional plants.

Other possibilities also exist for integrating CIM systems with other data-processing systems both internal (eg. cost accounting systems, distribution and sales systems) and external (eg. subcontractors and customers) to the company

(Ebel and Ulrich 1987). Each development carries with it a set of advantages, eg. computer links with subcontractors are vital for effective Just-In-Time (JIT) production systems which reduce capital costs through reduced inventory. Overall the integration of computer systems aims to produce a highly competitive organisation, flexible and organised, and able to cope with modern unpredictable economic markets.

Management decisions are vital to the use, diffusion and viability of new technologies (see chapter 2, section 2.1). Ebel and Ulrich (1987) report on Forster and Syska's (1985) study of 73 companies in the Federal Republic of Germany (on their experiences of linking different computer systems together). The results show that overall management expectations were higher than actual achievements, ie. positive effects of integration of design and manufacture had been overemphasised in order to sell the appropriate technology. A similar study in France in 1986 (Desclaix 1986) shows management held slightly more realistic expectations which could possibly be attained. This is thought to be a function of the growing accumulation of experience with such systems and therefore should lead to even more realistic expectations in the future.

The other group of developments in CAD systems is that which would "radically" alter its nature. One possible direction is the development of human-centred computer systems. Cooley (1987) defines the human-centred concept as:

> "a computer-integrated manufacturing systems will be more efficient, more economical, more robust and more flexible if designed to be run by a human, than a comparable unmanned cell".

This concept is encompassed by the ESPRIT project 1217 which was set up to develop a manufacturing cell comprising integrated CAM, CAD and CAP modules, in three European countries. Economically, this was expected to provide benefits from:

- Increased efficiency resulting from incorporating the operator's skills and experience into the running of the cell.

- Human-centred systems provide more stimulating and challenging work resulting in a higher degree of motivation in the operator. In addition the operator will need to provide greater intelligence, involvement and commitment in their work.

In the particular case of CAD this implies adapting the technology to encompass the user's tacit knowledge built up from experience in using the drawing board.

2.5 Technology and the Role of the Supervisor

While the supervisor role has its own set of problems (section 2.3.2) it is possible that the introduction of new technology accentuates and exacerbates these. In some contexts the new technology might also initiate new problems. This section aims to explore the thinking that surrounds the early and more modern debates of the effects of new technology on the role of the supervisor.

The two main alternative views about the effects of technological change on supervision (Dawson 1986) are:

- the role of the supervisor is becoming more **peripheral**, ie. technology and work re-organisation are causing the erosion of the supervisory role because they allow control of the operations to be removed from the point of production, so the supervisor becomes peripheral to management;

- the role of the supervisor has become more **pivotal**, ie. new technology has caused the overall complexity of the production process to rise, therefore the supervisor becomes redefined as a "technical expert" with a narrow span of control but as such is pivotal in the control of smooth production flow.

Edwards (1979) examines new technology and how it might enable management to alter the role of the supervisor. This could be done through transferring the traditional supervisory activities (directing and monitoring labour) to the new technology. Further, computerised technologies can be set up to monitor and evaluate work performance, thereby eroding the supervisory tasks of detection, inspection and evaluation. The overall result is the erosion of the traditional functions of supervision.

However this analysis of the effects of technological change on supervision are based on a rather narrow analysis of supervision, ie. in terms of the traditional labour control functions. Dawson (1986) suggests that with the introduction of new technology there could be a redefinition of supervision and a shift in supervisory emphasis. Although the traditional labour oriented function of supervision might be eroded, the wider skills and concerns of supervision could provide an important role for the supervisor within technological innovation.

Another study examining the role of the supervisor in production in a range of companies, saw a shift in emphasis (Woodward 1980). This can be characterised as a move away from labour/people issues towards machine and process supervision. This study identifies not just one supervisory role but many, ranging from the traditional "policing" role seen in unit and small batch production organisations to the "technical expert" and "trouble shooter" role seen in process production organisations.

Both sets of studies agree that the role of the supervisor has changed through the introduction of new technology. However while Edwards says this signals the eventual elimination of traditional supervision, Woodward argues for a range of supervisory roles developing in different categories of production industries. The difference in opinions apparently derives from the differing emphasis each applies to the role of supervision. Edwards focuses on changes to the traditional *labour control function of supervision*, while Woodward examines changes to the role of the *formally defined first-line supervisor.* The conclusions that the role of the supervisor will be either "peripheral" or "pivotal" to workplace control under the influence of technological change, have arisen as a result of these conflicting emphases.

These two differing views are not necessarily contradictory. Where the technical expert supervisor is seen as an eroded version of the "traditional" supervisor and pivotal to the control process, it is still not pivotal in the management structure.

Within this general discussion of the effects of technological change on the role of the supervisor, computer-assisted technologies have been highlighted. The pervasive nature of computer-assisted technology suggests that it may have a wide and varied impact on organisational structures, across many different types of industries. It is likely that computer-assisted technologies will have the most important impact of any of the new technologies available at present.

2.5.1 Computer-Assisted Technology and the Role of the Supervisor - The Early Debate

Since the late 1950's the literature has seen a debate on what effects computer-assisted technology might have on middle management and supervision. The two central issues in this debate are, a) whether computer technology would be used to centralise or decentralise control of production operations (eg. Myers 1967) and b) whether computerisation would enhance or erode the layer between top management and the work force (eg. Whisler 1970). The early debate raises three main points (Dawson 1986):

1. Organisational structure is not **determined** by computer technology, but is affected by the strategies adopted in the introduction and use of the technology, ie. centralisation or decentralisation of the decision making function.

2. Centralisation strategies are likely to erode supervision through the removal of control from the point of production.

3. Decentralisation strategies may encourage either erosion **or** enhancement of supervision eg. retraining supervisors in the use of computer technology would allow them to hold better positions in the organisation, whereas without this it is highly likely their functions would be reduced leading to an erosion of their authority.

Therefore it appears that the strategies used in the introduction of computer technology are important in explaining the outcome on the role of the supervisor.

These early studies however tend to concentrate on the introductory process as the only indicator of the outcome of computerisation on the role of the supervisor. If technology has progressed, then surely the debate needs to do likewise. The early debate saw computerised technology very much characterised by the hardware and software of that era. With the introduction of the microchip and more modern programmes (section 2.2.3), the choices for centralisation or decentralisation of control may not be as definite as before. In addition the early debate failed to consider the longer term effects of either strategy or the resulting effects of changing strategy over time (whether planned or due to circumstances). Therefore examination of the role of the supervisor after the system is up-and-running might be a valuable source of inquiry.

So how is the 1980's supervisor coping with or adapting to computer technology? What do more recent studies say about the early debates? Did those early predictions come true?

2.5.2 Computer-Assisted Technology and the Role of the Supervisor - The Modern View

The general picture, found in more recent studies, indicates that computer technology is:

> "contributing to an erosion of both the labour orientated (traditional) and machine orientated (technical) role of the supervisor" (Dawson 1986).

Rothwell (1984) explores the effect of new technology on the management of people and the organisation of work in over 20 case study companies, in a wide variety of industries. Although the supervisory roles and functions differed in each company, Rothwell claims that it is possible to see some patterns and draw some conclusions. The general conclusion supports the hypothesis that supervisory functions are being eroded. Technology often reduces the supervisor's area of discretion, ie. the supervisor has less choice over what can/cannot be done due to the informal control system being displaced by a formal pre-programmed computerised system. Possible effects of the computer systems are:

- reduction in the level of co-ordination needed, eg. between a supervisor's own section and other sections;

- reduction in the supervisor's status as perceived by the management, eg. information available to a much wider audience, therefore the supervisor is no longer seen as a specialist;

- development of other specialist managers, eg. Data Processing managers who might be perceived as being in opposition to the supervisor's role;

- indirectly reducing the likelihood of career progression for the supervisor, through general erosion of the role.

However the link between new technology and erosion of the supervisory role is not a concrete one. Rothwell (1984) demonstrates that some computer systems allow greater centralisation and functional integration thereby showing a "flatter" hierarchy, including greater autonomy at lower levels. This results in an enhanced role for the remaining supervisors.

Enhancement of the supervisory role is not homogenous. In some cases the new technology allows supervisors to give greater attention to the "people" side of the job, through automation of the routine planning, progress chasing and paperwork, ie. development of the supervisor's team-building and "indirect" motivational skills. In other cases supervisors are required to become "technical experts", spending their time on fault finding, combatting breakdowns with the hardware as well as liaising with others both up and down the production line.

Kerr et al. (1986) also recognise that there might be fewer supervisors in the future. Those that remain would have a radically different role to that of "traditional first-line supervisors". This was not necessarily to imply role erosion, but could be a move to activities centred around both external representation and internal human relations.

Rothwell (1984) is also very critical of the extent to which managers foresaw, planned and "managed" the changes involved in the introduction of new technology. On the whole the results show this to be inadequate and left the supervisors with diminished responsibility and utility. Therefore Rothwell concludes by questioning the need for the role altogether.

This question of whether the role of the supervisor is needed after the introduction of new technology is also addressed by others (eg. Wagel 1987, Kerr et al. 1986, Rose et al. 1987). Burnes and Fitter (1987) examine the impact of advanced manufacturing technology (AMT) on supervision. Although not able to determine the exact future development of the role of the supervisor they conclude that the increased complexity of technology and increased interdependence of component stages would cause a shift in emphasis for the supervisor towards dealing with "system problems". They also suggest that totally eliminating supervisors is a mistake because it is the informal supervisory practices which enable the effective functioning of a work group. Computerised systems can provide management with highly visible pictures of the supervisor's actions and possibly deter them from making any risk-involved decisions.

Two of the major benefits of advanced manufacturing technologies are the increased productivity and improved quality. These can only be achieved through effective maintenance of the computer systems. The supervisor is in an optimal position to use his interpersonal skills to negotiate quick access to the support systems vital to the maintenance. Therefore, instead of automating the supervisor's job, the opposite could be argued. The supervisor role should be enhanced to take advantage of interpersonal skills and to enable him to coordinate production across functions.

Simmonds and Senker (1988) also address this question and attack the above argument. In the section detailing the outline for the completion of their project they pose the question:

> "Will the traditional role of the drawing office supervisor disappear with more widespread use of CAD? How will the design function be coordinated in the future?"

Simmonds and Senker's follow-up report (1989) unfortunately does not investigate this area further. Their findings do, however, show the development of a CAD manager role (including a significant increase in the size of the support team between 1981 and 1988) which has two main objectives: a) strategic management (of the system, integration of the design and production processes, plus system expansion) and b) technical support. The CAD managers had mainly come from the promotion of "middle level design engineers" but in the empirical interviews Simmonds and Senker only reported interviewing one CAD supervisor.

A few researchers (eg. Buchanan and Boddy, Rothwell, Dawson and McLoughlin) have written extensively about computer technology and the role of the supervisor. Most agree with the Child and Partridge (1982) hypothesis that supervisors are "lost managers". Buchanan and Boddy (1983) argue that there are four main paths to the erosion of the role of the supervisor:

1. Where the supervisor's responsibilities are incorporated into the new technology eg. work pacing by the machinery.

2. Where the computerised technology automatically captures and analyses production performance information.

3. Where information gathered through the new technology provides a "window" on individual performance.

4. Where there is a loss of skill superiority by the supervisors to their subordinates or others with specialist technical computer expertise.

McLoughlin and Clark (1988) show that in the case studies of Buchanan and Boddy (1983) there was only one case where the supervisor role was abolished. This plant (continuous process) then showed a 50% increase in labour productivity and a more consistent quality of production (as compared to a conventional plant). However Buchanan and Boddy (1983) also showed that in a similar situation, where computerised technology had been introduced and the supervisor role retained, there had also been a 50% improvement in labour productivity and a more consistent quality of product. (This highlights the degree of conflict present in the literature and the care which must be taken in interpreting that data.)

Dawson and McLoughlin (1988) agree that the "skill superiority" of work groups and operators under a supervisor erodes his authority while broader organisational changes indicate a change to the supervisory system and possibly some parts of the organisational system become redundant.

Although the term first-line supervisor is commonly used in the research literature, it is important to recognise that definitional problems of supervisory tasks and roles do occur (eg. Thurley and Wirdenius 1973). It is possible that some individuals within an organisation act in a supervisory capacity although they are not necessarily defined as a "supervisor". Thurley and Wirdenius argue for the use of the term "supervisory system of control" which Dawson and McLoughlin (1988) define as:

> "A network of formally and informally recognised roles, all interrelated, which are concerned with the direct day-to-day control of production or services."

The main point to draw from this is that the implications of new technology for supervisors are not just concerned with the traditional labour control aspects of the first-line supervisor's job but also the wider operational control this supervisory network exerts.

This section began with a reference to the four models of Child and Partridge, but some writers now feel that this is too narrow, because the definition of supervisor underlying these models is too narrow (Dawson and McLoughlin 1988). The introduction of computer-based systems allows for the redesign of a range of roles within the supervisory system. The argument is that these new roles should be centred around an "information manager" role, who can make full use of the technology's ability to provide real time information on the status and performance of work operations. This also echoes Rothwell's (1984) findings on the enhanced supervisory roles. However Dawson and McLoughlin (1988) specify that for this to be possible with CAD, the organisation has to be moving towards Computer Integrated Manufacturing (CIM), which is not yet prevalent in this country. Therefore their hypothesis is more of a proposal for the future position of design supervisors than a "solution" for today's situation.

One other previous study that has directly investigated the introduction of CAD technology in engineering drawing offices has also looked at some of the possible changes in the supervisory role. McLoughlin (1990) reports his investigation of five organisations' experiences of adopting CAD in the early 1980's. Although different forms of work organisation around the CAD system were evident in each case study company, it was possible to classify them according to two independent variables:

1. type of operator jobs created:

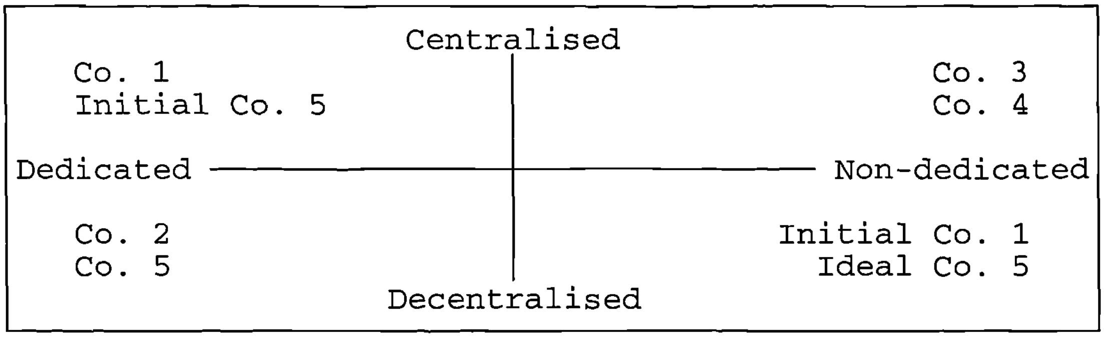
   - dedicated, ie. full-time CAD draughting staff;
   - non-dedicated, ie. using CAD for a project was optional.

2. location of the CAD workstations:

   - centralised, ie. all together in a CAD "bureau";
   - decentralised, ie. dispersed and mixed in with the conventional drawing office.

Each company could then be evaluated in terms of its relative position according to the form of organisation surrounding the CAD system (figure 2.11).

Figure 2.11 **Two Dimensions Surrounding a CAD System** (source: McLoughlin 1990)



The narrow task range and discretion area in Company 1 matches the perception and use of CAD as an electronic drawing board. However this resulted in a "distant" relationship between the operators and the system and therefore a degree of job dissatisfaction.

In Companies 3 and 4 the greater autonomy for design and draughting office staff matches Buchanan and Boddy's idea of "complementary relationship" between the skills of the users and the capabilities of CAD. But complementarity can be "frustrated" by inappropriate management, ie. the CAD management provided CAD services but the CAD users reported to non-CAD trained supervisors (in Companies 3, 4 and 5). Therefore the operators used the system less because their supervisors did not encourage them to do so. In addition the management's attempt to increase system utilisation through shift working (Companies 3 and 4) had the opposite effect and the situation became worse.

2.6 Chapter Summary

Apart from briefly looking at some of the literature on job design and redesign (Child 1984), the role of the traditional first-line supervisor (Bean et al. 1985-6) and the four classic models of supervisory development (Child and Partridge 1982), the first part of chapter concentrates on the relevant literature concerning new technology and in particular CAD. Using a framework based on the traditional "lifecycle" implementation process for a CAD system the review has attempted to demonstrate the range of perspectives that exist in each stage. Each stage is vulnerable to any number of problems which each perspective tries to address. Several core issues emerge:

- the recognition that computer technology does not exist in a vacuum, but includes human and organisational aspects which need to be addressed throughout the whole "lifetime" of a system;

- implementation of a computer system does not begin with the arrival of the hardware/software and end with the system running for the first time *but* is a complete process beginning with the state of the organisation (ie. level of development the company has reached) prior to the introduction of a computer system through the justification process, initial introduction, dealing with resistance to change from both the organisation and from individuals, long-term running of the system, evaluation of the system and eventual move (possibly evolution) to a new improved system;

- a lack of senior management's recognition of the strategic value of computer technology;

- that strategic choices exist, which affect the organisation (Child 1984) and the decisions made regarding a computer system are often part of these choices, ie. choices made in the initial implementation of a new technology are very important in how successfully it is later utilised (Mumford 1969, Johnson et al. 1985, Dawson 1986).

Of particular importance to this thesis, little has been written about post-implementation of CAD systems. Only Stark (1988) has focused on "mature" CAD systems and finds a change in emphasis from high pressured initial problems to patterns of regular/predictable events. However for effective use of the system Stark recommends that the system should have guidelines so it will become fully integrated with the rest of the company, ie. CIM. While this is a popular view, it assumes that the rest of the company has the technology to link with the CAD system and that a CIM strategy is automatically appropriate for the company. While the technological integration is possible in some organisations, this says nothing about the potentially serious ramifications of integrating individuals across the organisation.

Finally the future possibilities for CAD technology alone are extremely wide and varied. While some of the more "far-fetched" ideas are improbable, it is almost certain that CAD technology is progressing at an increasing rate. While the technological advances alone will not counter many of the problems discussed in this chapter, future CAD systems designers do have the choice to acknowledge some elements of the human factors and the organisational context in which a CAD system is used (the separation between design and use of a computer system will be discussed further in chapter 3). Projects such as the ESPRIT human-centred systems (Cooley 1987) which seek to integrate tacit knowledge for primary users may also provide a better working tool for supervisors.

The last section of this chapter examined some of the early and more recent debates on the effects of new technology on the role of the supervisor. Some researchers argued that the supervisory role would become more peripheral (Edwards 1979) through technological change, while others argued it would become more pivotal (Woodward 1980). This dichotomy of views arose from differences in focus between changes in the labour control function of supervision (characterised in the more peripheral argument) to changes in the role of the formally defined first-line supervisor (characterised in the more pivotal argument).

The more modern view is that computer technology results in the erosion of both the traditional and technical role of the supervisor (Dawson 1986). However, Thurley and Wirdenius (1973) and Dawson and McLoughlin (1988) argue that to see supervision as only concerned with the traditional labour control aspects of the formally defined role of the first-line supervisor is too narrow. Dawson (1986) proposes the reconceptualisation of supervision as a supervisory network or "supervisory system of control" which can be used to examine "the effects of computer technology on the function of supervision" (the supervisory system is discussed further in chapter 3).

CHAPTER 3
THEORETICAL FRAMEWORKS

3.1 Introduction

This chapter contains four mutually exclusive sections (3.2, 3.3, 3.4 and 3.5), gathered together in this chapter because each details a different theoretical framework used to support and analyse this research. The first framework examines the concept of supervision and proposes the idea of a "supervisory system" (section 3.2). The second framework looks at analysing qualitative data using a "Grounded Theory" approach (section 3.3). The third framework introduces the idea of "cognitive mapping " (section 3.4). The fourth framework considers new technology within a "Structuration Theory" perspective (section 3.5).

3.2 Supervisory Systems: A Conceptual Framework of Supervision

3.2.1 Introduction

It became clear from the literature review that a number of complexities and lack of consensus surround the identification of any job role, in this case that of a design supervisor within a large organisation. In many situations individuals may be perceived as holding "supervisory relationships" without holding an official supervisory title. To overcome this a conceptual framework was adopted (from Dawson 1986) to enable a clearer understanding of individual roles within the design function of any organisation.

3.2.2 Definition of Supervision

Supervision may be defined in many different ways and one useful broad definition is supervision as the:

"direct control of workplace operations (whether by human or non-human means)" (Dawson 1986).

This locates supervision within the context of the *overall control of the workplace* ("control" here refers to the control of the whole workplace and includes some degree of autonomy for individuals within that). Major components of the supervisory control function include:

- planning workplace operations;
- directing workplace operations;
- monitoring workplace operations;
- evaluating workplace operations;
- correcting and adapting workplace operations.

Each component can be achieved through a number of different "personal" and "impersonal" control methods.

Previous researchers (ie. Reeves and Woodward, Edwards) have developed a four-fold categorisation of control systems, which varied according to:

i) the degree to which the control system was either integrated or fragmented;

ii) whether the control was performed personally or impersonally.

Therefore the supervisory control elements (as shown above) may be distributed and incorporated into other methods of controlling shopfloor operations, eg. elements of control embedded in production machinery; administrative/bureaucratic means of control embodied in operating rules; the formation of "self-supervising", autonomous work groups (in the sociotechnical sense of control over their own job tasks).

Using this framework the relationship between the control functions of supervision and computer-assisted technology can be investigated. Dependent on the findings, recommendations can then be made with regards to such areas as, widening the supervisory area of control, full automation of systems and the abolition of the supervisory role, etc.

3.2.3 Supervision and Span of Control

The span of control, in this context, generally refers to the ratio of subordinates to supervisors at each level in the "supervisory hierarchy of control". Since the focus is on the labour control function of supervision, this applies only to changes in the traditional supervisory role and not to changes in the control function of supervision.

Dawson proposes that the concept be expanded to refer to "the discrete area of operations under the supervisor's direct control in the production of a good or service". Consequently where the reduction in control of one element (eg. labour) is offset by extension in another control function (eg. process/machine supervision) it is possible for the role to be eroded, enhanced or redefined. Further, some aspects of individual roles may be eroded/redefined while others may be enhanced/created, ie. changes to individual roles do not always equate with changes in supervision.

This concept is mainly used in the analysis of overall changes in the control functions of supervision, and indicates other elements of supervisory control. But it does not provide a framework for detailing shifts in supervisory emphasis (which is developed below).

3.2.4 Supervisory Control Functions

One common characteristic of supervisory positions across industries is that they all, in some way, control the direct workplace operations. To be more useful for analysis the supervision control characteristic can be broken into four broad elements, each has different emphasis:

Table 3.1 **Classification of Supervisory Control Characteristics**

Function type	**Control characteristics**
i) *Labour control function*, where the main purpose of supervision is to direct, monitor and regulate the work of labour at the workplace.	This represents the traditional labour control functions including directing the work, monitoring and evaluating the performance and disciplining non-compliance of labour. In addition the other control functions to be included here are dealing with human contingencies (eg. accidents to staff, absenteeism) and other labour management tasks (eg. allocation of work, staff grievances).
ii) *Product control function*, where the main emphasis of supervision is on the "product" of the operating system. The key task here is to use inspection to maintain the required standard of "product".	Within this the supervisor may concentrate on one or more areas out of: • the production methods used by the operators; • the use of materials and cost of production; • the quality of goods or service produced.
iii) *Resource control function*, where the main purpose of supervision is to control and co-ordinate material resources in the production of a good or service.	Supervisors use direction, appraisal and regulation of resources to ensure efficiency of operations. Again they are in direct control of the operating system. The key task here is alleviating bottlenecks and preventing material shortages.

Function type	Control characteristics
iv) *Machine control function*, where the main emphasis of supervision is on the maintenance of the technical system of production.	In this "machine-oriented" operating system, the supervisor generally requires extensive technical skills and knowledge. The supervisor's primary concern is with monitoring the machine elements of production and ensuring the continuity of the technical systems (as opposed to controlling the pace of work and levels of worker effort).

The general framework presented above offers a broader concept of supervision and can be used to analyse the general effects of a change in technology. It shows shifts in supervisory emphasis under different technical and computer-based operating systems, as opposed to changes in particular first-line supervisory roles. However it is important to acknowledge that the main emphasis of the supervisory control function might not be the same as the main job tasks of the individual supervisor (eg. where the supervisor's main function was to control the output of the operating system but the main job task was to deal with equipment malfunctions and staff absenteeism).

This framework does not argue that the supervisor's tasks are either "universal" or "static" and, as has been stated before, tasks vary greatly across organisations. Therefore any investigation of the supervisor's job needs to be conducted at their place of work. The following section now discusses a framework which can be used to identify the supervisor's hierarchical position or "powerbase".

3.2.5 The Supervisor

The central argument presented here is that the supervisory function can be dispersed across several organisational levels and therefore it is misleading to focus only on the "pure" role of the first-line supervisor (see Thurley & Wirdenius, Dawson etc.).

In the next sections the criteria for identifying and defining supervisor's positions will be described, followed by an examination of the levels and types of supervisory positions.

3.2.5.1 Identifying and Defining Supervisory Positions

The most common method in the literature for defining supervisors is to use "formal" job titles (eg. the foreman). One problem with this is that foremen may not hold comparable positions within the organisational structure in different production environments (see Thurley and Wirdenius, National Institute of Industrial Psychology (NIIP)) therefore solely using the job title is inaccurate. Other problems occur because the control function of supervision may be the concern of a number of individuals, each holding one of a range of different job titles.

Another possibility for identifying supervisory positions is "job task", and some tasks may be said to be more easily identifiable as "supervisory tasks" than others, eg. monitor performance of subordinates, identify needs for further information/input. But difficulties arise because of the variety of tasks and problems dealt with by the supervisors.

Therefore to define supervisory positions it is necessary to use the broader definition of supervision shown above. This identifies individuals as holding a "supervisory relationship" according to the criterion that they **participate in the direct control of workplace operations**. This allows a wide variety in the job titles and tasks associated with these positions.

In practice it appears the control function of supervision is distributed across a network of interrelated roles each with different supervisory elements and relationships. To combat this the criterion of "authoritativeness" can be used to identify and differentiate between supervisory roles.

Using the authority and status attributed to individuals by management locates "formal" supervisory positions, but bypasses "informal" supervisory positions. These are individuals who are not formally defined or recognised as holding supervisory jobs but in practice do perform some supervisory functions. Etzioni (1964) recognised this informal organisational command structure and suggested a three-fold distinction:

Figure 3.1 **Etzioni's Three Fold Distinction between Officers, Formal and Informal Leaders** (source: Etzioni 1964)

Officers
individuals whose power is solely dependent on their formal organisational position

Formal leaders
individuals who combine organisational authority with personal influence

Informal leaders
individuals with no formal organisational power, but whose position is determined by consensus of their advocates

This suggests that "informal leaders" exist outside the traditional organisational charts. One solution is to use the perceptions of the individual's subordinate(s) and superior. Therefore supervisors can be identified according to the "extent of their authority (and hence status) accredited by their management and/or operatives" (Dawson 1986).

3.2.5.2 Level and Types of Supervisory Positions

Even though supervisors can be identified, they may still occupy one of a number of different "levels" and "types" of supervisory positions, across and within particular organisations. These occur on a continuum with "mixed" managerial-supervisory roles at one end and "mixed" supervisory-operative roles at the other.

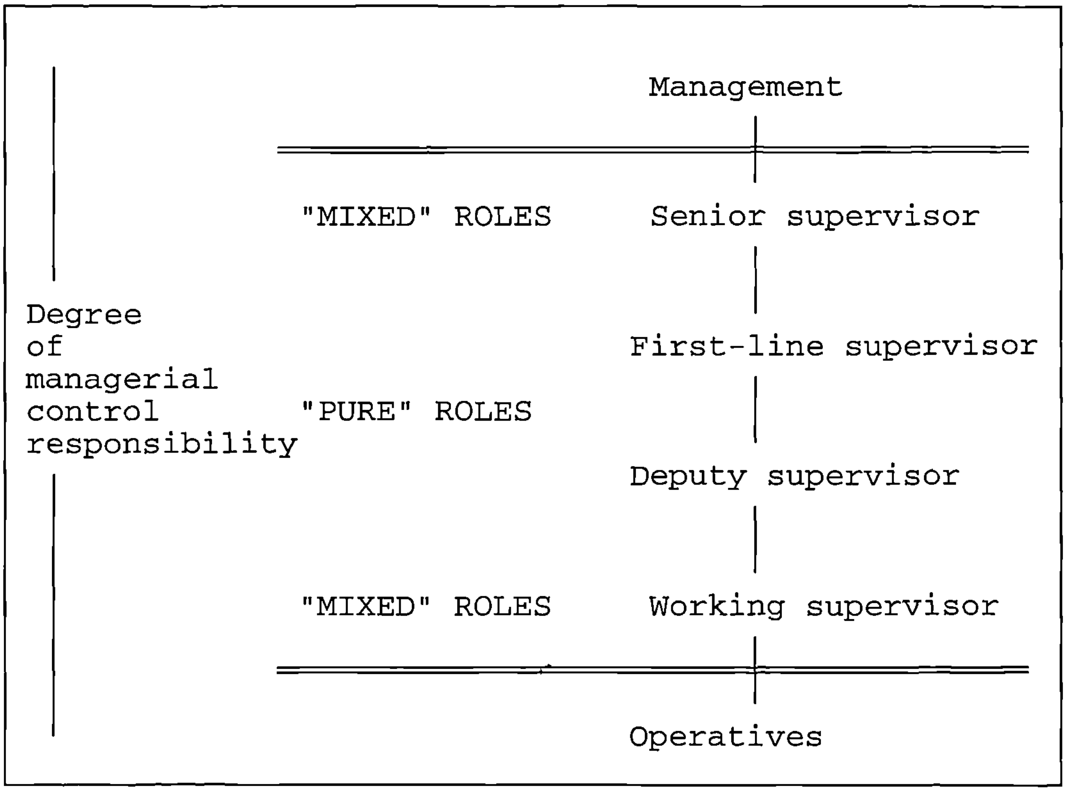
Although there are many layers in an organisation, for analytical purposes, earlier researchers have suggested a four-level categorisation of supervision (eg. National Institute of Industrial Psychology (NIIP) 1951, Wirdenius 1979, Betts 1980). Dawson suggests a modified version of the NIIP categorisation in which each stage is classified as "mixed" or "pure" (again, this is misleading because in practice nearly all supervisory roles would involve clerical, supervisory, operative and managerial type tasks), where "pure" signifies the principal concern of the role is one or more tasks related to *direct control of workplace operations.*

This distinction is a modification of Thurley and Wirdenius' own classification in which:

- "pure" roles indicate direct control of production and formally recognised as "supervisory";
- "mixed" managerial-supervisory roles indicate formal "supervisor" status but with more specialised work;
- "mixed" supervisory-operative roles indicate the operative is informally recognised as doing supervisory tasks.

This can be represented in what Dawson calls a *supervisory hierarchy of control* (figure 3.2).

Figure 3.2 **Supervisory Hierarchy of Control** (source: Dawson 1986)



Each of the levels and types of supervisor roles shown in figure 3.2 is explained below:

Level 1: Working supervisor

This is a "mixed" supervisor/operative role, often seen with the title head-worker, ganger, chargehand, leading operator, leading-hand etc. The category also includes operatives with some specific responsibilities and recognised authority over activities of their own work group.

Level 2: Deputy supervisor

This role controls workplace operations in a limited section of his own and/or act as deputy/assistant to a first-line supervisor (where he is also a deputy first-line supervisor, this role could also carry out tasks directly when not needed to deputise). The role can be "mixed" or "pure" according to the size of the supervisory hierarchy and actual tasks being carried out (ie. whether the supervisor is involved in overseeing/controlling workplace operations or not). The titles most often seen associated with this supervisor are section supervisor, deputy supervisor, assistant foreman, junior foreman, etc.

Level 3: First-line supervisor

This role is a traditional first-line supervisory position eg. foreman, section leader. It includes a range of formally defined first-line supervisory functions including machine-oriented first-line supervisory roles found in technically complex operating systems. This is a "pure" type of supervisory role in the sense that individuals directly control workplace operations. Individuals in this role are generally seen by both management and workforce as the immediate "boss of the work group" and expected to mediate between the two.

Level 4: Senior supervisor

This role incorporates managers who to some degree regularly and directly plan, monitor, evaluate and regulate workplace operations. This role covers many job titles including manager, assistant manager, department head, superintendent, senior foreman, etc. This is a "mixed" managerial supervisory role involving individuals who would generally have direct responsibility for control over a whole shop or discrete operating area and often liaise with senior management.

This strata of supervisory roles provides the interface between management and the workforce. They are the part of the management control mechanism, in direct control of workplace operations.

To summarise, Dawson argues for a **supervisory hierarchy of control** which is defined as:

> "a number of different levels which can be distinguished according to their location within an authority and status structure and according to the degree to which they participate in the function of supervision".

The difficulty which arises in a real world setting is the definition and identification of individuals who are at the upper and lower edge of the supervisory hierarchy (see NIIP 1951). It appears that because their titles and "mixed" supervisory tasks do not fit in with the picture of the "pure" supervisory role, these individuals on the edges of the supervisory hierarchy have often been omitted in many of the studies involving the traditional first-line supervisor (eg. Hirschhorn 1983, Earl Sasser Jr & Leonard 1980, Wooff 1989 Rose et al 1987, Hansen Jr 1987).

However using the above framework both the "mixed supervisory-operative" and "mixed managerial-supervisory" roles can be identified by their relative tasks and status. Typically the mixed supervisory-operative individuals (often titled "working supervisors") take their authority from their peers or management and periodically carry out supervisory functions, while the mixed managerial-supervisory individuals (often titled "senior supervisors") are those who are clearly identifiable as part of the management structure and are involved in the daily difficulties of workplace control.

3.2.6 The Supervisory System

Using the above framework it appears there is a much broader concept of supervision than has previously been supposed. Concentration on the formal titles and job roles for supervision is no longer necessary. Instead it is possible to see a whole framework of supervisory positions in a dynamic system. Thurley and Wirdenius call this a "supervisory system of control". Dawson and McLoughlin (1986) offer a definition of the supervisory system as:

> "A network of formally and informally recognised roles, all interrelated, which are concerned with the direct day-to-day control of production or services."

The implications of new technology for supervisors are not just concerned with the traditional labour control aspects of the first-line or any type of supervisor's job. New technology also has the potential to affect the wider operational control this supervisory network exerts.

By definition the supervisory system is situated at the interface between management and operatives and is therefore in a vulnerable position. When situations occur in which "product" control is changed (eg. technological change) two outcomes are possible. The first involves centralising control at a higher level, ie. management, while the second involves encouraging operatives to take greater responsibility for themselves and their work. The likely result is significant change to both the supervisory system and the individuals within it. In order to understand changes in the individual supervisory roles and changes to the wider workplace control of supervisory systems, they must be examined in the light of changes in work organisation and management control (Dawson 1986).

As Dawson clearly highlighted, the case of computer technology is particularly important because the associated changes in organisation may enhance or erode the area of control of supervisors and/or supervisory systems. However this should not be viewed merely as the result of the capacity of the technology to carry out supervisory tasks and functions. Changes to the organisation of work (eg. the formation of semi-autonomous work groups) and changes to management control (eg. centralising control at a higher management level) need to be included in any examination of the changes in supervision which are associated with the introduction and running of a computer-assisted technology.

3.3 Grounded Theory: Analysing Qualitative Data

3.3.1 Introduction

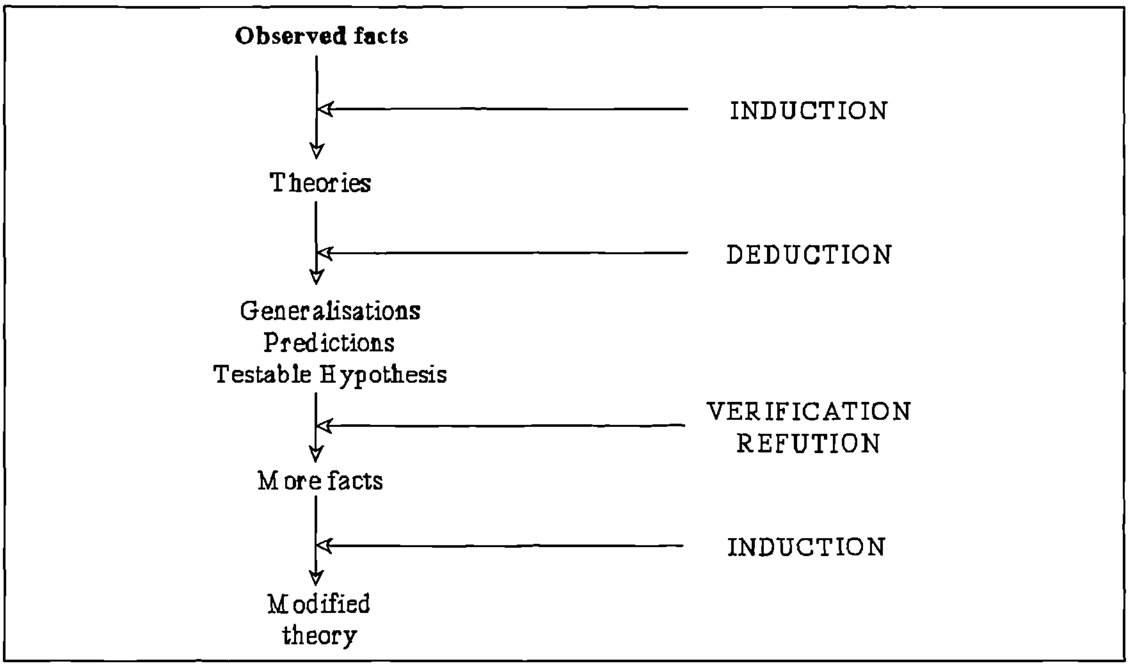
Large amounts of non-standard data in a qualitative study make for problematic analysis. In order to retain as much as possible of the important features of the data, it should be systematically sifted and sorted into themes using some process or procedure.

3.3.2 Grounded Theory (from Thorpe 1989)

One method of transforming large quantities of data, so that innovative insights can be drawn out (ie. a theoretical account), is called "Grounded Theory". This is based on the work of Glaser and Strauss (1968), in which the emphasis is placed on the induction of data. This is contrary to the hypothetical deductive model, in which the data is used to test, modify and revise a previously specified hypothesis (see figure 3.3).

In qualitative data analysis Turner (1981, 1983) advocates recording themes on cards along with their appropriate data entries. The cards are written for each interview and common themes grouped together. Where necessary these new

Figure 3.3 **Scientific Method: The Hypothetical Deductive Model**



groups are renamed to form new categories. Therefore the analysis proceeds by carrying out each of the nine stages of development of grounded theory as described below:

Figure 3.4 **Schematic List of the Stages in the Development of Grounded Theory** (source: Glaser and Strauss 1968)

Stage	*Main activity*	*Comment*
1	Develop categories.	Use the data available to develop labelled categories which fit the data closely.
2	Saturate categories.	Accumulate examples of a given category until it is clear what future instances would be located in this category.

Stage	*Main activity*	*Comment*
3	Abstract definitions.	Abstract a definition of the category by stating in a general form the criteria for putting further instances into this category.
4	Use the definitions.	Use the definitions as a guide to emerging features of importance in further fieldwork and as a stimulus to theoretical reflection.
5	Exploit categories fully.	Be aware of additional categories suggested by those you have produced, their inverse, their opposite, more specific and more general instances.
6	Note, develop and follow-up links between categories.	Begin to note relationships and develop hypotheses about the links between the categories.
7	Consider the conditions under which links hold.	Examine any apparent or hypothesised relationships and try to specify the conditions.
8	Make connections, where relevant, to existing theory.	Build bridges to existing work at this stage, rather than at the outset of the research.
9	Use extreme comparisons to the maximum to test emerging relationships.	Identify the key variables and dimensions and see whether the relationship holds at the extremes of these variables.

A major criticism of this systematical approach is that its nature, which provides the "academic rigour", also harms the process and in a sense becomes a reductionist approach. This is the antithesis to research and analysis in qualitative data being about "feel" (Thorpe 1989). It is possible that writing on cards mechanises what is essentially an intuitive activity. But in the case of a more inexperienced researcher it provides both the academic and psychological insurance that nothing important is inadvertently missed.

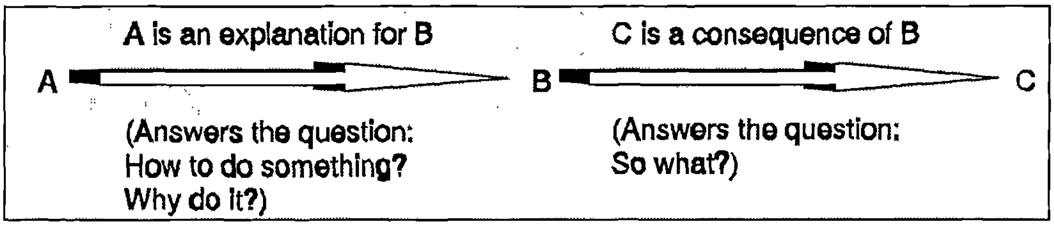
3.4 Cognitive Mapping

3.4.1 Introduction

The technique of "cognitive mapping" has been developed from "Personal Construct Theory" (Kelly 1955). Three key assertions are found in Kelly's theory: that people make sense of their world through contrast and similarity; that people seek to explain their world (why is it so? what made it so?); and that people seek to understand the significance of their world by organising concepts hierarchically. In the traditional application of Personal Construct Theory, individuals are asked to express their view of the world in terms of constructs, each having a positive and negative pole (expressing the concept and its perceived opposite). The relationship between the constructs is then evaluated through an exhaustive paired or three-way comparison to develop what are known as Repertory Grids.

Cognitive Mapping, originally developed by Eden *et al* (1979) as a technique for use in strategic decision making in organisations, adopts Kelly's concept of constructs, but uses them in a much less rigid way. Constructs are identified from the statements individuals use in describing a situation during an interview and are represented as brief phrases in natural language. Sometimes the negative pole will be given, but often it is assumed to be implicit. Rather than carry out the Repertory Grid comparison, the links between constructs are identified from the chain of argument employed in describing the situation. The relationship between constructs is assumed to take the form of explanations and consequences (as shown in figure 3.5). The relationship may be positive (ie construct A reinforces construct B) or negative (construct A operates in the opposite direction to construct B - reinforcing the negative pole), or connotative (implying a relationship between the constructs, but of unknown or neutral effect).

Figure 3.5 **Basic mapping convention for representing relationships between constructs**



The product of a cognitive mapping exercise is therefore a map (in the style of a directed network) made up of nodes (consisting of phrases used by the individual to describe the situation) and arcs (links identified from the individual's description of the situation). The structure and content of the map is validated by discussing it with the interviewee. Eden (1989) has defined a cognitive map as,

> "a model of the 'system of concepts' used by the client to communicate the nature of a problem...a model amenable to formal analysis...a network of ideas linked by arrows; the network is coded from what a person says."

3.4.2 Applied Cognitive Mapping

The mapping is initially carried out with pencil and paper during a normal interview. The large number of constructs generated in a one hour interview (about 100) often results in a very "messy" picture/map being generated. This then needs to be "tidied-up" both for analysis and feedback to the interviewee. As part of this tidying process the map can be transferred to a specific computer package (GraphicsCOPE), which has been developed to operationalise cognitive mapping. It enables much easier handling of large numbers of constructs and introduces a much higher degree of flexibility in manipulation of the maps.

Following the tidying of the map (using GC), the information is then presented back to the interviewee for amendment, and/or confirmation that it is an appropriate representation of their viewpoint. Rather than working with the whole map, particular chains of argument can be separated out and are much easier to examine. At this point there is wide scope for negotiation over the content and structure of the map, using the physical map (whether working directly with the software or on printed output) as the "negotiative object". Having established some agreement over the basic outline for the map, the next step is to begin to make use of it. In practical terms maps of more than about 30 concepts are too difficult to deal with as a whole and GraphicsCOPE includes analytical routines which can aid the identification of: clustering of concepts, the beginnings and ends of chains of arguments (often described as assertions and goals), constructs which have many others associated with them (described as issues), or which are branching points in a chain of argument (option points). This analysis can help in guiding the validation and interpretation of the map.

In its application in strategic decision making, cognitive mapping is used as part of a more general method known as Strategic Options Development and Analysis (SODA). In this approach different stakeholders whose views have been individually mapped are brought together in a meeting (a SODA workshop). The individual maps are compared and a collective map is negotiated which seeks to merge those of the individuals. Where there is uncertainty or different views about the meaning of constructs this can be examined in the individual maps and debated amongst the meeting participants. By retaining elements of the original (individual) maps in the collective map, the stakeholders' sense of ownership of the group viewpoint is encouraged. By providing a rich representation of individual viewpoints the similarities and differences between different stakeholders can be studied and debated. Apart from the process and affective benefits of such negotiation, the collective map can serve as an agenda for strategic action by identifying shared goals, problems and options.

3.5 Structuration Theory and New Technology: A Coherent Theoretical Framework

3.5.1 Background

It is an established fact that modern research and writings need to acknowledge the organisational context which surrounds the use of a technology. However previous efforts have been criticized for their failure to accumulate consistent research findings or develop coherent theoretical frameworks (Markus and Robey 1988). Part of the problem is that a wide diversity of perspectives is adopted by organisational researchers and fundamental issues behind these perspectives have yet to be properly examined and resolved (see Burrell and Morgan 1979; this thesis adopts the perspective that some resolution of these issues is possible, or at least should be sought).

Markus and Robey (1988) identified three major defects in research focusing on the interaction of organisations and new technology:

- inattention to the question of causal agency;
- over-reliance on variance models in theory;
- failure to distinguish among individuals, groups and organisations as levels of analysis.

They recommended emergent models of causal agency (with the social meaning associated with technology as a central theme), using the logic of process theory (which is concerned with explaining how outcomes develop over time) and linking multiple levels of analysis (ie. both micro and macro levels).

However this, too, was criticised for failing to develop a specific theory or framework, which could be used to guide further research (Orlikowski and Robey 1991). As a possible solution, Orlikowski and Robey presented a theoretical framework built on Giddens' Structuration Theory (Giddens 1990).

The social science theoretical controversy (mentioned before) focuses on which perspective is most appropriate for exploring and understanding social phenomena, in this case the study of technology in organisations (see section 2.4). Which set of assumptions is more appropriate: either objective/positivist (the institutional aspects of social systems which are perceived as being independent of and constraining human action) or subjective/interpretivist (social systems as the result of meaningful human behaviour)? Each of these assumptions can act as an underlying epistemology which guides the researcher and, hence, research. However these two philosophical positions represent the extreme ends of the same continuum, along which can be situated a variety of ontological assumptions and real-world approaches. Easterby-Smith et al. (1991) presented the key features of these two paradigms to highlight the main differences in the viewpoints (table 3.2).

Table 3.2 **Key Features of Positivist and Phenomenological Paradigms** (source: Easterby-Smith et al. 1991)

	Positivist paradigm	*Phenomenological paradigm*
Basic beliefs:	the world is external and objective observer is independent science is value free	the world is socially constructed and subjective observer is part of what observed science is driven by human interests
Researcher should:	focus on facts look for causality and fundamental laws reduce phenomena to simplest elements formulate hypotheses and then test them	focus on meaning try to understand what is happening look at the totality of each situation develop ideas through induction from data
Preferred methods include:	operationalising concepts so that they can be measured taking large samples	using multiple methods to establish different views of phenomena small samples investigated in depth or over time

Positivist studies ("functionalist" in Burrell and Morgan's terminology) propose the existence of *a priori* fixed relationships within phenomena which generally are measured by *structured instrumentation* (such as a questionnaire survey), with the emphasis on "objective" consistent repeatable measurements. Interpretivist studies, in contrast, assume that through interacting with the world, people create and associate their own subjective and intersubjective meanings. Thus phenomena may be understood through accessing these meanings, which have been uniquely assigned by participants.

There is much to be gained from a "psychological" analysis of society, but it could be argued that some factors are still missing (for instance much of the psychological work tends to ignore cultural variation and thus tends to produce culture-bound, ethnocentric explanations of human behaviour). Psychology often seems to be naive and inattentive to issues of power, coercion and the rest of the "macroscopic" constraints over human behaviour. Equally it is possible to reify social phenomena out of all context and to ignore the very real feelings, meanings and intentions that social actors use to judge their surroundings. As Thomas and Thomas (1935) said:

> "If men define situations as real, then they are real in their consequences".

The *philosophical difference*, in the underlying perspective guiding a study, has been argued as being one of the main reasons for the lack of unifying, substantive paradigms in sociological, organisational and information systems disciplines (Hirschheim and Klein 1989). However Orlikowski and Robey (1991) point to Giddens' structuration theory as a possible solution:

> "He (Giddens) has developed a theoretical perspective...to accommodate the two traditions and hence offers a resolution to the heated debate...in Giddens' view of social reality, both are equally important, and hence both should inform social theorizing and empirical investigations."

Giddens' theory is used to build a theoretical framework which explores how new technology is created, used and becomes institutionalised within an organisation. This goes further to show how the technology is both a product of human action and a medium for human action.

Clark (1990) summarises the core of structuration theory (from Giddens) in a series of four interrelated points:

1. *Social practices* lie at the root of the constitution of both individuals and society - this shifts the focus of social theory away from a) the individual actions and experiences of an individual actor, and b) the existence and requirements of some kind of societal totality.

2. Human agents are knowledgeable and have the capacity to exercise their powers to accomplish a social practice - people often know what they can do (whether directly or in a "tacit" sense) in their daily interactions, and under given circumstances are able to do it[1].

3. These social practices are *routinised and recursive*, ie. ordered and stable across space and time - people draw on "structural properties" (ie. rules and procedures), which are institutionalised properties of society, to construct the visible patterns (social practices) that make up society.

4. Structure is both the medium and outcome of a process of "structuration", ie. it is activity-dependent, as seen in the *production and reproduction of practices across time and space* - Giddens named this double involvement of individuals and institutions the "double hermeneutic", which can be used to highlight the way that theories, concepts and research findings themselves can have an impact on the environment/context in which they were

[1] However Lukes (1979/1987) argues that in most cases people do not recognise when their real interests are at stake, ie. they are excluded from the social and political context of decision making. Therefore people can only act in a knowledgeable way given the limits of their personal knowledge.

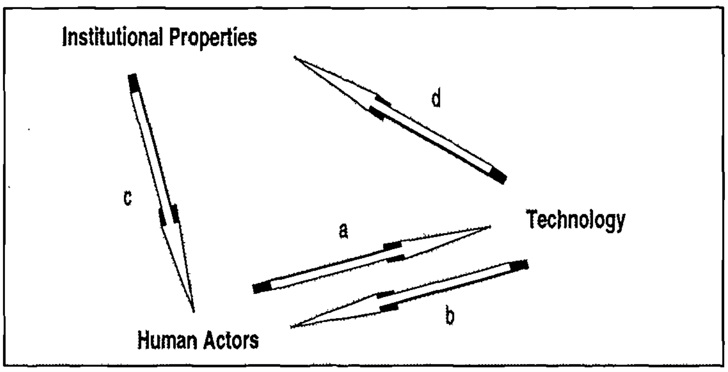
Thus as Giddens (1990) says:

> "findings, together with theories and concepts, can constitutively reorder basic characteristics of social life in ways which range far beyond immediate contexts of research."

3.5.2 Theoretical Framework

However Giddens does not explicitly address the issue of technology in his "structuration paradigm". Orlikowski (1992) has attempted to use the structuration viewpoint to examine technology within organisational settings. Therefore technology may be seen as one kind of structural property of organisations developing and/or using technology. Technology embodies and, hence, is an instantiation of some of the rules and resources constituting an organisation. Orlikowski (1992) discusses the "duality of technology", ie. technology is created and changed by human action *but* is also used by humans to accomplish some action. A corollary of the duality premise is that technology may be "interpretively flexible", such that the interaction of technology and organisation is a function of the different actors and socio-historical contexts implicated in its development and use.

Figure 3.6 **Structural Model of Technology**
(source: Orlikowski and Robey 1991)



Technology is the *product of human action*, ie. physically constructed by actors working in a given social context (arrow a, figure 3.6). Thus technology is created and maintained by human actors and has to be used by human actors to have any effect. Technology also *assumes structural properties*, ie. it is socially constructed by actors through the different meanings they attach to it and the various features they emphasise and use.

In addition technology is *built and used in a social context* which exerts an influence on it (arrow c, figure 3.6). Human agents act, in an organisation, through use of the organisational store of knowledge, resources and norms (ie. the organisational structures of signification, domination and legitimation). Once deployed, technology tends to become "reified" and institutionalised. It loses connection with the human agents who construct it and give it meaning and therefore appears to be part of the objective, structural properties of the organisation.

However agency and structure are not independent. The ongoing action of human agents in drawing on a technology objectifies and institutionalises it. Therefore if people changed the technology (either physically or interpretively) every time they used it, it would not assume the stability or "taken for granted" status necessary for institutionalisation. There are *consequences of interacting with the technology*, in particular the ability to influence the social context in which it is used (arrow d, figure 3.6). In using a technology the human agent either sustains or changes the institutional structures of the organisation in which they are situated, ie. reinforcing or undermining the structures of signification, domination and legitimation.

Technology is also the *medium of human action*, ie. when deployed and used in organisations by humans, it mediates (enables and facilitates or constrains) activities (arrow b, figure 3.6). One crucial aspect of human action is that it can be knowledgeable and reflexive. Therefore agency refers to capability rather than intentionality, although human actions may have intended and unintended consequences. While the personal action of human agents using technology has a direct effect (intended and unintended) on local conditions, it also has an indirect effect (often unintended) on the institutional environment in which the agents are situated. The results cannot be guaranteed, even where the actions are directly intended to preserve or change some aspect of the institutional environment.

Orlikowski is concerned with how the duality of technology is often suppressed in organisational discourse. The pattern appears to be that a one-sided view of technology arises because one aspect of the duality, eg. the flexibility of technology, is "invisible" in the organisation. Alternatively there may be a recognised dualism, but one which emphasises only one view of technology.

Often a technology is developed in an organisation different from the one in which it is used (figure 3.7).

Figure 3.7 **The Separation of Development and Use for Technology**

Development	**Use**
Vendor Organisation	Customer Sites
Actions that *constitute* the technology	Actions that are *constituted by* the technology

<----- Separated by time and space ----->

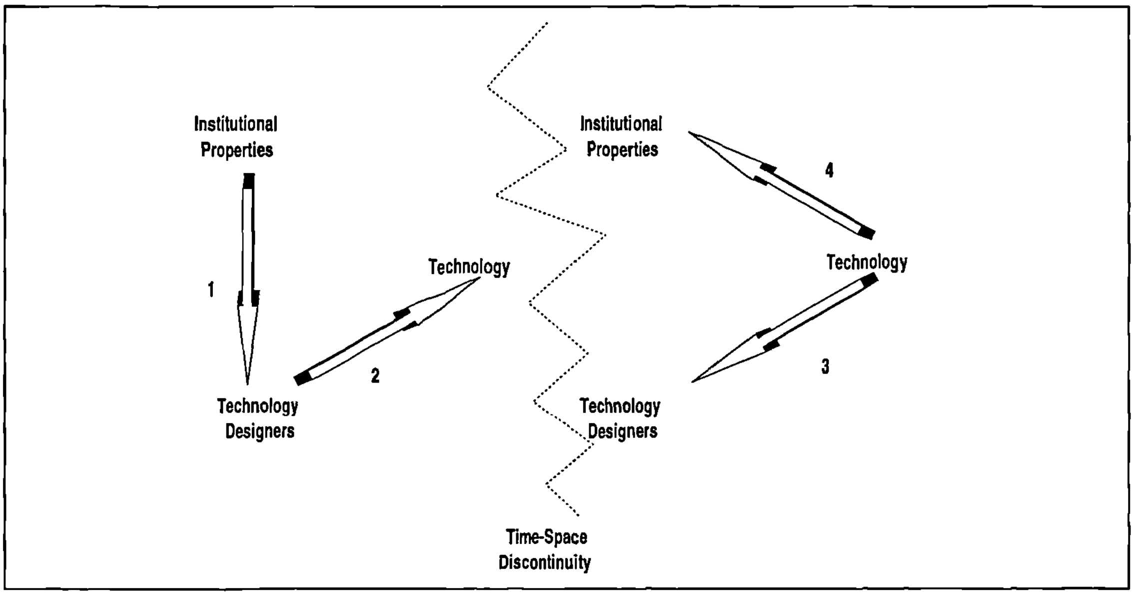
Therefore designers tend to adopt an "open systems" perspective on technology, whereas users treat it as a "closed system" or "black box".

The time and space discontinuity (shown in figure 3.8) is also related to the "temporal scope" idea. Research can focus on different temporal stages of the technology and this influences whether technology is seen as a *fixed object* or *product of human action.* Recognising the *time-space discontinuity* between design use of a technology allows an insight into the conceptual dualism in the literature.

Instead of seeing design and use as disconnected moments or stages in the life-cycle of a technology, the structurational model of technology posits artifacts as potentially modifiable through their existence.

It is useful for analysis, to differentiate between human action which affects technology and human action affected by technology. In this way the human-technology interaction is seen as having two iterative modes: a) design mode; b) use mode (see figure 3.8). Therefore this idea of the recursive design and use of technology allows them to be differentiated on the basis of the degree to which users can effect redesign.

Figure 3.8 **Traditional Models of Technology Design and Technology Use** (source: Orlikowski 1992)



Left hand side of the diagram:

Constructed nature of technology is seen when the focus is on design and development of a technology.

Arrow 1 represents the influence of the institutional properties, of their organisation, on the designers of the technology.

Arrow 2 represents how the designers fashion and construct a technology to meet managerial goals.

Therefore these studies are less likely to treat technology as fixed or objective, and more likely to recognise technology's dynamic and contingent features, eg. strategic choice studies.

Right hand side of the diagram:

The focus here is on examining the utilisation of a technology in a workplace.

Arrow 3 represents how a given technology influences the users of that technology.

Arrow 4 represents how the technology also affects the institutional properties of the organisation, in which it is used.

Therefore these studies are less inclined to focus on the human agency who initially produced the technology and tend **not** to recognise the ongoing social and physical construction of the technology, that occurs during its use.

It is possible that there is greater engagement, where the human agents are more involved in the initial development of a technology. However this should not stop the user from having the potential to change the technology (physically and socially) through their interaction with it. In using a technology the users "interpret, appropriate and manipulate" it in various ways, influenced by social and individual factors.

However despite the opportunities for change, rigid and routinised views of, and interactions with, technology often develop. These developments are a function of the interaction between technology and organisations, **not** inherent in the nature of the technology (cf. views on the myth of technological determinism, Buchanan and Boddy 1983). Even the most "black box" technology has to be understood and activated by human agency to be effective. It is in such interactions that users shape technology and its effects, eg. operators routinely deviate from formal, rule-bound operating practices to deal with complex interdependence, unanticipated events.

As mentioned above, depending on the specific technology, users have varying capacity to control their interaction with the technology and hence its characteristics. It is possible that users could exercise control at any time. Therefore, according to Orlikowski (1992), the apparent divide of design and use stages is artificial and misleading. Notwithstanding that, the divide between design and use stages is a "real" social phenomenon. Therefore if users do not perceive opportunities to exercise control, or more actively perceive they are not able to affect the design stage, then this divide has "real" consequences (cf. Thomas and Thomas (1929) on people's perceived consequences being real in the actual consequences for them).

"Interpretive flexibility" in this framework is taken to be the degree to which users of a technology are engaged in its constitution (physically and/or socially) during its development or use. Interpretive flexibility is an attribute of the relationship between humans and technology and therefore is influenced by three classes of characteristics:

- characteristics of the material artifacts (eg. software and hardware);
- characteristics of the human agents (eg. experience, motivation);
- characteristics of the context (eg. social relations, task assignment, resource allocation).

Because of these factors influencing the flexibility in the design, use and interpretation of technology, there is only finite interpretive flexibility.

Interpretive flexibility is then constrained by the material characteristics of the technology (since technology is physical it is bounded by the state of the art in materials, energy etc.), institutional contexts (ie. structures of signification, legitimation and domination) and differing levels of knowledge and power affecting actors during the technology's design and use.

3.5.3 **Structural Model of Technology** (from Orlikowski 1991)

The model of technology as based on Giddens' Structuration Theory has three major components:

1. Human agents - technology designers, users and decision-makers.

2. Technology - material artifacts mediating task execution in the workplace.

3. Institutional properties of organisations, including organisational dimensions, eg. structural arrangements, business strategies, ideology, culture, control mechanisms, standard operating procedures, division of labour, expertise, communication patterns, plus environmental pressures such as government regulation, competitive forces, vendor strategies, professional norms, state of knowledge about technology and socio-economic conditions.

3.6 Chapter Summary

A supervisory system (with four basic levels) has been proposed, which involves the concepts of more and less "pure" supervisory roles. The system identifies the roles according to the degree of direct daily control the individual is able to exercise and acknowledges the potential changes in the system which may be attributable to new technology. The chapter then explores grounded theory as a possible way of coping with and analysing large amounts of qualitative data (see chapter 6). Following this is an explanation of the theory supporting cognitive mapping, a short description of the analytical technique itself and an indication of the areas in which it has previously been applied. Finally this chapter examines the organisational context of new technology using and/or within a Structuration framework, which may then be used to illuminate the empirical findings later in the thesis (see chapter 8).

CHAPTER 4
METHODOLOGY

4.1 Introduction

Having investigated the background literature and established a conceptual framework (chapters 2 and 3), the next step is to examine the choice of methodology available for this research. This chapter introduces the topic of methods and strategies available for the collection and analysis of research data (both qualitative and quantitative). It provides an overview of the background methodology, leaving the more detailed discussion for future chapters (chapters 5 and 6).

4.2 Choice of Methodology

A perennial debate surrounds the relative merits of quantitative versus qualitative data, with respect to the underlying philosophies, the methodology used and the type of data collected.

The major methods associated with qualitative data collection are interviews, observation and diary methods, while the principal methods associated with quantitative data collection are surveys and questionnaires. However it is possible that each method could be used to collect either type of data, and the distinction simply reflects their conventional associations.

Each method has a range of options, primarily linked to the objectives of the research, and each has its strengths and weaknesses. The following table summarises the main range of the major methods (table 4.1):

Table 4.1 **Main Ranges for Qualitative Data Collection Methods**

Method	Main range		
Interview	Highly formalised	↔	Free-ranging conversation
Observation	Observation alone	↔	Participant observation (whether implicit or explicit)
Diary	Simple journal/ record of events	↔	Personal journal recording perceptions, feelings, reflections, insights etc.
Questionnaire	Factual Closed (eg. yes/no)	↔	Opinion Open (eg. list of things related to x)
Survey (both interview and questionnaire)	Stratified sample	↔	Random sample

Each method has been explored in depth in the literature devoted to methodology (Easterby-Smith et al., (1991) for an indepth examination); however an overview of each is given below:

Interviews -

Interviews are probably the most popular research method. At one level they are easy to carry out, especially at the "free-ranging conversation" end of the spectrum where the interview can be conducted in a relaxed atmosphere. However there are difficulties with this particular method. One of the main difficulties is that the success of the interviews very much depends on the skills of the interviewer. He needs to be able to employ a good technique for eliciting the required insights, creating and maintaining a smooth flow throughout the interview. In addition the interviewer needs to appreciate that a social interaction that is taking place and that the biases they themselves hold and their skills in recognising what is relevant and what needs to be recorded all determine the results of the interview. Other decisions need to be made about the degree of structure to be used in the interview (presumably, the less the experience of the interviewer, the higher the degree of structure needed prior to the interview) and the method of analysis of the, often lengthy, results (more details on analysis of results from interviews are given in section 3.3 and section 6.11).

Observation -

While the participant observer role offers a degree of insight into a situation unlikely to be found in any other method (particularly when the researcher is also counted as an employee of the company under study), the role can be both physically and psychologically tiring, with issues of ethics and confidentiality to deal with as well. At the other end of the scale the pure observer is rather detached from the situation under study, and often looked upon with suspicion by those being observed. Therefore the researcher is unlikely to understand truly what is happening in the situation and why things happen. In addition any form of observation entails quite a, difficult to secure, high level of cooperation by many members of an organisation and the organisation as a whole, (for political as well as practical reasons).

Diary -

A diary allows data from the perspective of an employee to be gathered, several different perspectives to be compared and the researcher to conduct other investigations in parallel. However this method relies on the diaries being kept by people who are able to express themselves articulately in writing. In addition it requires regular and sustained encouragement and reassurance by the researcher to the diary writers. Finally this method also entails quite a high degree of cooperation by an organisation and, in particular, by the individuals who are writing the diaries.

Questionnaire -

Questionnaires are also a very popular research method. There are a wide variety of designs feasible and it is important to construct the questionnaire carefully. This involves developing the question types, the layout style and ensuring that satisfactory levels of reliability and validity can be achieved (eg. Moser and Kalton 1971 or Youngman 1984 for useful guidelines). To summarise briefly the literature on questionnaires, beginning with closed question questionnaires which, although quick and easy to complete and analyse, may only generate results of a superficial character. Equally, open ended questionnaires may permit deeper, more probing, questions to be asked and also enable a relatively high degree of flexibility in the answers. However they are correspondingly more difficult to complete and analyse, involving a much greater investment of time from both the researcher and respondent (with again the possibility of only superficial data being collected, due to boredom and inattention by the respondent).

Survey -

A survey is more of a research strategy than a method, since it typically uses either questionnaires or interviews, or both. Thus the strengths and weaknesses of the survey approach rests on the relative strengths and weaknesses of the interviews and questionnaires used within it.

While the above is a brief guide to the major qualitative research methods, it is not meant to imply that there are no other equally valid techniques that could be employed in data collection, eg. experimentation, archival and historical analysis, tests/measures, checklists, etc.

4.3 Background to the Methodological Framework

As shown above each of the major research methods has both strengths and weaknesses. In addition it is often useful and provides greater validity to a study to combine a range of methods, as appropriate to the purpose of the research and the type of data to be collected or available.

Yin (1984/9) attempts to provide a framework to help decide which methods are most appropriate by focusing on the purpose of the study (ie. whether exploratory, descriptive or explanatory) and by using three boundary conditions:

- what form of research question is being asked;
- whether this requires control over behavioural events;
- whether the focus is on contemporary events?

Rather than decide which specific research method to use, Yin advises the decision should be which research strategy should be employed, within which a range of methods could be used. The research strategies are themselves not independent, with large areas of overlap. Therefore the aim of this framework is not to force a type of strategy, but to avoid "gross misfits" between a research project and strategy.

Different combinations of the boundary conditions show which strategy is most appropriate in any particular research setting. Table 4.2, shows how the three boundary conditions are related to five major research strategies:

Table 4.2 **Relevant Situations for Different Research Strategies** (Source: Yin 1984)

Strategy	**(a) Form of research question**	**(b) Requires control over behavioural events?**	**(c) Focuses on contemporary events?**
Experiment	how, why	yes	yes
Survey	who, what*, where how many, how much	no	yes
Archival analysis	who, what*, where how many, how much	no	yes/no
History	how, why	no	no
Case study	how, why	no	yes

* "What" questions, when asked as part of an exploratory study, pertain to all five strategies.

4.3.1 Forms of Research Questions

The basic categorisation for types of research (table 4.2 column a) questions is that there are "who, what, where, how and why" questions.

"What" questions can be of two forms. The first is exploratory questions (eg. what decisions led to the introduction of new technology?) in which the aims are to develop hypotheses and areas for further exploration. The second "what" questions take the form of "how much" or "how many" (eg. what changes have resulted from a particular management reorganisation?) and therefore are better suited to archival or survey strategies. Similar to this last case, "who" and "what" questions indicate survey and archival analysis strategies. These questions are particularly pertinent when the research goal is to investigate or describe a phenomenon or when it is to *predict* specific results.

In contrast "how" and "why" questions indicate exploratory style studies, often using case studies, histories and experimentation as the strategies. This is where the research focus is on operational links which must be traced over time, as opposed to mapping frequencies or incidents. It is important to keep in mind that areas of overlap among the strategies are large; therefore for some questions there exists a choice of strategies.

4.3.2 Extent of Control and Degree of Focus over Events

This section looks at the extent of control an investigator requires over behavioural events and the degree of focus, he adopts, on contemporary as opposed to historical events (figure 4.2, columns b and c).

In a situation where the investigator has virtually no access or control over actual behavioural events, a history strategy is preferred. In these situations the context is such that no-one is still alive to report, even in retrospect, on what happened. Therefore the investigator is forced to rely on documents (primary and secondary) and artifacts (cultural and physical) as the main sources of research. If a history strategy is used to investigate a contemporary event, then this strategy significantly overlaps with case study.

In contemporary settings, where relevant behaviours cannot be controlled, the case study approach is particularly appropriate. It utilises the same techniques as a history, plus two others (direct observation and systematic interviewing).

In situations where behaviour can be systematically controlled, experiment is the most appropriate strategy. Generally the experiment is conducted in the "controlled" environment of the laboratory, allowing a focus on one or two specific variables. If the experiment is conducted in a field setting, commonly called "a social experiment", a wider range of variables can be investigated. Yin (1984/9) again emphasises the overlap of strategies by showing that experimental strategies include situations in which behaviour cannot be directly manipulated by the investigator, but where the logic of experimental design may still be applied (commonly called "quasi-experimental" situations).

4.4 Positivism and Phenomenology

In investigating aspects of management and organisations, researchers need to be aware of their own assumptions and biases about what is "important". The philosophical stance adopted will, to some extent, determine the kind of assumptions made about the subject matter under investigation thereby influencing the whole research project, including the choice of methodology. The basic dichotomy can be said to be between research focused on *the things themselves* (which lends itself more to a positivist/objective worldview), and a focus on *people's views about things, and the relationships between them* (which lends itself more to a phenomenological/subjectivist worldview).

The positivist view can be classified as premised on the existence of fixed *a priori* relationships within a phenomenon (Chua 1986). This view is often characterised by the intention to test theory (ie. the attempt to increase the predictive understanding of a phenomenon) through the use of tools such as:

- formal propositions;
- quantifiable measures of variables;
- hypothesis testing;
- drawing inferences about a phenomenon from a sample of a stated population.

On the other hand, the interpretive (or subjectivist) view assumes that people create and associate their own subjective and intersubjective meanings as they interact with the world around them. Thus, many phenomenon may be understood through accessing the meanings that people allocate to them. This leads the researcher to seek a relativistic and shared understanding of a phenomenon (cf. a focus on the feelings, meanings and intentions that actors give to situations). The intent within this view is to understand the deeper structure of a phenomena. Instead of generalising from one setting to a population, the understanding of a phenomena can then be used to *inform* other settings.

These two worldviews are not mutually exclusive, and aspects of both may produce the most productive research. The dependent variable in the choice of research strategy and methods most appropriate in a particular area does not appear to be any of those described above. It is derived from "the nature of the social phenomena to be explored" (Easterby-Smith et al. 1991, quoting Morgan and Smircich) with the amount that the "base subject material" in a study is quantified appearing to strongly influence a researcher's choice between mainly positivist or mainly phenomenological methods, eg. in finance and accounting research is generally focused on measurable and quantifiable factors with the researcher remaining as detached from the data as possible.

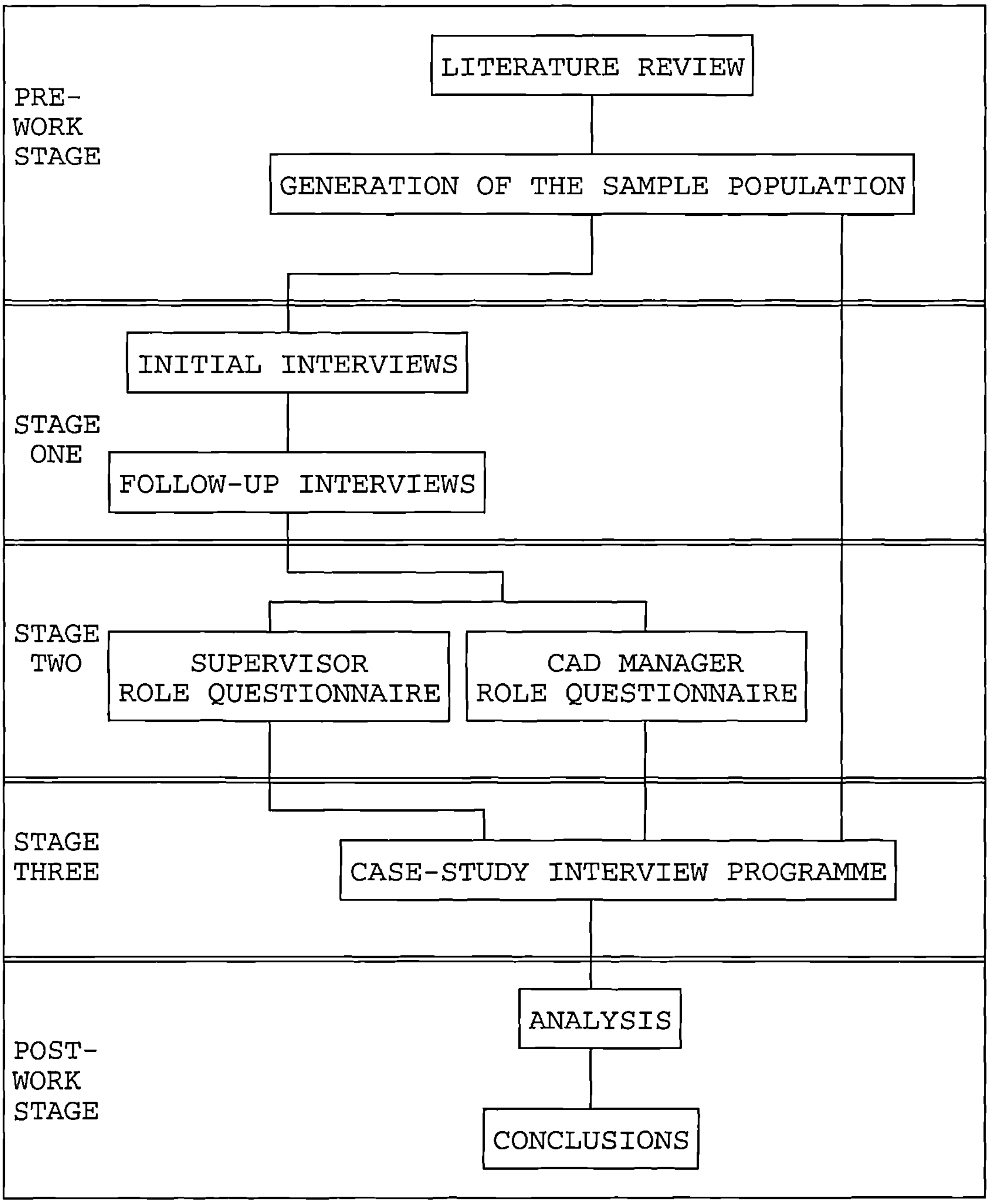
4.5 Research Framework

After evaluating the above factors and the information requirements as identified in the literature review it was decided that a range of techniques should be used to elicit both qualitative and quantitative data. The choice was also influenced by consideration of the relevant sample population, the analysis framework as well as time and financial constraints. In each stage of the project, reference to the methodological framework suggests which research tool is most appropriate. This resulted in the three stage research framework summarised below:

STAGE ONE -	Initial interviews/discussions; Follow-up interviews (building on the initial interviews).
STAGE TWO -	Postal role questionnaires.
STAGE THREE -	In-depth interview survey.

A flow diagram presenting the research framework of the complete project is presented below, figure 4.1.

Figure 4.1 **Flow Diagram Representing the Stages of the Research Project**



The stages of this research framework are summarised below (nb. the interview and questionnaire programme are described in greater depth in chapter 5):

4.5.1 **Pre-work Stage** - the literature reviews and generation of the interview population.

The first stage was based on information elicited by the SERC research grant number GR/D/26597 closing report and the following conference paper (Wells 1986, 1987). Succeeding this was a comprehensive review of relevant literature. This was aided by a library search for references relevant to both new technology (in particular references to CAD) and human, social and organisational issues connected with the project area (in particular references on supervisors and management). The citation index and BIDS (Bath Information Data Service) are very useful in locating articles which have referenced recognised articles (and therefore had a high likelihood of being in the same or associated area) and they can also be used to locate other articles, in the same area, by recognised authors. Because of the limited budget imposed on university libraries, it was necessary to make extensive use of both the inter-library loans system and the ACAS Work Research Unit library system.

Throughout the project the literature review ran continuously in parallel with the other elements of the research framework. In addition it has been instrumental in directing the research framework. References for the literature examined in the course of the project have been recorded in a computerised database, allowing easy and flexible access.

Reviewing the literature (chapter 2) quickly shows that much research has already addressed the problems involved in the implementation of a CAD system and the human and organisational issues faced by line managers. However very little previous research has approached the post-implementation phase of CAD or looked at the role of the first-line supervisor and CAD from an empirical viewpoint. This led to the development of the research area and research framework and through to the research questions. From these the project developed into three stages:

4.5.2 **Stage One** - the initial interviews and a short programme of follow-up interviews.

These were intended to complement and extend the literature survey and to investigate the research aims from the perspective of the manager responsible for the CAD system and the general organisation. The follow-up interviews were a first attempt at exploring relevant issues, both in greater depth and from the perspective of primary and secondary users of the CAD system.

The initial interviews were conducted with the manager responsible for the CAD system in ten cooperating companies and the follow-up interviews in six of these companies with a cross-section of individuals from the design and drawing offices (further details are provided in chapter 5).

4.5.3 **Stage Two** - two role questionnaires, one investigating the activities of the first-line supervisor and the other investigating the activities of the CAD manager (although it was expected that in the larger companies, some of these activities would be carried out by other members of the CAD support team).

These two questionnaires were designed specifically to support the pre-work stage and stage one information and establish firm conceptual models of the roles of the first-line supervisor and the CAD manager. These role questionnaires were sent to a sample of seven companies (only two of which were in the stage one sample population) and 14 usable replics to the first-line supervisor role questionnaire and 9 usable replies to the CAD manager role questionnaire were received. Details of the planning, design, application and results from the role questionnaires are given in chapter 5.

4.5.4 Stage Three - a set of in-depth interviews applied to a cross-section of individuals in the design and drawing offices of five co-operating companies.

Building on the previous stages of the project it became apparent that with the complicated set of features surrounding both the implementation and use of a CAD system and the functioning of a line supervisor, a series of in-depth interviews (also called an "interview survey") were needed.

In particular it was found that the nationalised shipbuilding industry in Britain had directly prompted a number of major shipyards to implement similar CAD systems shortly before privatisation (see section 6.4.1 for more detail). Four of the major shipyards were approached to take part in the in-depth interview programme. A local toolmaking company was also approached and agreed to take part in this in-depth interview survey.

Three separate interview structures were constructed, one each for the design/ draughting supervisor, CAD manager and designer/draughtsman. The in-depth interview survey strategy and structure are discussed fully in chapter 6 and presented in Appendix IV.

4.5.5 Post-work Stage - the analysis and conclusions drawn from the information elicited through the various stages of the research.

One of the most important stages in research is the analysis of the raw data such that inferences and insights can be drawn out. In addition the results were then compared with a theoretical framework, to explore whether further useful insights might be gained (chapters 7 and 8).

4.5.6 Validation

The pre-work stage, stage one and stage two all included a series of visits and exchange of information with other researchers in the same research field. This enabled the researcher to:

i) Gauge more effectively the current state of the general research area. It is well known that literature "lags" behind the actual research field, therefore through personal contacts the most up-to-date relevant research could be explored.

ii) Explore some of the "theoretical data" derived from the literature search and receive advice and criticism on this research project from a peer group of experts, thereby allowing greater confidence in the validity of the research project and the methodologies employed.

Further than this, validity of the research has been tested by publishing some results and tentative conclusions in a refereed journal and presenting them in a conference paper:

- *Role Conflict in Design Supervision*, paper published in the refereed journal IEEE Transactions on Engineering Management, special issue on the Social and Organisational Dimensions of Computer-Aided Design, Part II, November 1989.

- *Design Supervision: Facing the challenge of Computer-Aided Design*, paper presented at the 2nd International Conference on Human Aspects of Advanced Manufacturing and Hybrid Automation, Hawaii, August 1990.

Both the published and presented papers were received favourably, the research paper now cited both in discussion papers on the general research area

(McLoughlin, 1989; 1990) and in another more recent paper concerned with more general management aspects of CAD (Robertson and Allen, 1992).

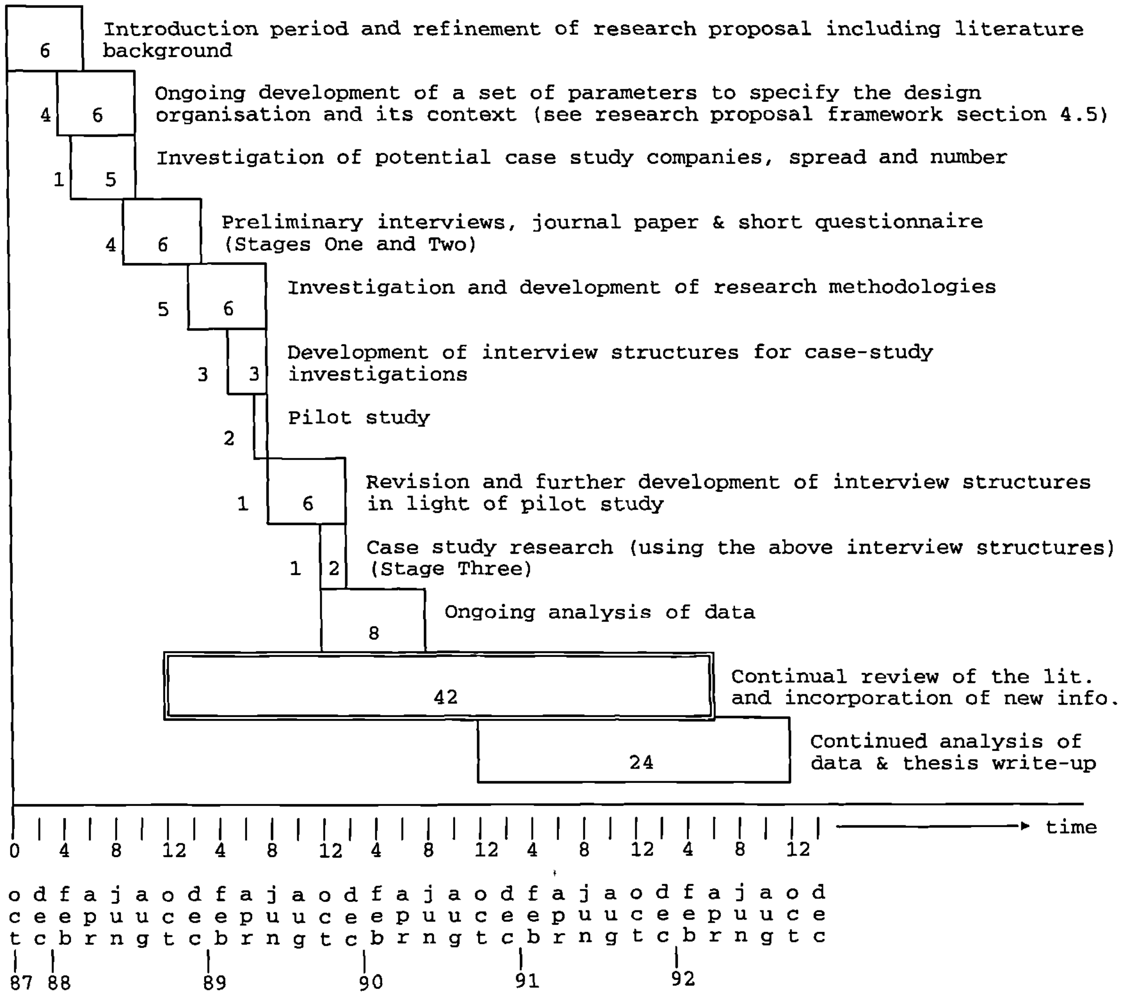
4.6 Comparison with the Methodology of Others

The only directly comparable work with that presented here is Dawson (1986) who used a single lengthy in-depth case study to examine the change in supervisory roles in one industry. This involved a very high degree of cooperation from the organisation he was studying as well as a high degree of participation by the researcher. For this study it was not possible to gain a similar degree of access in one company. In addition, the set of shipyards provide an interesting set of companies working within a traditional heavy mechanical engineering industry. Therefore this is a research population most likely to be a rich source of relevant information. Rather than try and cover a wider area using some form of questionnaire survey, it was decided that a smaller sample of more in-depth investigations (in the form of interviews, chapter 6) would tap this richer vein of research material.

4.7 Research Schedule

An important measure used to control the research programme was a rolling time plan (Gantt chart). This was updated as the programme progressed, and the final version is presented in figure 4.2.

Figure 4.2 **Research Schedule 1987 to 1992**



(lit. = literature; info. = information)

CHAPTER 5
INITIAL INTERVIEW AND QUESTIONNAIRE PROGRAMME

5.1 Introduction

The project consists of three stages, with differing research methodologies used in each. The reasons behind the use of these methodologies are discussed in greater detail later in the chapter. The research methodologies used are:

1. Initial interviews/discussions with a set of companies in a range of industries plus follow-up interviews in a subset of those companies.

2. Two questionnaires, focused on specific roles, applied to a subset of companies identified in the preliminary interviews.

3. An indepth interview survey with five companies, four of which were from the same industry.

This chapter discusses the planning, design, implementation and analysis of the first two stages of the research project (as described in chapter 4, section 4.5).

5.2 Objectives

The initial discussions, follow-up interviews and role questionnaires have three main objectives:

1. To identify the major variables involved with the introduction and running of a CAD system, focusing on those relevant to the role of the first-line supervisor.

2. To generate and confirm a stable picture of:

- the role of the first-line supervisor in design/draughting;
- the role of the CAD manager.

3. To form a base for a future in-depth interview programme in the design/drawing offices of a number of companies.

5.3 Initial and Follow-Up Interviews

A series of initial discussions and interviews were conducted with managers responsible for a CAD system. This initial interview programme served to both acquaint the researcher with the research area (*in situ*) and begin an understanding of the many variables involved in the implementation and post-implementation phases of a CAD system. In particular the aim was to identify key issues in the following three areas:

- the running of a CAD system in the post-implementation phase;

- organisational change(s) seen in this post-implementation phase of a CAD system;

- potential or actual development(s) in the role of the first-line supervisor in design and draughting.

Following the initial interviews, follow-up interviews were conducted in six of the companies. Unlike the initial discussions with CAD managers, these follow-up interviews were conducted with members of the design and drawing offices. The follow-up interviews have two main aims:

- to confirm or contradict the information obtained in the initial interviews;

- to provide perceptions of any changes associated with the CAD system, from the perspective of other members of the design and drawing offices.

5.3.1 Interview Sample Population

A number of companies had already shown an interest in the research through publicity of the project area (mainly through a conference presentation of the background to the research, Wells 1987). An approach, by telephone, was made to a number of the resulting contacts to determine whether they satisfied two basic criteria:

- whether they contained a drafting or design function, using a CAD system, for some tasks;

- whether the design or drafting section was large enough to require the presence of a supervisory system (ie. an organisational hierarchy with at least three levels, including designers and draughtsmen).

There were also a number of constraining variables in the choice of the interview sample. These were:

- **Geographical limits** - the sample population was limited to companies within Britain. This allowed easy access to a large population with no language or communication problems.

- **Cost and cultural limits** - real world relevance would have been more complete if the research could have included some form of cross-cultural comparison. However this was prohibited by the costs and time scale involved in using an international sample population. In addition, without careful control, an international comparison could easily bring bias to the results.

- **Time factors to be considered** - because of the dynamic nature of the process involved in the implementation and post-implementation running of a CAD system, a longitudinal study would have been most applicable. However, time constraints directed the use of cross-sectional research methodologies.

- **Other factors to be considered** - In Britain and Europe CAD systems are used in a number of industrial sectors. Dataquest (a leading CADCAM market analyst) regularly monitors the sales of CADCAM systems and therefore provides a good picture of the state of the market (table 5.1).

From table 5.1 it is clear that the mechanical engineering industry invests most heavily in CADCAM, therefore this is one of the most critical sectors to investigate.

In addition, companies involved in electronics design in some way eg. pcb, ic, eda, have core business expertise in similar areas to those of new technology itself. Due to their familiarisation with this type of technology, they are less likely to face the same level of problems which mechanical engineering companies face in learning to use systems based on an "alien" technology (Simmonds and Senker, 1988, highlight the application sector as being a significant factor in the organisation's approach to new technology).

Table 5.1 **European CADCAM Revenues by Application Sector**

Application		**% share**
Mechanical Computer-Aided Engineering	(mcae)	60
Architectural/Eng/Construction	(aec)	12
Electronics	(eda)	10
Printed circuit board layout	(pcb)	9
Mapping		6
IC layout	(ic)	3

Source: CADCAM International November 1988

For the reasons presented above and to control the number of variables involved in the project and allow greater confidence in future comparisons between companies, the interview population was restricted to those companies using primarily mechanical engineering CAD systems.

Out of those approached, ten companies met the criteria of the research and lay within the interview sample constraints. These companies were mainly large scale organisations, operating in a variety of industries, mainly within the mechanical engineering sector. A profile of these companies is presented in table 5.2 below.

Table 5.2 **Profile of the Initial Interview Companies**

Company	Sector Type	Number in Drawing Office	Number of CAD Workstations
1	Shipbuilding	100	28
2	Aerospace	100	29
3	Vehicle Manufacture	300	52
4	Process Plant Design	70	25/30
5	Aerospace	350	125
6	Process Plant Contract Engineers	150	70
7	Process Plant Design	1500	300
8	Vehicle Manufacture	100	22
9	Telecommunications	14	6
10	Aerospace	300	100

5.3.2 Interview Design

The structure of the initial interview questions is four separate sections (as shown in Appendix III):

1. Organisation culture;
2. Technological change and support;
3. Technology and the company product;
4. Management of the role of the first line supervisor.

Each section aims to investigate the changes associated with the implementation of a CAD system. Originally the interview structure was designed through consultation and informal talks with computer support personnel and other researchers. In line with the development of the programme, this structure was then refined following the first few interviews. Data recorded in the initial interviews provided the basis for the next stages of the research programme.

5.3.3 Implementation

Each of the ten companies was first contacted by telephone, at which time the company's suitability for the project was established as well as their possible co-operation. Further telephone conversations led to the arrangement of site visits with managers responsible for the running of the CAD system.

Prior to the visit a summary of the research area and an outline interview structure was sent to the company, so that the interviewee would know in advance the areas to be discussed.

The site visits consisted of interviews with the contact person lasting about one hour. At this time a request was made to have discussions with other members of the design and drawing offices. Follow-up interviews with the other member of the design and drawing offices were arranged in six companies.

5.4 Follow-up Interviews

The follow-up interviews were conducted with a limited cross-section of support staff, using a more focused interview structure (Appendix III). The follow-up interview structure was developed using the information gathered in the initial interviews and discussions with other academics. This structure is split into five main sections:

1. the job history;
2. the role of the interviewee;
3. the technology used, ie. the CAD system;
4. the products being designed;
5. the design organisation.

Each section begins with questions requiring factual answers and later develops into questions about wider issues and more personal perceptions. All questions in these interviews were "open-ended" (as opposed to "closed", see section 4.2) in structure. The reason for structuring the interviews was to guide the interviewer, rather than constrain the interviewee.

5.5 The Role Questionnaires

Having used the initial interviews to gather basic information on the design and drawing offices post-implementation of a CAD system, the decision was taken to investigate further the parameters of the design supervisor and CAD manager roles, using a short questionnaire survey. This decision was also influenced by results of the first interviews and information in the literature highlighting the difficulties of using a role name alone to identify a person's actual role in a company.

Therefore using the information generated in the literature review and the findings from the initial company interviews, two questionnaires were constructed. One questionnaire investigated further the components of the role of the design function (or first-line) supervisor, and the other investigated further the role of the CAD manager (full details of both questionnaires are reproduced in Appendix III).

5.5.1 Questionnaire Content - The Design Supervisor Role

The list of role activities of the design office supervisor used in the questionnaire is shown in table 5.3, below. It was based on design experience (of the researcher and colleagues), the literature review and the initial company interviews.

Table 5.3 **The Role of the Design Supervisor in Design**

A1.	To take the DESIGN BRIEF information given to him and use his expertise to define the content and format of the OUTPUT information required from his design group, and the internal and external standards it must meet.	A2.	To assess the capabilities of the RESOURCES (technical and human) already allocated to him to achieve that output in the required timescale and to seek further resources if necessary.
A3.	To plan the ALLOCATION of those resources to meet the work demands.	A4.	To gather the necessary INPUT information for the members of his group to begin work, adding relevant knowledge from his own expertise (some of this gathering may be carried out by the subordinates themselves).
A5.	To MONITOR the performance of his subordinates for content and quality, obtaining specialist advice if necessary to allow this to be carried out. Reporting progress periodically to project and design management.	A6.	To identify needs for FURTHER INPUTS from inside or outside the design organisation necessary to achieve the design objectives (this is probably the most important technical part of the supervisor"s role in creative design, where he feeds in his own experience and knowledge as the design develops).
A7.	To MOTIVATE his subordinates by showing interest and encouragement, giving support and advice, ensuring that the objectives are clear and, if needed, dealing with disciplinary problems.	A8.	To CHECK the final output of the subordinates before the information is passed to downstream departments.
A9.	To plan and implement DEVELOPMENTS and improvements to the general performance of his group by identifying training needs (on and off the job), considering opportunities for increased responsibilities (eg. wider or more difficult technical areas, self-checking, partial supervision of more junior designers) and developing more efficient and effective procedures and work methods.	A10.	To examine developments and improvements in the relationship between his group and upstream and downstream groups eg. better attitudes, better communications.

The first eight elements of the design supervisor's activity list are associated with the basic steps in the design process (Pahl and Beitz, 1984). The first set of activities, A1 to A4, represent the information-gathering stage in which the supervisor ensures that all the relevant information for his staff is present, in an acceptable form, and any further staff or equipment are obtained. The set of activities, A5 to A8, represent the concept, embodiment and detail design phases, where the supervisor uses his skills to advise, monitor and motivate his staff and finally check their output. The last two activities, A9 and A10, represent the strategic stages in which the supervisor adopts a more managerial position and considers the overall welfare of his section and how its effectiveness could be improved.

5.5.2 Questionnaire Content - The CAD Manager Role

The list of role activities of the CAD manager used in the questionnaire is shown in table 5.4, below; again the activities list was developed from the literature review and preliminary interviews.

Table 5.4 **The Role Activities of the CAD Manager Role**

B1.	Developing a STRATEGY for the implementation and expansion of CAD in the design function, encompassing hardware, software and user capabilities.	B2.	STRATEGIC PLANNING for the spread of CAD TRAINING - decisions concerning which departments and which members of those departments are to receive CAD training.
B3.	Periodic REPORTING to management about the progress of the CAD system and development of the volume of work for which CAD is used.	B4.	ASSESSING VENDOR UPDATES, eg. new software issues, and preparing capital expenditure justifications and budgets.
B5.	Deciding on JOB ALLOCATION to the CAD system - this decision could be made on a job-by-job basis or by applying a set of guidelines developed from experience of initial pilot projects on CAD.	B6.	Monitoring and investigating relevant NEW DEVELOPMENTS in the CAD MARKETPLACE as a source of information for planning the general direction for development of the system hardware and software.
B7.	PLANNING the content and timing of the various stages of TRAINING in order to develop designers and make appropriate use of the capabilities of the CAD system.	B8.	Carrying out the TRAINING PROGRAMMES and initial user development.
B9.	MONITORING and assessing the day-to-day running of the system, and identifying DEVELOPMENT NEEDS eg. increasing memory size as system utilisation increases, meeting new and emerging design needs.	B10.	DEVELOPING MACROS and subroutines for parametric design, repetitive design elements and analysis etc.
B11.	Investigating any SYSTEM PROBLEMS and liaising with the vendor about these "bugs"; providing the necessary feedback to users.	B12.	Implementing SYSTEM UPDATES.
B13.	Providing general TECHNICAL HELP to users.	B14.	ALLOCATING TERMINAL TIME to users (and between sections) and reserving time for training eg. controlling a booking system.
B15.	Developing, implementing and maintaining company STANDARD CONVENTIONS eg. document naming and numbering conventions, drawing layout conventions. In addition, developing and implementing user LIBRARIES, user-defined commands, user-defined tablets etc.	B16.	Performing the daily, weekly and monthly HOUSEKEEPING, archiving, dumping, reporting of utilisation etc. of the system.
B17.	Arranging for and monitoring THE SYSTEM MAINTENANCE.		

The sequence follows a scale of responsibility level from "long-term strategic planning" (B1) to "day-to-day running of the system" (B17). It was expected that in large organisations the day-to-day, "non-people management" responsibilities (activities B9 to B17 inclusive) would be looked after by a systems administrator, leaving the CAD manager free to fulfil his main role as a **strategic planner and implementer**.

5.5.3 Planning the Questionnaires

In order to make best use of time, money and resources, involved in a project, a questionnaire survey should be carefully planned prior to initiation. Moser and Kalton (1971) provide a framework for the planning stage, which consists of:

1. The identification and choice of the sample population.
2. Effective methods of obtaining high response rates.
3. Appropriate analysis of the information.

NB. The role questionnaires were designed with specific objectives for which a relatively small sample population was sufficient, ie. to provide a clearer understanding of the role activities for both the design supervisor and CAD manager.

5.5.4 Identification and Choice of Sample Population

Initially the same ten companies used in the first stage of the project were targeted as the sample population for the role questionnaires. However seven of the stage One companies declined to participate in the roles questionnaire survey. Therefore the sample population was expanded to include other companies, generated through contacts in the first stage ten companies.

The first encounter with the new companies was through a telephone conversation which established whether they matched the criteria for the project (as described in section 5.2.1). In all the companies approached, for the role questionnaires via this method, the agreement for participating in the survey was secured. Following this, the questionnaires were sent by post to be distributed by the contact (generally the manager with responsibility for the CAD system) within the company to the relevant individuals, ie. either members of the supervisory system or members of the CAD managerial team.

Four "new" companies were approached and agreed to participate in the role questionnaires survey, in addition to the three companies from the original sample. Table 5.5 (below) presents a profile of the seven companies which agreed to participate in the role questionnaires survey.

Table 5.5 **Profile of Role Questionnaire Companies**

Company	**Sector Type**	**Number of CAD Workstations**
1	Aerospace	29
2	Vehicle Manufacture	52
3	Shipbuilding	120
4	Shipbuilding	50
5	Shipbuilding	76
6	Machine Tool	14
7	Shipbuilding	28

In each company, the sample population for the first-line supervisor role questionnaire consisted of individuals who declared themselves to be in the design or drawing office supervisory system (although not necessarily with the title first-line supervisor).

In each company, the sample population for the CAD manager role questionnaire consisted of individuals who were either managers responsible for the CAD system or members of the CAD support team.

5.5.5 Factors Significant in Questionnaire Response

Using a questionnaire survey method involves two major problems which should be recognised and taken into account in the planning stage:

a) low response rate;

b) poorly considered responses.

A low response rate lowers the sample size and, because non-respondents may hold different perceptions from the respondents, may introduce bias into the results. Therefore measures need to be taken to ensure non-response is kept to a minimum. Jolliffe (1986) proposes that the main reasons for the occurrence of non-response are failure to contact the correct respondent and refusal of the targeted respondent to complete the questionnaire. Once recognised these factors can be included in the pre-planning stage and appropriate measures taken to avoid them.

5.5.6 Contacting the Correct Respondent

Although it is possible in a larger postal survey for non-contact with the company itself to occur (eg. change of address), in this relatively small and controlled sample population this was unlikely to happen.

However with a sample population of separate companies, identification of the correct respondent for each of the questionnaires could have been problematic. In particular the first-line supervisor role can be performed by individuals with a range of titles eg. section leader, senior designer, principal engineer etc. Therefore both set of questionnaires were sent to the contact person within each company (in the main the manager responsible for the CAD system) with a covering letter requesting:

i) the CAD manager role questionnaire to be completed by the CAD manager and/or CAD support team members;

ii) the first-line supervisor role questionnaire to be completed by design supervisors or section leaders, whether using CAD or not.

Although the chances of non-response or response by incorrect respondents were increased by this method, it was judged to outweigh the biases and misappropriate approaches that might have been made if direct mailing to respondents had been attempted.

5.5.7 Countering Refusals to Participate in the Questionnaire Survey

There are many reasons why an individual might not agree to participate in a questionnaire survey. These include,

- inconvenient time to contact the individual;
- lack of motivation or interest in the subject matter;
- the individual feeling their privacy being invaded (beyond normal work boundaries);
- complicated, and therefore off-putting, questionnaire format.

5.5.7.1 Contact Timing

Although the point of contact time may be an important factor with more lengthy questionnaires, the short nature of this questionnaire (two A4 sides using a quick reply format) was expected to counter this.

5.5.7.2 Motivation

Having optimised time, length and all other response factors, if respondents do not feel the survey is of any value or worth, particularly to themselves, they will often not respond. Care was thus taken to clearly state the practical objectives and implications of the research.

5.5.7.3 Anonymity and confidentiality

Anonymity was maintained in that each role questionnaire did *not* ask the respondent to specify their name, only present job title, job grade and age. Confidentiality was not a problem with these questionnaires because the information dealt with was exclusively related to job roles. In addition, managers in each company had plenty of opportunity to vet the questionnaires before allowing them to be distributed.

5.5.7.4 Format

The role questionnaires were constructed with extremely clear and open formats. Each role questionnaire was headed by a statement of the rationale and aims for that questionnaire. The response modes were also clearly set out with space provided for additional comments where needed.

The length of the survey was an important factor in a successful response. The document could have been reduced to A5 size to present the questions in a compact manner and therefore present a less intimidating document for the respondent. However this would have involved a significant decrease in the visual quality of the document. Therefore it was decided to use either two A4 size sheets printed on one side only, but decrease the overall length by a slight reduction in the print size (from 12 to 10 point). Only one response format was used for both questionnaires. This ensured that the questionnaire document was not too formidable, thereby allowing the respondent more time to properly consider his response.

5.6 Initial/Follow-up Interviews and Questionnaires Analyses

One of the major weaknesses of the questionnaire format, used here, is that it did not allow or encourage the respondents to identify tasks which were not listed. However it was expected that if these other tasks existed then they would be elicited in stage three, using semi-structured interviews.

The role questionnaires analyses are presented below, first for the design supervisor, then for the CAD manager.

5.6.1 The Design Supervisor Role Questionnaire Analysis

The analysis is based on fourteen usable replies from design supervisors. Out of these, eleven described themselves as section leaders, principal engineers or designers. They all claimed to carry out all the activities (as shown in table 5.3), with the following exceptions:

- one respondent shared A2 and A3 (resource assessment and allocation) with "technical planners";

- two respondents replied that they did not do A8 (checking) because self-checking was practised in their company;

- one respondent did not do activities A7 (motivating), A9 and A10 (group internal and external development) - these were the responsibility of the assistant chief draughtsman;

- two respondents believed that A10 (external group relationships) was not applicable in their company.

Number twelve, a "principal analyst", carried out all the activities except A3 (resource allocation), A9 and A10 (group internal and external development) which he saw as the responsibility of more senior people.

Number thirteen, a young "CADCAM support engineer", claimed to carry out all the activities. Number fourteen was a "junior manager - mechanical engineering". He carried out all the activities except A6 (further input), A8 (checking) and A10 (group external relation); A5 (monitoring) was shared with the senior project engineer and A7 (motivating) and A9 (internal group development) were shared with the design manager and research and development director.

Therefore a high degree of correspondence between the respondents' roles and the activity list can be assumed. Activities A1 (design brief definition) and A7 (motivating) were regarded as the most important and/or most frequently carried out by those who provided comments; A3 (resource allocation), A4 and A6 (initial and further input gathering) were the next most important.

Further support comes from the initial interviews where first-line supervisors whose roles closely match the analysis can be identified. For instance, the section leader in one company described his job as follows:

> "To produce a scheme (design intent) in response to the design problem given to him (A1). After this evaluation, the section leader estimates a time scale for the design (A2) and allocates it to a subordinate (A3). Once the design is completed, it is sent to detailing and finally to manufacture. The section leader still does **some** design work, but only in the area of preliminary design."

5.6.2 Discussion

An important feature of the role is whether or not the first-line supervisor himself does design work. If, as above, some design work is included (albeit only at the conceptual stage) and this design activity is retained after CAD is introduced, it is possible his role may come under less stress than if he does no direct design work. This is because the first-line supervisor is applying current design work methods and using the current design technology; he may therefore be better able to appreciate the implications of the changes in working practices associated with CAD.

5.6.3 The CAD Manager Role Questionnaire Analysis

The following results are based on nine usable questionnaires (one was incomplete). The job titles of the respondents were varied. Seven titles contained reference to the CAD technology; the other two were "project engineer - electrical" and "section leader". However it was clear from their replies that they had major systems responsibilities.

The role questionnaire results strongly confirm that the activities in the list **were** carried out in the sample companies. Only six "not done in this company" answers were received, out of a total of 144 answers:

- Two were activity B14 (allocating terminal time); in at least one of these responses the terminals were distributed to the user sections and there were are very few users. Therefore allocation of the system was not required.

- The other four all came from the same respondent - a "graphics support manager" (computer services department); some criticism of the company can be inferred in that the following activities were not done:

B3 (periodic reporting to management);

B5 (job selection for CAD) - "this is subject to debate at the current time";

B6 (CAD marketplace monitoring) - "tends to be only ear to the ground";

B10 (developing macros) - "handled by third party".

Ownership of the activities, however, seemed to vary widely between the companies. One hundred and fourteen usable replies about "who did what" were received. One group of activities formed a recognisable role, that of CAD system support engineer, in seven of the nine companies. The activities were:

B8 - User training;

B10 - Macros (if applicable);

B11 - System problems;

B12 - Implementing systems update;

B13 - Providing user help;

B15 - Standards and libraries;

B16 - Housekeeping.

The analysis supports the hypothesis that a specific CAD manager role exists, to a degree (though one subject was entitled merely "section leader", another "CADCAM support engineer" and a third was split between two technical jobs - CAD manager and system manager). The principal activities were:

B1 Overall CAD strategy;

B3 Management reporting;

B4 Vendor update assessment*;

B6 CAD marketplace;

B9 System monitoring*;

B14 Terminal allocation;

B15 Standards and libraries*.

* these activities were also shared with the CAD System Support Engineers.

Some activities were shared between these two and the design function line management; in particular:

B2 - CAD training strategy;
B5 - job suitability for CAD;
B7 - CAD training planning.

Finally some mention was made of activities that were handled by people outside the design function:

- a separate computing department for
  - B9 - identifying system development needs;
  - B16 - housekeeping;
  - B17 - arranging system maintenance.

- the training department for
  - B2 - CAD training strategy;

- outside consultants for
  - B6 - CAD marketplace developments;
  - B10 - development of macros;
  - B12 - implementing system updates.

Because of the nature of the data and the relatively small sample size, it is not possible to draw any general conclusions about the relative importance and frequency of the activities.

One systems administrator in a case study company gave his perception of the main elements of his role as being:

- to look after the daily running of the system:
    - dealing with software/hardware problems (activity B11)
    - training new recruits and existing members of staff, and meeting special training requests, etc. (activity B8)

- to develop enhancements to the system:
    - combating present problems (activity B9)
    - meeting the needs of the user (activity B10).

5.6.4 Discussion

Two important features of the relationship between the first line supervisor and CAD manager roles can be identified from the analysis of both initial, follow-up interviews and the role questionnaires:

1. There are areas of overlap between the new CAD-oriented roles and the traditional role of the first line supervisor, eg. in the areas of training, allocation of resources and identifying and meeting the personal development needs of the designer or draughtsman, etc;

2. The objectives of the CAD manager and the traditional supervisor are fundamentally different:

    - the CAD manager is **primarily** concerned with the effective and efficient use of the system, through the people who directly use it;

- the first line supervisor is **primarily** concerned with delivering, on time, the right quality of design output information needed to meet the design brief.

Therefore the new CAD management roles may be perceived by the first line supervisor as a direct threat to his job. Not surprisingly, several of the follow-up interviews indicate that there had been resistance to the implementation of CAD from some first line supervisors. This had taken the shape of either directly refusing to schedule work for CAD or allowing their subordinates to work on it. Management had failed to recognise or avoid this serious impediment to the implementation of CAD.

5.7 Chapter Summary

Having established the background to the project, this chapter set out the early stages of the empirical research, which have been called stages One and Two in the research framework.

In stage One a set of preliminary discussions and interviews were conducted, with both CAD managers and other members of design and drawing offices. These were used to explore the research area and gather basic information on design and drawing offices which use a CAD system for some aspects of their work.

In stage Two a short postal questionnaire was used to confirm the validity of the activities proposed as being associated with the design supervisor and CAD manager roles.

The major finding from these preliminary parts of the study was that the objectives of the CAD managers and of the design supervisors' roles do not match. Therefore their objectives in using the CAD system are also unlikely to match. This will be explored further in the following chapters.

The results from these two stages of the project were used to provide the basis for the in-depth interview survey, conducted in the case studies, which are described in detail in chapters 6 and 7.

CHAPTER 6
CASE STUDIES

6.1 Introduction

Having explored the general area through the initial interviews and elicited some focused information on the roles of design supervisors and CAD managers, it was recognised that greater indepth investigation of the research area was needed. To examine the perceptions of individuals working in design and drawing offices it appeared that a case study strategy using a series of semi-structured interviews would be most appropriate (see chapter 4, stage 3). This would also gain indepth, current, qualitative information with which to build on the information already gathered.

This chapter explores the rationale behind case study strategies, the development of the specific interview structures, conducting those interviews and the planning and analysis of the data collected.

6.2 Choice of Case Study Methodology

The research framework showed case studies to be the most appropriate choice as the main methodology in this research project (see chapter 4). However they are also seen to be "soft" and "unscientific". Therefore it was considered essential that the background and rationale behind case study methodology was explored.

6.2.1 Justifying the Case Study

Case studies are the preferred method of investigation under the criteria:

- when "how" or "why" questions are asked;
- the investigator has little control over events;

- the focus is on a contemporary phenomenon within a real-life context.

Problems with the case study methodology include:

1. Lack of rigour - but this can be improved; also occurs in other types of research eg. in designing questions for a survey.

2. Generalisation - the concise answer is that (as with experiments) case studies are generalisable to theoretical propositions, not to populations or universes.

3. Take too long - this does not need to be true; case studies do occupy a long time in the "field" or detailed observation (ethnography and participant-observation).

6.2.2 Definition of a Case Study

Yin (1989) defined a case study as an empirical enquiry that:

- investigates a contemporary phenomenon within its real-life context; when

- the boundaries between phenomenon and context are not clearly evident; and in which

- multiple sources of evidence are used.

Case study research includes both single and multiple case studies and can be limited to *quantitative* evidence (in the same way that both experiments and survey questions can look for qualitative evidence, eg. when seeking categorical evidence).

There are four different applications for qualitative case studies, which are:

1) to explain causal links in real-life interventions too complex for survey or experiments;

2) to describe the real-life context in which an intervention occurs;

3) to produce an evaluation which can benefit from an illustrative case study of the intervention;

4) to use case studies to explore situations where the intervention being evaluated has no clear, single set of outcomes.

6.2.3 Research Designs

Every piece of empirical research has an implicit or explicit research design. This is the basic research "blueprint" which contains the logical sequence connecting the empirical data to the initial research questions, and finally to the research conclusions.

The case study research design has been defined as having five distinct components (although not necessarily independent):

1) The study's questions - case study is most likely to be appropriate for "how" and "why" questions.

2) The study's propositions - each proposition directs attention to aspects which should be examined within the scope of the study. If the case study is exploratory then it will *not* have any propositions, but instead needs to state its "purpose".

3) The study's unit(s) of analysis - these define what the "case" is about, eg. an individual, an event, a process, an organisation, etc. In general the unit is related to the way in which the initial research questions have been defined.

After the general definition has been established, clarification of other factors become important such as which particular individuals are to be included in the unit and which are to be left outside it (the context) or the specific time boundaries needed.

4) The logic linking the data to the propositions - this can be accomplished in a number of ways. One example is "pattern matching" (Campbell 1975) where several pieces of information from the same case are related to a theoretical proposition. When two potential patterns are considered rival propositions (ie. an "effects" proposition versus a "no effects" proposition) then all that is needed is to show that the data fits one pattern better than the other and so link the data to the propositions.

5) The criteria for interpreting the findings - this is a difficult area, possibly solved by statistics but currently no precise way for setting criteria exists.

6.2.4 Role of Theory Building as Part of Design of Study

The preceding five components begin the process of constructing a theory related the research topic. Theory-building prior to data collection is now becoming recognised as a vital part of case study methodology (Yin 1989). This does not imply the development of a complete or "grand" theory but a "blueprint" sufficient to guide the study.

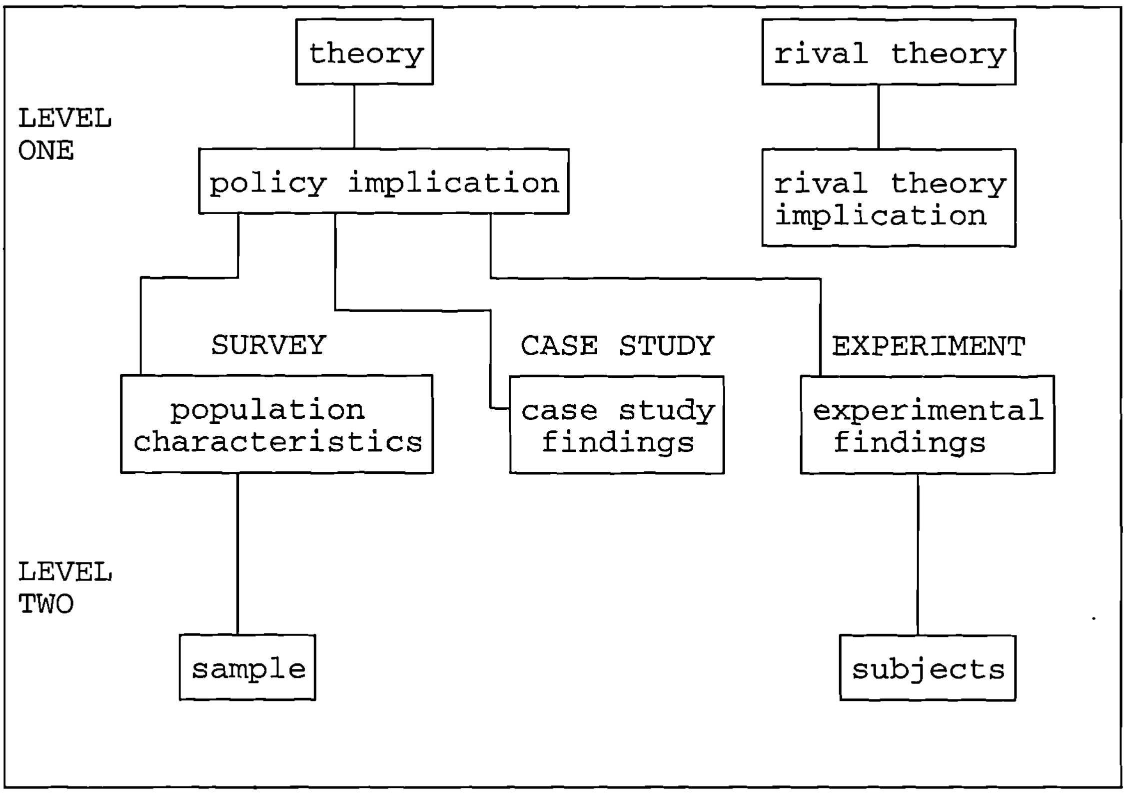
Any case study (even exploratory or descriptive case studies) should be preceded by statements about: i) what is to be explored or the purpose of the description, ii) the purpose of the exploration or description and iii) the criteria by which the exploration will be judged successful or the topic(s) likely to be at the heart of the description. In addition it is important to be aware of the range of theories that might be relevant to the study, eg. in a study comparing different companies the theories might cover individual, organisational or wider social issues. Appropriately developed theory is the level at which generalisation of results can occur.

Usually results are generalised by either "analytic generalisation" or "statistical generalisation". The latter is where:

> "an inference is made about a population on the basis of empirical data collected about a sample" (Yin 1984/9).

This is known as a "level two" inference (see figure 6.1). Statistical generalisation is very common because research investigators can easily access formulae which determine the confidence with which generalisations can be made. However it is a

Figure 6.1 **Making Inferences: Two Levels** (Source: Yin 1984/9)



fatal flaw in case studies to conceive statistical generalisations as the method of generalising the results of the case. Cases are not sampling units and should not be chosen as such.

For case studies the more appropriate method is analytic generalisation where:

> "a previously developed theory is used as a template with which to compare the empirical results from the case study" (Yin 1989).

If two or more cases support the same data then replication may be claimed. Even more powerful is where two or more cases support the same theory and do not support an equally plausible rival theory. This is know as a "level one generalisation" (see figure 6.1).

6.2.5 Quality of Research Designs

Yin (1989) defines four tests relevant to judging the quality of any case study research design:

- construct validity: establishing correct operational measures for the concepts being studied;

- internal validity (for explanatory and causal studies only, not descriptive or exploratory studies): establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships;

- external validity: establishing the domain to which a study's findings can be generalised;

- reliability: demonstrating that the operations of a study (such as data collection procedures) can be repeated, with the same results.

Several tactics can be utilised for dealing with each of these tests, and these have been summarised in table 6.1 following (Yin 1989).

6.3 Planning the Semi-Structured Interviews

Having established that a case study strategy using semi-structured interviews would be most appropriate for this stage of the research, careful planning was still required to ensure that high quality data would be elicited, from which valid conclusions could be based.

6.3.1 Aims and Objectives of the Interviews

The main aim of the interviews was to examine the supervisor role within both design and drawing offices within companies using a CAD system. Thus the objectives of the interviews were to collect design/draughting supervisors' perceptions of their situation, the company as a whole, the individuals within it and their interactions with the CAD system. To supplement this and provide greater reliability to the study, it was also decided to interview a sample of designers/draughtsmen and CAD managers (or computing managers with special responsibility for the CAD system) within each of the companies.

Table 6.1 **Case Study Tactics for Four Design Tests** (Source: Yin 1989)

TESTS		CASE-STUDY TACTICS	PHASE OR RESEARCH IN WHICH TACTIC OCCURS
Construct validity	establishing correct operational measures for the concepts being studied;	use multiple sources of evidence; establish chain of evidence; have key informants review draft case study report;	data collection; data collection; composition;
Internal validity	(for explanatory and causal studies only, not descriptive or exploratory studies) establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships;	do pattern matching; do explanation building; do time-series analysis;	data analysis; data analysis; data analysis;
External validity	establishing the domain to which a study's findings can be generalised;	use replication logic in multiple-case studies;	research design;
Reliability	demonstrating that the operations of a study (such as data collection procedures) can be repeated, with the same results.	use case study protocol; develop case study database.	data collection; data collection.

6.3.2 Sample Selection

Basic criteria for companies to take part in this study had been set for stages one and two (see section 5.3.1) of the research, and these were still considered appropriate for this stage.

One of the companies in stage One was situated in the shipbuilding sector. Through the contact (CAD manager) in that company it was realised that the nationalised shipbuilding industry in Britain had directly prompted a number of major shipyards to implement one out of a limited choice of CAD systems. Shortly after this the industry returned to private ownership. Thereafter each shipyard was able to develop their own CAD system as was thought appropriate (for more detail see section 6.4.1). The first CAD manager contact also provided contacts with CAD managers (or computing managers with special responsibility for the CAD system) in four other shipbuilding companies (originally the stage one shipbuilding company was also to have taken part in the interview survey in stage three, but following a change in personnel where the CAD manager was not replaced, the company was not included in the latter stage).

Shipbuilding includes a long period of design and therefore use of a CAD system could have a potentially significant impact on both the phases of the design process and the viability of the company as a whole. The economic environment for British shipbuilding can be characterised as generally very unstable, experiencing a steep decline since the early 1960's (Todd 1991). Therefore it might be expected that the introduction and effective use of a CAD system be of great importance for the whole industry. However this very traditional mechanical engineering environment is also characterised by huge degrees of entrenchment, particularly especially where innovative ideas are concerned.

Therefore the shipbuilding industry can be seen to be an interesting sector in which to situate the study, caught between the two forces of traditional inertia (resistance to change) and economic instability (prompting the need for change and progress).

Finally, a local toolmaking company (with international links) was included in this stage, as a check on the information gathered from the shipbuilding sector and to highlight any major contrasts.

In this initial piece of research, to facilitate cross-organisational comparison of results, the research was concentrated on one specific industry. The shipbuilding industry was particularly useful as all the various companies had introduced CAD at similar times. Care will have to be taken when generalising from these conclusions to other industries, but the insights gained may still usefully inform organisations using of CAD in any other area. In addition, the information gathered in stages One and Two anchor the overall research project in a wider context.

Each of the companies was contacted via the telephone, to ensure they met the basic criteria for the project and would be willing to take part in the study. Ideally specific individuals would be chosen as a random sample from the various drawing and design offices. However for the companies to participate the interviewees were chosen by the CAD managers soliciting volunteers from design and drawing office managers. It was explained to the CAD managers that the study required a representative cross-section of individuals rather than respondents who held only positive perceptions about the CAD system. As far as could be established, through later questioning of the interviewees, this request was adhered to.

The sample for stage Three of the study consisted of interviews with:

- 5 CAD managers (or computing managers with special responsibility for the CAD system) and 3 CAD support team members;
- 12 first-line supervisors (5 in design and 7 in drawing offices);
- 11 designers/draughtsmen using CAD (5 designers and 6 draughtsmen).

During the analysis it was recognised that one designer and one draughtsman fulfilled the requirements and carried out the tasks of an "informal" supervisor, and therefore should be regarded as such throughout all the data analysis.

6.3.3 Design of the Interview Schedule

Following the literature review and the results of the first two stages of the research a detailed interview structure was developed. The aim was for this structure to be used by the interviewer as a framework or guide, ensuring that similar topics were covered in each interview (as opposed to a rigorous structure constraining an interview).

The interview schedule was initially developed for individuals at the supervisory level, and then modified accordingly for use with individuals at the designer/draughtsman and CAD manager levels. In addition a first draft of the interview structure was presented to a senior Teaching Company Assistant at Liverpool University, who had a long history of practical industrial experience, and then modified to take account of the comments.

In addition a small pilot study was carried out with a local engineering company. This consisted of a full run-through of the interviews (one of each of the three structures) including solicited comments from the interviewees on the conduct and content of the interviews. The interview structures were again modified in the light of the interviewer's experiences and the comments received.

Each interview schedule was split into eight major sections (see Appendix IV):

A. Job history and career
B. General job training
C. Job role
Ca. Interaction with superior and staff (supervisor interview only)

D. Job satisfaction

E. Computer-Aided Design facilities available

F. Training for CAD received

G. Extent of CAD use

H. General section

In the interview structure for supervisors, the first section (A) aimed to gather basic and background information on the interviewee. This was followed by a section (B) looking at the individual's general training, a section (C) on what tasks they carried out and what information was passed around, a section (Ca) on interaction with others in the company and a section (D) probing job satisfaction, and what might be done to improve this.

Having established the individual's place in the organisation, and what role they actually carried out, the interview then turned to the examine perceptions of the introduction and usefulness of the CAD system, section (E). Following this was a section (F) on training relating to the CAD system and a section (G) on the perception of relative proficiency and the amount the supervisor and his staff actually used the CAD system. Finally the interview closed with a general section (H) looking at the Trade Union presence in the company and its support for new technology, and the individual's perceptions of the future, both for themselves and the company in general.

The interview structure for the designer/draughtsmen differed only in that some irrelevant questions (mainly related to management of staff) were removed and some extra questions, concerning their perceptions of factors affecting supervisors, were added. Equally the CAD manager interview structure differed very little except to gather more detailed information on the CAD system itself, eg. number of workstations, systems selection method, types of system evaluation, etc.

6.3.4 Conducting the Interviews

A successful interview is more likely to be achieved if the correct "interview situation" is planned and established (Benson 1989, Hawkins 1989). Although it is generally recommended that initial contact is made directly with interviewees, in this study this was not possible. Instead general preparatory information (or the interview structure itself, when requested) was given to company contacts who then liaised with potential interviewees.

Thus it was left to the company to arrange the programme of interviews. Each interview programme took place over approximately two days, and on company premises.

6.3.4.1 Interview Environment

Following the experience gained in stage One, where possible, the interviews were conducted on the company site, in a separate place from where the interviewee normally worked. This was done for a number of reasons:

- To remove the individual from their ordinary work situation and so allow them to concentrate fully on the interview.

- To remove the interviewee from interruptions, such as from telephone or personal callers.

- To allow the interviewee to talk in an environment of confidentiality, especially important for open plan offices,

- To allow the interviewer to spread out papers, notes and use a tape recorder etc. without disturbing the normal workplace of the interviewee.

- To lend greater authority to the interview through using a neutral space and as such encourage them to provide a higher quality of response.

A number of other factors were also important when planning the interviews to ensure the production of as high quality output as possible.

6.3.4.2 Opening the Interview

Each interview began by presenting a covering letter to the interviewee (see Appendix IV). This stated the interviewer's name and role. It also clearly explained that the interviewer was an independent researcher, unconnected to that company or any other, but attached to the Industrial Studies Department of Liverpool University. It also clearly stated that the interview would be conducted under conditions of confidentiality and assured anonymity.

6.3.4.3 Purpose of the Interview

The purpose of the interview was explained to the interviewee, and that a series of similar interviews were being conducted in that company and others.

6.3.4.4 Anonymity, Confidentiality and Language

As well as the assurance given at the start of the interview, the interviewer also explained that the purpose of the interview was not to elicit any technical details about shipbuilding, *per se*. Consequently it did not seem likely that company confidentiality would arise as an issue during the interview.

It had also become apparent that there was a need for the interviewer to communicate that a basic level of general knowledge about design and aspects of design specific to the particular industry could be assumed. This was intended to convey the idea that they could speak and use language as they would normally in their work situation, without the need to add detailed description to specific terms (unless the interviewer prompted for clarification of unusual or uncommon terms).

Equally the interviewer had to keep in mind that the language they themselves could use should not be overly technical, obscure or open to easy misinterpretation. This was also reflected in the written interview structure, to continually remind the interviewer of this aim, eg. the question regarding the nature of the "relationship" between the supervisor and CAD manager was re-phrased as "How does your role relate to that of the CAD manager?".

6.3.5 Interview Strategy and Tactics

Each interview followed the interview structure as described previously (section 6.3.3). As already explained, the structure was used as a guide, allowing other topics to be explored and a greater depth of information to be gathered.

The structure was designed such that the interview began with questions relating to the background of the interviewee, information which the interviewee would know and have easily to hand. Having established a context in which to situate the individual (and a relaxed atmosphere), it was assumed the individual would answer subsequent questions with greater informality (Eden et. al., 1983 and Easterby-Smith et. al., 1991 discuss similar issues in the importance of establishing trust with the interviewee). This tactic was taken further in each section, which began with a few questions asking for more quantitative or "factual" information and then moving on to more qualitative judgemental information.

Finally each interview concluded with an open question asking for "any other comments" from the interviewee, and a question regarding the interviewee's perception of the interview itself.

Each interview lasted approximately one hour, although in some cases interviewees were keen to talk and the interview was allowed to run on to one and a half hours. Although some interviewees might have wished to speak for longer periods, since the company contact had been told that the interviews would last about an hour, it was not thought fair to the company to let the interview run too long and interfere with both the interviewee's work schedule and the interview programme arranged for the interviewer.

6.3.5.1 Recording the Interview

The layout of the interview structure was such that answers to specific questions could be written next to them and other comments recorded in the generous margins or on the reverse side of the pages.

However other methods of recording also exist, such as tape recording. Yin (1984, 1989) has outlined some of the disadvantages of this method:

- an interviewee (or the company) may refuse permission or appear uncomfortable in its presence;

- there are no specific plans for transcribing or systematically listening to the contents of the tapes;

- the interviewer is clumsy with the mechanical devices such that the tape recorder creates a distraction during the interview itself (this may also occur if the interviewer runs out of either or both battery power and blank tapes);

- possibly the most important, the interviewer perceives that the tape record is a substitute for "listening" closely throughout the course of an interview.

Meanwhile Easterby-Smith et. al. (1989) add that the major factor in the decision about whether to tape an interview lies with the interviewee's anxiety, concerning confidentiality and the use to which any information divulged can be put.

Notwithstanding the above criticisms, permission to tape interviews was secured from both the managers concerned and the individuals involved in two of the sample companies. This was done because the advantages of having an accurate record of complete interviews was felt to outweigh its disadvantages. The primary advantage being as a method of detailed analysis which is not influenced by the interview situation where the bias of the interviewer may affect conclusions. It also allows third party validation of the result, should this be required.

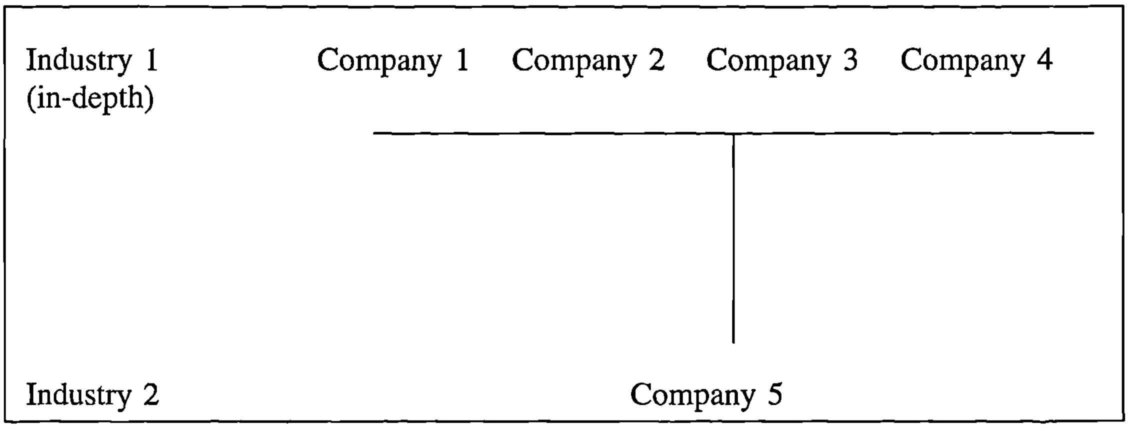
Thus although the interviews were being taped, the interviewer continued to take notes. This let the interviewee see that their responses were being actively noted and stopped the interviewer from letting the tape recorder take over the interview (see Yin's criticism above). The tape recordings were later used to augment the notes taken during the interview.

The role activities list questionnaire from the earlier research was not used in this part of the study. However the answers to a number of those questions in the interviews relating to the individual's activities were compared with it and the results were summarised and differences highlighted.

6.4 Sample Formation

The sample consisted of four companies in one specific traditional mechanical engineering industry (see section 6.3.2). The aim here was to appreciate and understand the environment in which the companies were working better. In addition a mechanical engineering company in another industry was examined to provide a contrasting case. Thus a "T" shaped sample structure was used (see figure 6.2, below).

Figure 6.2 **Sample Structure**



The criteria for selection of companies was that the drawing and design offices should be large enough to have at least three levels of management hierarchy thereby requiring the role of first-line supervisor (irrespective of formal job title), and that each should have at least eight CAD workstations. Details of the case study companies are given in table 6.2, below.

Table 6.2 **Outline Details of the Case-Study Companies**

Company	Sector Type	Approximate Number of CAD Workstations	Number of Regular users	Size of CAD/Computing Development Team (incl. CAD Management)
ShipCo 1	Shipbuilding	50	64	3
ShipCo 2	Shipbuilding	76	130	2
ShipCo 3	Shipbuilding	120	200	18
ShipCo 4	Shipbuilding	30	25	3
ToolCo	Machine Tool	14	14	4

6.4.1 A Short History of British Shipbuilding (1970-1985)

To provide a sense of the context in which the CAD systems were initially introduced in the shipbuilding companies, a brief history of modern British shipbuilding follows.

The recent history of the UK shipbuilding industry is a complex picture (Stråth

1987). Around 1970 the industry had over 40 companies with manual workers in the industry organised into 11 unions, acting under an umbrella organisation, the Confederation of Shipbuilding and Engineering Unions (CSEU, colloquially called Confed). Although Confed was a bargaining organisation it wielded very little power because most unions conducted their own collective bargaining. At this time, there were over 100 collective bargaining agreements in place in British shipbuilding.

In 1971 poor cash flow caused the Upperclyde Shipbuilders to collapse financially, but with a full order book. During the resultant work-in (September 1971 to April 1972) the Labour Party and the TUC began working towards nationalisation of the shipbuilding industry. In 1973 the Labour Party, together with Confed and the TUC, issued a pamphlet detailing five reasons for nationalisation of the shipbuilding industry in Britain. The main points in this were (see Hogwood, 1979):

1. No other industry had failed to increase its absolute output for twenty-five years in a period when world output had grown four-fold.

2. No other industry, with the exception of the aircraft industry, had received so much public finance and support; shipbuilding would continue to require that support.

3. Few other industries had failed to modernise and re-equip to the disastrous degree of shipbuilding and ship repairing.

4. The history of labour relations in the industry, despite recent improvement, had been poor.

5. The coming few years would continue to be difficult for shipbuilding internationally; the industry needed a clear and firm national strategy, which

could only come from a nationalised shipbuilding organisation.

In 1974 a Labour government was elected to power and began, together with Confed, to further investigate the question of nationalisation. After much political resistance, and a rather difficult passage through Parliament (including the dropping of ship repair from the nationalisation Bill), nationalisation was finally accomplished on 1 July 1977 with the formation of the British Shipbuilders (BS) Corporation. It appears that whatever the political reasons surrounding the delay in the passage of the Bill, one other effect was to increase the already unsteady conditions surrounding the shipbuilding industry at that time.

British Shipbuilders brought together about 40 companies (in various states of decay) with no common plan, organisational structure or financial system. Although senior management attempted to create a viable centralised structure with the line management in each company reporting directly to their chief executive, each company management stubbornly retained its own ideas about what to do.

Although BS was formed in mid-1977, compensation for the takeover of the different shipyards took a long time to organise. By the end of 1978, it became apparent that huge losses on orders had been inherited along with the shipyards. It also appears that some of these companies had been very close to bankruptcy immediately prior to nationalisation (Hogard, 1979, estimated a combined deficiency on asset value of around £20 million). Therefore much of the early focus of the management at BS was on finding orders to keep the yards working in the short-term. However even with much marketing effort, and some orders aided by subsidies from the shipbuilding intervention fund, the first nine months of 1978 saw only 12 ships (77 440 tons) ordered from British yards, compared with 36 ships ordered in 1977 (372 322 tons). After this dire situation, September 1978 saw some slight improvements, through confirmation of orders which had been waiting for approval for subsidies by the European Commission.

In 1977 there had been 168 different bargaining agreements, but by 1978 this had been reduced to only one bargaining group. British Shipbuilders undertook to "level out the differences between the yards, and between staff and non-staff" and in 1979 signed the Phase 1 Agreement (on wages and salary restructuring, harmonisation and productivity). Confed signed the agreement, on behalf of all workers within British Shipbuilders. One outcome of the agreement was that all wages were to be determined nationally, for the whole concern. Therefore local shop stewards suddenly became controlled by, and reliant on, national officials. At the same time there was still no overall system of financial control, and production and marketing remained decentralised.

In September 1979, both British Shipbuilders and Confed signed the Blackpool Agreement, which allowed for a cut in jobs as long as there were no compulsory redundancies. In 1980 the chairman of British Shipbuilders attempted to increase central management power through centralised financial control and a decentralised production and productivity responsibility. Following this, the yards were grouped together in five divisions according to their product profiles. The new approach also paid much less attention to the unions, neglecting to include them in high-level financial discussions, and leaving Confed in a much weakened position. This attitude was reflected in the lack of co-operative objectives and a "watering down" of definitions seen in the Phase 2 Agreement, signed in 1980, and the Phase 3 Agreement, signed the following year.

From 1980 onwards, the Blackpool Agreement was progressively weakened as a result of a number of minor cases. At the same time, since the Conservative Party manifesto for the 1979 election had contained promises of privatisation, government talks on this subject began. Confed strongly objected to privatisation, but were also facing pressure from the increasing internal tensions between local and national union leadership. Through the decentralisation of responsibility for productivity measures, such as local productivity agreements, individual yards were beginning to perceive each other as competitors, rather than colleagues. Confed also realised that the commitment of the workers to nationalisation in the 1970's had become replaced by a belief that nationalisation had resulted in contraction and lower wages in the 1980's.

In 1981 British Shipbuilders decided that each of the major shipyards should, with their financial backing, evaluate and implement a small CAD system. In 1983 Confed signed the Phase 5 Agreement and by 1984 it was clear that they were a severely weakened organisation without much influence on shipbuilding politics.

In 1985 the UK shipbuilding industry was finally privatised with the yards passed to various private owners. Since then each company has been free to follow its own path regarding the development of its CAD system.

However more contemporary literature on the British shipbuilding industry holds no better news. Harrison (1990) examined the historical and modern state of British shipbuilding, and looked at the consequent regional impacts. His list of acknowledged problems for the contemporary British shipbuilding industry includes poor management, bad work practices, poor industrial relations, low investment, lack of price competitiveness, poor delivery records and the lack of an effective domestic demand linkage, the erosion of technological competitiveness. The book concludes with the statement:

> "the British shipbuilding industry has declined, and continues to decline, significantly over a very long period of time."

6.5 The CAD System Introduction and Implementation Process in the Sample Companies

As part of the initial acquaintance process in each company, the basic path of introduction and individual perceptions of the implementation process of the CAD systems was elicited.

The path of CAD system introduction and implementation for each company is presented below. In each interview there were specific questions which probed for individual perceptions related to the CAD system introduction process. These questions are presented, for reference, in table 6.3 below:

Table 6.3 **Questions Related to Individual Perceptions of the CAD Introduction Process**

Supervisor	**Design/Draughtsman**	**CAD Manager**
What do you think were the main reasons behind the company's *original* decision to bring in CAD?	What do you think were the main reasons behind the company's *original* decision to bring in CAD?	What do you think were the main reasons behind the company's *original* decision to bring in CAD?
Did you express any concerns, raise any significant matters?	Did you express any concerns, raise any significant matters?	
Do you think there was enough involvement of the supervisors, in general (section leaders) in the implementation of the CAD system?	Were the supervisors involved in the implementation of the CAD system? If NO, do you think this non-involvement in the implementation phase has had any effect on the way the system is used today?	Do you think there was enough involvement of the rest of the design office staff in the implementation of the CAD system?

6.6 ShipCo 1

In 1982, this shipbuilding company implemented a CAD system (CADAM) consisting of 11 workstations. Later the CAD system was moved from seven separate locations around the company into one central area, mainly to facilitate control over the allocations of workstations.

One supervisor expressed concern over the timing of the introduction of the CAD system, ie. that it should have been introduced later because at that time there was no specific plan guiding the use of CAD. He argued that management's attitude appeared to be captured in the phrase, "just hope for the best". Other concerns were technical, concerning the suitability of the geometry of the output from CAD for use by the lofting department. No important issues were raised at the time of introduction because ShipCo 1's management did not fully understand the potential impact of the CAD system. The supervisor felt that, at the time, management was only concerned with people using CAD to produce drawings faster than previously possible.

One design/draughtsman expressed a concern about the apparent lack of planning in the introduction of the CAD system. In particular he criticised the physical layout of the system. Although a centralised CAD room had been created, not all necessary information resources were available inside it. Therefore CAD users had to move in and out of the CAD room, and this design/draughtsman perceived that it might be advantageous to have the CAD system dispersed among the general drawing offices.

The CAD Manager felt that in introducing the CAD system, management had listened to "the wrong people" who were critical of CAD, eg. the chief draughtsman, rather than consulting the experts. The specific problem was that the chief draughtsman did not want to show his ignorance of technical matters and therefore did not consult with the experts himself.

6.6.1 Perceptions of the Implementation Process

One supervisor (drawing) felt that there had been a lack of involvement of supervisors in the implementation process which had resulted in a lack of interest in the system and, further, to a differential between ability to use the CAD system and actual usage, among the supervisors. In ShipCo 1 all drawing supervisors and all draughtsmen use the CAD system, while only one out of four design supervisors can or does use it (although one of their number used to be a CAD trainer).

One draughtsman remembered how the CAD system had originally been introduced into the department and "allocated a space", with no real involvement of designers, draughtsmen or supervisors. In addition, a very poor training programme meant that a lot of trial and error, or self-learning, had to be used by those working on the CAD system. The non-involvement of supervisors in the CAD implementation process seems to have resulted in their current lack of knowledge about CAD procedures (eg. procedures needed to draw/produce a drawing). However the draughtsman did appreciate that the supervisors could now be afraid or find it difficult to begin to learn about the CAD system.

The CAD manager held a rather different view of the introductory process. He perceived that the company lacked a "knowledge base" from which they could work. The company only began to realise the potentials involved in using CAD, when training its personnel. Therefore he did not see how there could have been more involvement because up to that point in time the company didn't appreciate the capabilities of their CAD system.

Table 6.4 **Summary Table of Perceived Main Reasons Behind the Introduction of the CAD System in ShipCo 1**

Role type	**Perceived reasons**
Supervisor (drawing)	speed/time savings; more accurate;
Supervisor (drawing)	speed/time savings; British Shipbuilder's directive;
Draughtsman	increase productivity; general investment in new technology;
Draughtsman	more economical drawings production; speed/time savings;
CAD manager	British Shipbuilder's directive; improve performance as compared with competitors.

6.7 ShipCo 2

Over a period of eight years this shipbuilding company introduced a CAD system (CADAM). The system was established in 1981 with the introduction of two workstations. Together with British Shipbuilders/BMT, ShipCo 2 conducted a 12 month evaluation test. Following a further 2½ years development work, in conjunction with IBM and Lockhead, a suite of programmes was designed which enhanced CADAM and tailored it for shipbuilding uses (named Britships II).

In 1982, 14 more workstations were introduced to the company, mainly for training and steelworking uses. Since only four workstations were exclusively used for training purposes, none was free for post formal training exploration and consolidation, ie. apart from those four used for training the rest would be fully occupied with daily work.

In 1983, 16 more workstations were introduced to the company, followed in 1984, by 32 colour workstations with a further 12 colour workstations (non-IBM, therefore much cheaper) introduced to the company in 1988. In 1989, one further colour workstation brought the total to 76 in the company. These were dispersed around the design and drawing offices, in small batches.

One supervisor said that when the CAD system was being introduced there were concerns over pay and training related to it. The issue of pay concerned whether there would be an extra allowance for using CAD or not. The issue of training was caused by the company trying to be selective over who was trained, which in turn caused friction between the departments. The supervisor argued that if the company had engendered better communication they could easily have avoided the inter-departmental friction.

The design/draughtsman interviewed in ShipCo 2 said that the introduction of the CAD system had led to concerns about demarcation problems arising from difficulties experienced in identifying a break-off point between design and draughting. In addition some individuals in the drawing office appeared to have been worried that design would take their jobs away from them. However the shipbuilding industry often appears subject to general worries related to job security.

This CAD manager also described the passive nature of introduction of the CAD system saying that the company as a whole "didn't handle the introduction of CAD, just accepted it ... as a means of doing drawings". He also perceived a more recent change in ShipCo 2 towards a view of the CAD system as a company resource.

6.7.1 Perceptions of the Implementation Process

One supervisor (design) remembered a lack of involvement in the CAD system implementation process in that the implementation agents only comprised individuals from the computing department and senior management. Although he also recognised a lack of planning in this implementation process, he acknowledged that the company has adapted to use the system "as best as it wants", ie. the concept that the company, itself, knows how best it should be using the CAD system. This lack of planning was also rationalised by a perception that use of the system could not have been foreseen, therefore the limitations of the system had to be accepted.

However another supervisor (drawing) felt that the involvement of supervisors in the CAD system implementation process had been satisfactory. One supervisor from each department had been seconded to the research and development (R&D) team concerned with developing CADAM for shipbuilding. The rationale behind this was to allow the supervisors to use their experiences to help with the development of CADAM (resulting in collaboration with IBM and Lockhead, in "Britships II", a suite of shipbuilding support programmes). This, together with the director of R&D's willingness to listen to those introducing CAD to the company, led this supervisor to rate ShipCo 2's management as "excellent" in relation to their handling of the introductory process.

The individual identified as being an "informal" supervisor (drawing) also observed how some areas had been introduced to CAD before others. However his emphasis was on the differential nature of introduction within the drawing offices. One drawing office (steel) was involved in the introduction of CAD (because the CAD system was most useful for accurate NC burning) with the rest of the drawing offices being trained to use it later.

One designer's perception was that no designers were involved in the implementation of the CAD system, but that this was acceptable. The company had been involved in customising the CAD system from a ship design perspective and this designer had been involved in the second stage, ie. testing the customised system. As with other designers he perceived a lack of involvement of supervisors in the implementation process, but saw no reason to think this had had any repercussions in the present use of the system.

The draughtsman however felt that draughtsmen had not been sufficiently involved in the CAD system implementation. He thought that, although a couple of drawing office supervisors had been included in the initial R&D section, the majority were not, and this had resulted in them not using the CAD system today.

The CAD manager also perceived a lack of involvement in the implementation process. He attributed this to British Shipbuilders driving the CAD system project, which in turn led to the system becoming "isolated", with a focus on draughting. He concluded that design managers should have received regular updates on the progress of the system, which might have enabled the system to be "open" to a wider audience.

Table 6.5 **Summary Table of Perceived Main Reasons Behind the Introduction of the CAD System in ShipCo 2**

Role type	**Perceived reasons**	**Example**
Supervisor (design)	improved job performance; speed/time savings; quality; reduce costs;	 speed up build time; improved quality of output;
Supervisor (design)	improve flow of information; speed/time savings; more accurate; quality; reduce costs;	 faster; improved quality of output; need for fewer staff;
Supervisor (drawing)	savings in time/speed;	shorten the timescale between award of a contract and completion of production drawings;
Informal supervisor (drawing)	speed/time savings; accuracy;	
Designer	speed/time savings; marketing;	save man-hours on tasks; impress prospective customers;
Draughtsman	quality; speed/time savings;	better quality jobs; jobs done in less time;
CAD manager	British Shipbuilder's directive;	

6.8 ShipCo 3

In the late 1970's this shipbuilder decided to implement a CAD system under the direction of British Shipbuilders (see above).

In 1984 a ComputerVision (CV) system was introduced in each of the three separate drawing offices. The first project implemented on CAD had previously been running for four years and was considered quite "ambitious". This was proved correct as the design model soon outgrew the limitations of the system. In turn, system response time rapidly fell and it became a "cumbersome" tool to use. Consequently respect for the system and motivation to use it were severely dented. Following privatisation of the company, a management consultancy firm was employed for a general efficiency inspection and audit. This consultancy made two recommendations:

- move from fragmented multiple drawing offices structure to project-based structure;

- consolidate CAD from separate offices into a central area thereby consolidating the existing body of knowledge.

In 1987, in line with the above recommendations, a purpose-built CAD room was opened.

During the initial CAD implementation, each drawing office supplied one "best" operator to become a CAD supervisor. In the later general reorganisation, the CAD supervisors became a non-CAD supervisory team providing first-line support exclusively for CAD users.

One supervisor pressed concerns that no-one in ShipCo 3 realised what implications the introduction of the CAD system raised, at the time. In addition, following the introduction of the CAD system, management appeared to lack control over it, eg. shortage of rules for naming files. This situation was later improved.

Another supervisor expressed concern over the timing of the introduction of the CAD system, ie. that it should have been introduced to the company earlier so that it could have been used from the beginning of the last major project. He also perceived that the introduction of the CAD system had lacked direction, ie. how best to utilise it. This is an issue which, he suggested, had still not been resolved.

One design/draughtsman interviewed in ShipCo 3 had few concerns about the introduction of the CAD system. The only comments he made were connected with technical details, such as the unsettling effects of software revisions on the system as a whole.

The other design/draughtsman was mainly concerned with the present effects of CAD; in particular he expressed a feeling of isolation due to the centralised physical layout. Another concern he expressed was the difficulty in quickly appraising his current workload when using CAD.

The CAD Manager perceived that the introduction of their CAD system had been passive in nature. The installation and training had been handled well, whereas the application was handled poorly, ie. CAD was "just plugged in" and it worked. The expectation appeared to be that people would know what to do, and no more than that.

6.8.1 Perceptions of the Implementation Process

One supervisor (drawing) perceived a lack of consultation with supervisors during the CAD system implementation process. If there had been some consultation with the design and drawing supervisors viewpoints would have been expressed to the CAD supervisors that might have changed direction of the development of the system.

The other supervisor (drawing) also perceived a lack of consultation with supervisors during the CAD system implementation process. He saw how non-involvement has resulted in problems with project duration, allocation and estimation. The scenario was of a large project, begun as a manual design task, with a drawing programme which did not include consideration of CAD and the extra modelling work needed. This meant that certain things that could have been done using CAD were not, which has resulted in present day production problems.

Both draughtsmen agreed that there was a lack of involvement of both drawing office staff and supervisors in the CAD system implementation process. One draughtsman observed how CAD had been introduced to some areas (eg. the mechanical section of the drawing office) before others. Therefore ShipCo 3 had developed certain aspects of its CAD system (eg. pipework) at the expense of others (eg. the duct work programme).

The other draughtsman highlighted the technical constraints resulting from the lack of involvement in the implementation process. Originally the vendor was to provide software to allow them to extract information from the double-layered models constructed in design and draughting. But this technical possibility was never realised and now they only use single line models, from which each draughtsman has to develop his own method for extracting drawings. Therefore "everyone does it his own way" with very little control over the process.

Table 6.6 **Summary Table of Perceived Main Reasons Behind the Introduction of the CAD System in ShipCo 3**

Role type	**Perceived Main Reasons**	**Examples**
Supervisor (drawing)	flow of information;	savings associated with links to production, eg. extraction of isometric drawings with associated information [although at present this doesn't happen, because only the technical office has access to information stored in CAD];
Supervisor (drawing)	aid to production dept; flow of information	as opposed to being seen as a draughting tool; downstream links, eg. direct to NC burner;
Draughtsman	more effective individual; speed/time savings;	role of new technology is to enable greater effectiveness; produce drawings faster;

Role type	Perceived Main Reasons	Examples
Draughtsman	reduce costs; speed/time savings;	save money through more productive working day; possibly produce drawings 30% faster;
CAD manager	British Shipbuilder's directive; improved technical design ; improved outputs;	

6.9 ShipCo 4

In 1983, this shipbuilding company implemented a (CV) ComputerVision "CADDS 4X" CAD system which by 1989, consisted of 30 workstations and 2 non-graphics PC's. Although the company did carry out benchmark tests on a variety of CAD systems, they said they were not able to make effective use of the results. Therefore this system was chosen primarily for its ability to handle complex 3D information. However the takeover of CV by Prime in 1988 has meant that only limited development of their CAD software had taken place over the two years prior to the study.

One supervisor expressed no concern over the introduction of the CAD system, whereas another was only concerned with the knowledge differential that might arise. This reflected the supervisor's worry that draughtsmen would be able to capitalise on the supervisor's lack of CAD-related knowledge for their own purposes, eg. produce less work, work more slowly, etc.

Another supervisor had informally expressed concerns about CAD to the Technical Director at that time (formal comments were not solicited by the Board of Directors, who were responsible for the decision to introduce to introduce CAD). His main concern was with involving the design offices more in using CAD and about generating integration between design and drawing offices, including the retitling of CAD users as design/draughtsmen.

The other supervisor also expressed concerns about CAD when it was initially proposed for the design office. His main concerns were regarding the lack of planning and systems management. Again there was a strong perception that management would let the introduction of CAD just "happen". As a consequence there seemed to be many crossed lines of authority, eg. people who reported to more than one superior, making it unclear who was to manage the CAD system.

The individual identified as being an informal supervisor in this company also expressed the concern that management had not planned the introduction of the CAD system. However he recognised that it is much easier to see what improvements to the introductory process could have been made in hindsight.

The design/draughtsman was concerned that during the initial introduction of the CAD system the drawing offices had worked "round the clock" shifts (mainly because training was at its peak level); however they now work a normal 37 hour week.

The CAD Manager perceived that both the introduction and running of the CAD system had been handled very badly by the management of ShipCo 4. Again the introductory process was perceived as being very passive in nature, ie. "it (CAD) just appeared one day", there had been no discussion with the relevant staff on how CAD was to be used. This resulted in the company wasting the first 12 months it had a CAD system. Therefore the CAD Manager attributed the major cause of failure of the CAD system, in the initial stages of introduction, to the actions of (or lack of action by) management.

6.9.1 Perceptions of the Implementation Process

One supervisor (drawing) said that initially there was enough involvement of supervisors in the CAD system implementation process since they were using it full-time. During this period their other supervisory duties were carried out by the "leading hands" (senior draughtsmen). For no reason that could be recalled the supervisors were withdrawn from working with the CAD system.

This supervisor held the view that the supervisor role was incompatible with working on CAD. He thought it possible that some supervisors complained and this was the reason why management pulled them off the CAD system.

Another supervisor (drawing) considered that there was a lack of involvement of supervisors in the CAD system implementation process. However because he had already worked in other departments where CAD had been introduced, he was already familiar with it.

A third supervisor (design) agreed there was a lack of involvement of supervisors in the CAD system implementation process. Part of this was connected with ShipCo 4's decision to aim the CAD system at draughting rather than design.

The rationale behind this was that the last major project was too far on in the design office to be worth putting on CAD. It was felt that to put CAD in the design office would hold them back. Therefore the design office staff did not use CAD for the first four years it was in the company. This supervisor expressed the view that the company should have involved the design offices, rather than the drawing offices, from the beginning.

The fourth supervisor (design) corroborated the lack of involvement of supervisors in the CAD system implementation process and the focus on draughting. He also saw a significant lack of planning, by management, in ShipCo 4's implementation procedure.

The company set up a CAD steering group to talk about how to perform different tasks, which was effective at developing relationships across the department and preventing invisible walls from being erected. However the group lost direction when the chairman (who had strong ideas about how CAD was to be developed) left the company.

The fourth supervisor perceived that the introduction of CAD into the drawing offices had been a "disaster", but ShipCo 4 could learn lessons from it. These lessons included the need to use the 3D capabilities of CAD to produce good design work and the need for formal conventions controlling how work is approached. He was convinced that there was "never any question that designers would use 3D". Although the design office suffers because not everyone has been trained in using the CAD system, he recognised that there were, and still are, time constraints which make this difficult to rectify.

The training history for the other supervisors in this particular design office was that one supervisor had not received any training, one supervisor had been a systems designer but still never received any training specific to CAD and one supervisor had received training a long time prior to the introduction of the CAD system into the design offices.

This last supervisor had also been trained "in the way the drawing office uses CAD". This appears to be significantly different from the way the design offices use CAD, in that he has to use paper printouts rather than work on CAD directly. However in order to get the paper printout he has to "plague the life" out of his staff working on CAD. Therefore CAD training can itself be inappropriate to a particular working environment. Without the appropriate training this supervisor finds it very difficult to make decisions that specifically relate to the CAD system.

Finally this last supervisor perceived an age differential among those trained for CAD. In general it tended to be younger people, ie. basic designers, who were first trained on the CAD system.

The individual identified as being an informal supervisor (design) in this company also observed how the system had been introduced halfway through the design process and therefore it does not flow cohesively from start to finish.

The designer perceived a lack of involvement of designers in the CAD system implementation process. It was introduced to the company purely as a tracing tool in the drawing office, whereas the company should have included the design offices when they first started to use the CAD system. The designer also agreed there was a lack of involvement of design supervisors in the introduction of the CAD system.

The CAD manager said he thought there should have been more discussion with the drawing office staff on what they felt the CAD system should and could do. ShipCo 4 could also have elicited suggestions from the design office staff on how CAD should be implemented. Instead discussions were held at high level only, and mainly by people with a non-technical background (a committee outside the company).

Table 6.7 **Summary Table of Perceived Main Reasons Behind the Introduction of the CAD System in ShipCo 4**

Role type	Perceived Main Reasons	Examples
Supervisor (drawing)	no choice;	British Shipbuilder's policy/push;
	speed/time savings;	
	way ahead for industry;	latest technology needed to enable them to compete/stay ahead in the industry;

Role type	Perceived Main Reasons	Examples
Supervisor (drawing)	popular/industry recipe;	"panacea for lack of work power";
Supervisor (design)	no choice; popular/industry recipe; changes in design process;	British Shipbuilder's policy/push; "mood" of the time; intention at the time was to move towards modular build and production saw CAD as essential for this;
Supervisor (design)	reduce costs;	increased productivity out of fewer people;
Informal supervisor (design)	no choice; speed/time savings; reduce costs;	British Shipbuilder's policy/push; improve production in draughting workforce; employ less people;
Designer	British Shipbuilder's directive;	company were "told to get CAD";
CAD manager	British Shipbuilder's directive; vendor pressure;	 "BUT management didn't really know what they were getting themselves into";

6.10 ToolCo

This machine tool manufacturer conducted its own CAD system feasibility tests to decide which best suited them. The result (the purchase of a Calma system) was influenced by the fact that both of their sister companies (in Germany and America) used this system. The company expected to capitalise on these relationships in that a large amount of data exchange with the sister companies would be technically feasible.

In 1983, the company decided to invest in their own FMS cell, and in 1984, the company secured a DTI grant for the FMS cell with the condition that AMT was involved.

In 1985/6, the company changed direction and decided that they would implement

"Integrated CAE" and brought in a project engineer to develop a CAE system. This resulted in 1986, with the company employing the present Systems Supervisor as part of a two-man team to plan the CAE system.

From 1986 to 1988, the CAD system progressed well but it has stagnated since then. Initially this company was provided with much supporting software from its two sister companies. However due to problems involved in tailoring this software for UK use, this stack of software started to "clutter-up" the programme library, without being seen as of any real use.

The present CAD system is distributed around the drawing offices as follows:

- mechanical engineering - 7 workstations;
- proposals - 2 workstations;
- controls (electrical) - 5 workstations.

The main problem for this CAD system is that it is still too small to handle a complete project, even with shift-working by users.

The supervisor's main concern regarding the introduction of the CAD system was with the physical layout. He expressed a preference for having all the workstations located in one area. In contrast, during the implementation the workstations had been put directly into the sections, and the supervisor was concerned that this had possibly caused embarrassment to supervisors who had not known what to do with them (this contrasts with the reason for dispersal given in another ShipCo, which was that by having a workstation in his section, a supervisor would feel compelled to allocate some tasks to be done using it, therefore encouraging the, albeit grudging, use of workstations).

One design/draughtsman interviewed in ToolCo expressed some concerns about the introduction of the CAD system. One concern was the influence of specific individuals on the perceptions of the CAD system. There had been some changes in management since the introduction of CAD (specifically a new chief engineer) and this combined with the perception that CAD had not lived up to expectations, led him to the view that CAD was now regarded as a "necessary evil". However he also perceived a positive change associated with the introduction of the CAD system, a change in his status from "operator" to "CAD designer".

The CAD manager perceived that although there was a good introduction of the CAD system to ToolCo, there was a problem in that the follow-up procedure was very disorganised. He perceived a severe lack of human resources planning prior to the implementation of the CAD system as well as lack of structure for the system from the outset.

6.10.1 Perceptions of the Implementation Process

When questioned about their own lack of involvement in the implementation of the CAD system, no-one in ToolCo expressed any particular worries. One design/ draughtsman acknowledged that this minimal degree of involvement had been sufficient (ie. one engineer had been "thrown" into helping the setup of CAD) while the other's view was that being involved in the implementation of CAD would have had little effect either way.

However both design/draughtsmen did recognise the lack of involvement of supervisors in the implementation process and some possible resultant problems. These included the supervisor's limited knowledge of, (i) the capabilities of CAD, (ii) how to use the system, and (iii) estimating time scales when working with CAD.

The supervisor (design) also perceived a lack of involvement of supervisors in the CAD implementation process, but saw no causal links with the present use of CAD.

The only factor in the implementation process which was perceived by the CAD manager as having an effect on the present functioning of the CAD system was the physical layout of the system chosen. He thought that a central CAD area would have allowed better usage of CAD, compared with separate machines dispersed around the company. However he was more concerned with the poor rationale for choice of individuals for training. Apparently management had compiled a short-list (basis unknown) of individuals from which to choose, as opposed to picking people with abilities best-suited to be trained for CAD.

Table 6.8 **Summary Table of Perceived Main Reasons Behind the Introduction of the CAD System in ToolCo**

Role type	Perceived Main Reasons	Examples
Supervisor	customer pressure;	
Design/Draughtsman	customer pressure;	their customers were introducing CAD therefore they were saying they wanted their suppliers to do the same, so the company had to implement CAD to survive;
CAD manager	customer satisfaction;	advanced technology to design and manufacture a product is what the customer wants;
	increased productivity;	from reduced lead times;
	presentation;	
	quality;	

6.11 Perceptions of the Introduction of a CAD System in all Companies

Table 6.9 presents a summary of the perceived reasons behind the introduction of a CAD system as drawn from all the case study companies. A number of interesting issues are raised by this.

First there is a wide range of different perceived reasons with the main options seen as:

- the possible savings in time taken to produce designs and drawings through the expected higher speed of throughput of work;
- the financial benefits from reduced costs through less re-work of materials in production, faster drawings modification and potentially less design/drawing staff needed or,
- a result of the British Shipbuilder's directive or policy that all their major shipyards should implement a CAD system.

The first two reasons are shown to be prevalent among both the supervisors and designers/draughtsmen. Whereas the CAD managers show a much higher awareness of the influence of the British Shipbuilder's directive on the decision to implement a CAD system (this is not relevant to ToolCo).

In tables 6.10 and 6.11, the specific concerns, about the introduction of a CAD system, from each interview group in the ShipCo's and ToolCo are brought together. A general pattern here appears to be that design/draughtsmen were concerned about more individual features, the supervisors were concerned about more control oriented features, ie. who controls what when working with a CAD system, and the CAD managers were concerned with the nature of the introduction and the wider organisational implications.

Table 6.9 **Overall Summary of the Perceived Reasons behind the Introduction of a CAD System from all Companies**

Company	Level	Popular/ industry recipe	Quality	Speed & time savings	Accuracy	BS policy/ directive	Economy/ productivity/ reduce costs	Customer pressure/ satisfaction	Improved performance	Flow of Information	Marketing/ Output	Other
ShipCo 1	S (drwg)			♦	♦							
ShipCo 1	S (drwg)			♦		♦						
ShipCo 2	S (des)		♦	♦			♦		♦			
ShipCo 2	S (des)		♦	♦	♦		♦			♦		
ShipCo 2	S (drwg)			♦								
ShipCo 2	D (drwg) (inf S)			♦	♦							
ShipCo 3	S (drwg)									♦		
ShipCo 3	S (drwg)									♦		2
ShipCo 4	S (drwg)			♦		♦						5
ShipCo 4	S (drwg)	♦										
ShipCo 4	S (des)	♦				♦						6
ShipCo 4	S (des)						♦					
ShipCo 4	D (des) (inf S)			♦		♦	♦					
ToolCo	S							♦				
Totals		2	2	8	3	4	4	1	1	3	-	
ShipCo 1	D (drwg)						♦					1
ShipCo 1	D (drwg)			♦			♦					
ShipCo 2	D (des)			♦							♦	
ShipCo 2	D (drwg)		♦	♦								
ShipCo 3	D (drwg)			♦								3
ShipCo 3	D (drwg)			♦			♦					
ShipCo 4	D (des)					♦						
ToolCo	D							♦				
Totals		-	1	5	-	1	3	1	-	-	1	

Company	Level	Popular/ industry recipe	Quality	Speed & time savings	Accuracy	BS policy/ directive	Economy/ productivity/ reduce costs	Customer pressure/ satisfaction	Improved performance	Flow of Information	Marketing/ Output	Other
ShipCo 1	CAD					♦			♦			
ShipCo 2	CAD					♦						
ShipCo 3	CAD					♦					♦	4
ShipCo 4	CAD					♦						7
ToolCo	CAD		♦				♦	♦				
Totals		-	1	-	-	4	1	1	1	-	1	
Grand Totals		2	4	13	3	9	8	3	2	3	2	

Key:

S (drwg) = Supervisor (drawing)
D (drwg) = Draughtsman
CAD = CAD manager

S (des) = Supervisor (design)
D (des) = Designer

S = Supervisor
D = Design/Draughtsman

inf S = informal supervisor

1= General plan to invest in new technology
2= Aid to production
3= Enable individual to be more effective
4= Improved technical design
5= Way ahead for industry
6= Changes in the design process
7= Vendor pressure

Table 6.10 **Summary of Concerns Expressed by ShipCo Interviewees about the Introduction of a CAD System to their Company**

Supervisors	Design/Draughtsmen	CAD Managers
- pay; - selection and friction; - communication; - lack of planning; - variable CAD usage; - timing; - lack of direction; - unknown implications of CAD; - lack of management control; - knowledge differential; - integration; - systems management;	- shift work; - lack of planning; - physical layout; - demarcation; - general worries; - software revisions; - work appraisal;	- lack of advice/uninformed advice agents; - passive nature of introduction; - lack of planning; - awareness; - severe lack of communication with the staff; - management actions;

Table 6.11 **Summary of Concerns Expressed by ToolCo Interviewees about the Introduction of a CAD System to their Company**

Supervisors	Design/Draughtsmen	CAD Managers
- physical layout;	- introduction process; - influence of individuals; - change in status;	- lack of follow-up to introduction; - lack of planning; - lack of structure for system;

nb. Some supervisors, design/draughtsmen and CAD managers did not express any concerns related to the introduction of a CAD system; therefore the assumption is that they felt the process had been relatively satisfactory.

6.12 Planning the Analysis

Following on from the theoretical background of Grounded Theory, the semi-structured interviews results were submitted to a modified form of grounded analysis (see section 3.3).

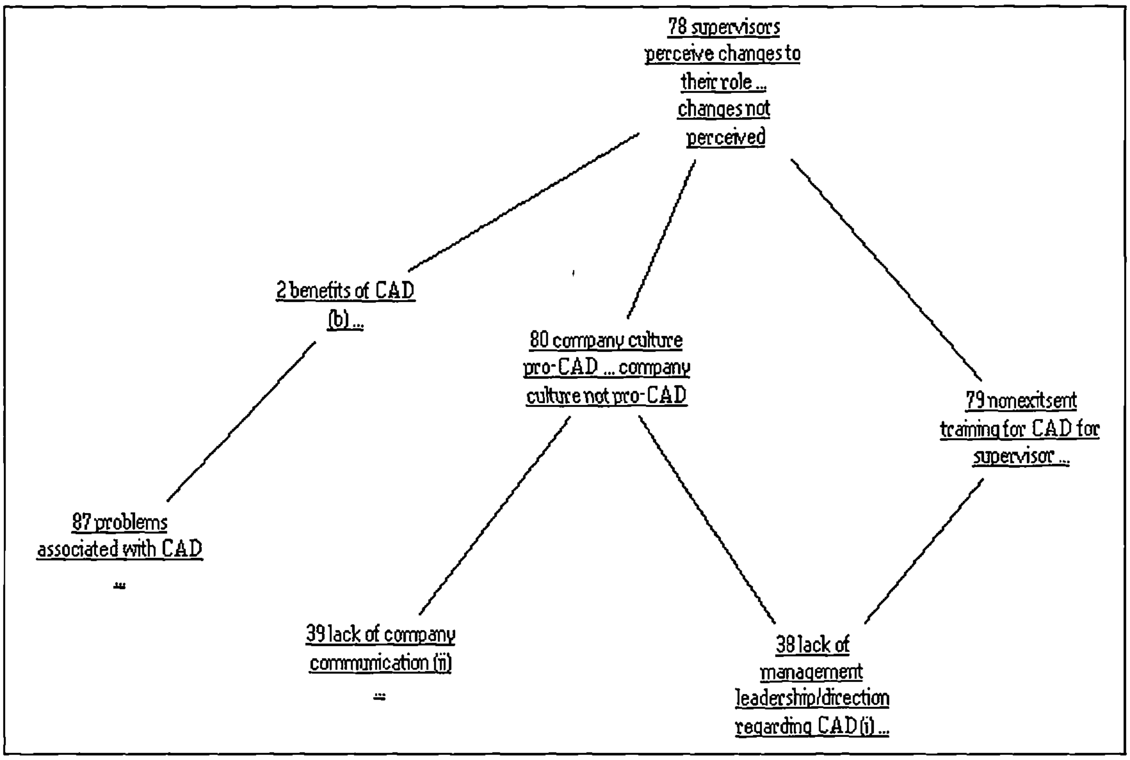
In the first stage the results of one interview were examined to elicit an initial set of "categories" which captured the substantive information (see Stage 1, Grounded Theory). Categories are taken to be a phrase or title which represents a heading under which "concepts" (ie. discrete happenings, events or other instances of phenomena) could be grouped. Next the remaining interviews were examined in light of the initial set of categories and either added into them, as appropriate, or new categories created to cater for data which did not fit into existing categories (see Stage 2, Grounded Theory). This part of the analysis needed only pen and file cards, where each card represented a category and contained exerpts from the interviews, with appropriate identifying coding.

In the next stage of the analysis a set of characteristics or definitions were developed for each category. Thus a number of characteristics were defined such that if a new piece of data were to be included in that category it would have to possess some of those characteristics (see Stage 3, Grounded Theory, section 3.3). In this part of the analysis the results from the three groups of individuals interviewed (supervisors, design/draughtsmen and CAD managers) were kept separate. In addition the analysed data from ToolCo was also kept separate, so that comparisons with the data from the four ShipCo's could be made more easily.

The resultant set of about 60 categories (some obviously much larger than others) were then treated as concepts and a causal map structure created, such as is used in cognitive mapping (see section 3.4 and Eden 1988, 1989 etc.). Within this the various categories were treated as nodes and linked using arcs which consisted of arrows, implying some causal relationship, or lines implying some connotative relationship (see Stage 6, Grounded Theory). Through the use of GraphicsCOPE (GC), which supports cognitive mapping the complete set of concepts could be mapped, including some appropriate goals etc., and so allow the generation of some structure for the data. Using GC the structure of the concept categories could be subjected to some elementary analysis, which highlighted seven (non-exclusive) categories, classed as major strategic issues (see figure 6.3).

A cluster analysis of the map's structure allowed the generation of a set of concept categories related to, and partially explaining, each of the strategic categories. This will be used as the basic structure for presentation of the analysis results.

Figure 6.3 **The Seven Major Strategic Issues**



6.13 Chapter Summary

This chapter began by looking at the reasons behind choosing a case study strategy using semi-structured interviews. It then focused on the design of these interviews and strategies to ensure successful outcomes from them. Having explained the formation of the sample population, a background history of British Shipbuilding was presented, to enable a fuller appreciation of the environment in which CAD was introduced in the four shipbuilding case study companies. Following this the focus changed to the historical route behind the introduction and implementation of the CAD system in each company as well as individual perceptions of the initial implementation process. Finally the chapter presented the rationale behind the data analysis where, drawing on Grounded Theory (as presented in section 3.3) and Cognitive Mapping, a set of seven major issues are drawn from the data. These mainly reflect the complex set of variables influencing the perception of change in the supervisory role and will be explored fully in chapter 7.

CHAPTER 7
ANALYSIS OF CASE STUDY DATA

7.1 Introduction

In this first section a general picture generated by the analysis will be presented. It is important to recognise that this is one set of interpretations of the data. Other researchers eliciting the same data, but within the framework of a different project, might have produced different interpretations. These too would be as valid as this analysis of the data, but within the framework of this project the following interpretations appear to be the most appropriate.

Within the sample of companies in this study, and using the semi-structured interview approach and grounded theory analysis (as described in chapter 3), seven major strategic issues relating to design supervision and CAD systems were identified (figure 6.3).

Each of the seven major issues can be seen as relating to different aspects of the wider picture investigated in the study. While these aspects may be "teased" out for analytical purposes, in the real world they are often interrelated and buried within a complex setting.

Rothwell (1984) in her findings on the impact of new technology on supervisors claimed to see some "patterns" emerging in her analysis. These patterns led her to group her findings under ten headings: planning change, style and approach, implementing change, supervisory training, erosion of roles and functions, degree of boredom (level of job interest), increased scope, key role, relations altered and reduction in numbers.

While this one method of presenting analysis results is frequently used, factors such as these are often "picked" as representative and may hide the complexity of the situation that has actually been examined.

First, with the focus of this project on the supervisory role (as a generic representation of the supervisory system) a major issue is whether or not changes to the supervisory role are perceived. While these perceptions of change are mediated by a range of factors, at a higher level of analysis, it is possible that three other major issues could exert specific influence; namely whether or not the general company culture is supportive towards the use of the CAD system, the degree of training specifically provided for supervisors in relation to their use of and supervision of others using the CAD system, and the perceived benefits of using the CAD system.

Similarly, while each of these issues is surrounded by a range of factors (or other categories), a further three influential issues were identified. Both the issue of company culture and attitude towards the CAD system and supervisory training may be influenced by the degree of management leadership/direction regarding the CAD system. Furthermore company culture may also be influenced by the issue of the degree of communication which exists within the company.

Finally the issue of perceived benefits of the CAD system may also be mediated by the issue of problems perceived as being associated with the CAD system (see figure 6.3, chapter 6).

7.1.1 Format of Results

All three groups of interviewees expressed some perceptions/views about most issues. These are presented in the following sections, as they relate to a specific issue or set of issues. In each section the data is presented in the order of the three the groupings: supervisors, design/draughtsmen and CAD managers. In some sections one or more groups did not comment on that particular issue and therefore only the views of the other one or two groups could be presented.

Where appropriate, the data gathered from ToolCo is presented separately, otherwise it is integrated with the presentation of the other data, as described above.

7.2 Perceived Changes in the Role of the Supervisor After the Introduction of CAD

Although not deterministic it appears that the introduction of a new technology is often seen associated with various types of change. The argument can be made that these changes are more important, and can lead to benefits or problems, rather than the introduction of new technology *per se*. Therefore perceived changes to the role of the supervisor can have significant consequences.

7.2.1 The Design Supervisory Role and CAD

This section investigates how the introduction of a CAD system has affected the design supervisor's role. This includes whether or not design supervisors perceive changes in their job roles attributable to the CAD system. Further, what type of changes occur and do they enhance or erode the supervisory role?

Supervisors

The perceived changes and their perceived consequences can be split into positive, negative and neutral groups. Positive is taken to mean that the change aids the supervisor in carrying out his role while negative is taken to mean that the change was detrimental to the role of the supervisor.

In addition some concepts contribute to "explain" the nature of the perceived changes, eg. change in perception (experience and appreciation), time (leads to pressure, isolation, skill differentiation, etc.), while other concepts can be seen as "consequences", eg. quality of output, access to information, issue of drawings.

Four factors emerged which were perceived as weakening or stressing their roles:

1. They felt there was some degree of "loss of control". For instance, where the supervisor cannot follow the path which his designer or draughtsman has followed (using the capabilities of CAD) to reach his proposed solution. Therefore the supervisor is unable to contribute his experience to the design. The implication is not that the supervisor needs the same CAD skills as the designer but that he does require more appreciation and understanding of the CAD system and its potential. Because the supervisor has lost some of this capability to contribute to the design process (activity A6, table 5.3) he may also experience a loss of prestige and satisfaction.

2. The supervisor's limited previous experience with CAD was perceived as hindering the estimation and allocation of man-hours for a job requiring some use of CAD. Experience of estimating takes time to build up. With CAD this is particularly difficult because the supervisors have very little experience of using CAD. Therefore they have very little experience on which to base their estimates.

3. Supervisors feel under ever increasing pressure to avoid design errors. Some of this pressure is attributed to the expectations held by others that proper use of the CAD system eliminates the errors. It is also attributed to the reorganisation of downstream departments which previously would have caught many errors before the design reached the shop-floor. For instance, in the traditional shipbuilding design process the loftsmen would have drawn out the design full or half size, thereby spotting any mistakes. With CAD, however, scale is irrelevant except when defining the output

drawings; therefore some shipbuilding companies no longer have loftsmen departments.

4. It appeared that where the CAD room was separate and distanced from the supervisor's group area, the supervisors felt they lost touch with their staff. They felt they did not have enough time to go to the CAD room (where they felt ill at ease anyway) and their staff did not bother to report back to them. Again the result was that supervisors perceived loss of control over their staff.

Several minor factors were perceived as enabling the supervisor to carry out his job with greater ease. These included:

- the increased quality of the design using CAD;
- the high flexibility of the system;
- the clean and attractive output from the system.

Interestingly the result of the interviews was that about half the supervisors perceived changes to their roles attributable to CAD; one supervisor said he did not know whether or not he perceived any changes because his objectives remained the same: he was merely using different tools. Whether the supervisor worked in design or draughting did not appear to be significant in this difference in perceptions.

It is possible that the division in the perception of change could be linked to differences in proficiency and frequency of CAD use by the supervisors. Ten out of twelve supervisors said that in an average day they used CAD 0-5% of the time (the other two said they used CAD 5-10% of an average day). However ten out of twelve supervisors (but not the same ten) said that, compared to other supervisors, they were in the top 25% in terms of proficiency (of the rest, one said he was in the middle 50% and the other did not respond).

When asked to compare their proficiency on CAD to that of designers or draughtsmen, only two supervisors put themselves in the top 25%; five placed themselves in the middle 50% and four in the bottom 25% (again one supervisor did not respond). Thus, although the supervisors perceive themselves to be highly proficient among their peers, they do not see this as high proficiency compared with their staff. Examining the subject's details revealed the supervisor's perception of CAD proficiency did not relate to which office he worked in or to their perception of change or not.

Of the two individuals defined as informal supervisors, one (in draughting) estimated that he spent up to 50% of his time using CAD, but that his proficiency compared with others was in the middle 50% range. The other (in design) estimated he spent about 5-10% of his time using the CAD system (generally in one short but continuous burst), but that his proficiency was in the top 25% compared with others. Although isolated cases, this seems to indicate that both individuals appeared to use the CAD system more than the formally designated supervisors, as well as building up relatively proficient skills on it.

Design/Draughtsmen

Designers and draughtsmen held a range of views about the types of tasks which characterised the supervisory role as well as any changes which might have occurred. They recognised that some supervisors were still drawing and doing calculations etc., some rarely used CAD, some had an affinity for CAD and enjoyed using it, while others had a "head in the sands" attitude, and did their best to ignore CAD.

Attitude here relates to the degree an individual is prepared to change or to offer a level of resistance to change. Some designers and draughtsmen linked attitude towards change with age, ie. the older the individual the less prepared he is to change.

One aspect of the perceived changes with CAD was that there had been an increase in the difficulty experienced by the supervisor in carrying out his tasks. This had happened for a number of reasons:

1. it was more difficult for the supervisor to keep track of what a draughtsman was doing on CAD;

2. the system itself was difficult, for him, to understand;

3. consequently it was more difficult for the supervisor to understand what the draughtsman was trying to achieve.

Other changes noted included changes in the technical aspects of the job of the supervisor. The perception of CAD as an electronic drawing board, and its concomitant effects, was also often mentioned in the interviews.

CAD Managers

The CAD managers' views generally reflect a different way of approaching the CAD system. On the question of changes to the job of the supervisor CAD managers' see the variation between individuals as the dominant variable.

There is variation in supervisory attitude towards CAD such that some supervisors are very involved, while others rely on their subordinates (primary users) to act as a buffer between them and the CAD system. This was also reflected in attitudes towards the physical location of the CAD system. Where there was a centralised CAD system, some supervisors will locate themselves in that room, whereas others will not. This can be seen in the supervisors' own perceptions of isolation from their staff and the development of skill differentials between them.

Working with CAD the supervisor's job may now contain technical aspects such as checking and releasing drawings through CAD. However although the medium of checking may be changed, essentially the content of that particular task remains the same.

Some of the CAD managers also suggested that changes to the role of the supervisor would be inevitable as experiential learning occurs. That is, in the future, older supervisors will leave and younger ones will be promoted, who have themselves used CAD, and therefore will be familiar and accustomed to working with it.

Finally some of the CAD managers perceived the need for supervisors to be taught better management skills, ie. how to manage people, in order to be better able to work with staff using the CAD system.

Four other concept categories appear to have the most direct influence in contributing to the perceived changes in the role of the supervisor post-CAD introduction. These are:

- perceived changes in the role of the supervisor after the introduction of CAD;
- techniques for raising job satisfaction;
- the quality and quantity of CAD system update courses;
- the Trade Union support of CAD (including whether or not a new technology agreement was negotiated).

Below each of these there may be up to three more levels of concept categories, each providing possible insight into the next level above.

7.2.2 Supervisors' Perceptions of Changes to their Role

Supervisors in the ShipCo's expressed mixed views about their perceptions of change and any consequent implications. Four of the supervisors did perceive changes, four did not and two were unsure. The one supervisor in ToolCo did not perceive any changes to his role.

In the other roles, four design/draughtsmen in the ShipCo's did not perceive changes to the role of supervisors, while one commented that his supervisor had limited involvement with the CAD system, "he does not use CAD for drawing". Similarly the two design/draughtsmen in ToolCo saw no change to the role of the supervisors in their company.

Out of the CAD managers in the ShipCo's, only two made any comments, one saying that they did perceive changes in the tasks carried out by supervisors, but the other saying that they did not know. With respect to perception of changes in supervisory role, all three CAD managers saw no change. However one CAD manager said that he thought the role should change so that supervisors "become more involved in managing the people instead of telling them how to do the job".

Finally, the CAD manager in ToolCo said that he perceived no changes to the role of a supervisor in his company, but connected this to their lack of training in supervising the CAD section.

Supervisors' views

Table 7.1 **Positive Perceived Changes in the Role of the Supervisor Post-CAD Introduction**

Concept	Example
progress check;	better feedback of how things are going, can check progress of drawings in some respects better;
quality of output;	legible finished product; can produce "sexy", cosmetically attractive images;

Concept	Example
technical flexibility/access to information;	changes can be done more easily and can compare the old and new part and see if changes are good or not; 3D view on screen useful, like ease of being able to view something; from 3D model;

Table 7.2 **Negative Perceived Changes in the Role of the Supervisor Post-CAD Introduction**

Concept	Example
time;	now can go and check on CAD, but because not enough time to go down there so have to use prints; staff are in the CAD room and so makes it difficult to allow for time to visit people there (drawing office not work a shift system) therefore two ways, a) demand on Supervisor's time not allow him to visit CAD room, b) draughtsman do not bother to report back after being in the CAD room;
pressure;	from the system for proper allocation of files; to get job out on time, but no control over the time plan and no experience of planning a job with CAD; also keeping to programme with CAD difficult because of limited number of draughtsmen on CAD;
greater workload and more responsibility;	geometry now has to be very accurate, but did not used to have to worry about it as used to be redrawn by loftsmen; more administration/control of drawings
job more difficult;	other supervisor's find job harder; more complex;
checking;	has to be done through prints (where traditionally was no checking system, just talk to draughtsman at the board); do not check the geometry in CAD, just the general build; could always look at drawing and say whether a mistake or not;
worry about/deal with system crash;	possibility of system crash, although now more reliable than used to be;
move in creative and decision making levels;	in another case have seen much of the creative level and decision making passed down a few levels in the hierarchy to people working on the screens; they have the options in front of them and can evaluate and report back, with smaller decisions made there and then

Concept	Example
isolation of supervisor;	if movement of decision levels happen in this company could be a problem with supervisor being "left out" because cannot replicate the path to an answer that his staff have done; physical location of system makes it difficult to supervise people, cannot relate to them;
skill differential;	if supervisors not understand the methods used on CAD, cannot advise on the best way to do something, therefore lost some elements of control; very useful that supervisor knows about CAD and what to do, ie. pitfalls;
changes in perception;	whole set of new potential problems which might be brought to you, got to have an appreciation of that; build it up through experience, developing deeper appreciation of how CAD goes together, but is secondhand;

Table 7.3 **Neutral Perceived Changes in the Role of the Supervisor Post-CAD Introduction**

Concept	Example
same objectives just different tool;	
issuing drawings;	only 1 supervisor issues drawings through CAD, other section leader's should do this but do not;
choices in role of supervisor;	whether wants to be a hands on designer or step-back and be a supervisor;

Designer/Draughtsmen Views

The views of design/draughtsmen highlighted the procedural issues connected with CAD, eg. the supervisor is supposed to put drawings into a ship file for release which he is also supposed to check but sometimes the checks were not carried out, eg. where the supervisor has to rely on the design/draughtsman providing him with a printout of the CAD drawing each time, it is highly likely he will soon stop "requesting" the printout (see "checking" in the supervisor section above).

In ToolCo the design/draughtsmen highlighted two interrelated variables. This was that CAD could be equated with a manual design system, ie. "see it as another drawing board" while the supervisor still had the same lack of control over the situation and did not "know what was going on as much as before".

Supporting Categories

Four other categories were seen as feeding in or influencing the above question of perceived changes to the job of the supervisor. These categories are: general perceptions of CAD, other CAD related tasks, the supervisor's perception of their main contribution (which is also associated with another category, the more general perceptions of an individual's main contribution) and perceived lack of authority.

7.2.2.1 Perception of CAD

In this category, one of the main concepts was the supervisor's requirements that he can appreciate and understand what his staff do such that he is able to offer guidance both relating to the design itself and manipulating CAD to bring about the design.

Other concepts include management's over-expectations (that with CAD, designers and draughtsmen can do things that they could not do before) and management's lack of understanding about the CAD system itself and about what they are asking others to do using the system.

Some concepts relate more to potentials enabled by use of the CAD system which are not being accrued. Some supervisors perceived that their companies were missing out on downstream benefits (because not all departments use the CAD system), while others saw that CAD should be more than a drawing instrument and should not be used for small drawing tasks.

Some supervisors expressed doubts about CAD (that using a CAD system is not just about pressing the buttons, but depends on the user's engineering experience), and more specifically that problems occurred through infrequent use of the system, ie. after a few months of not using the CAD system, the techniques do come back fairly quickly, although using the help facility slows work down.

Overall, designers and draughtsmen thought that working using the CAD system was enjoyable and satisfactory.

The CAD managers also saw perceptions of the CAD system as both problems in management perception and problems, worries etc. arising out of usage. CAD managers perceived the management view of CAD as just "we need it", as well as a significant lack of direction on what they "want" out of using the CAD system.

The CAD manager's more general perception was that users worried that the CAD system would in some way be connected to a decreased number of draughtsmen, and a degree of techno-fear, which exacerbated this worry.

7.2.2.2 Other CAD Related Tasks

One extra task was specified, relating to the job of the supervisor, which has arisen since the implementation of the CAD system. This was the task of "liaison officer" for the department for the purposes of CAD development. In this the supervisor reports directly to the naval architect, as staff officer, regarding planning, identification of other computer developments and research opportunities. Therefore in this particular case, the supervisor's job has changed, a change directly connected with the CAD system.

In addition people at the design/draughtsman level specified two extra tasks they might carry out, which have arisen post-CAD system introduction. There was the role as "sponsor" for a compartment (of a ship) and a role which included special responsibility for the section's computers. The former consists of collecting and collating information from other disciplines and putting this onto the CAD system. It also involves some "trouble shooting" in the department, and carries a higher priority than other draughting work. The latter is more administrative, involving completion of the paperwork associated with and keeping track of the load on the CAD system. Basic trouble shooting and turning machines on and off, morning and evening, was also involved.

7.2.2.3 Perceived Lack of Authority

Several concepts connected to the CAD system appear to lead to a perceived loss of authority for the supervisor.

Design and drawing offices are generally controlled by a programme, or series of programmes, which monitor and schedule the priorities for the tasks constituting a piece of work. Generally the supervisor maintains and adjusts the programme, to reflect the current circumstances. In the case of a senior management making decisions about whether one programme holds higher priority than another, and the manager's securing labour resources, it can be seen that the supervisor's authority is decreased, or perceived to be lacking.

The CAD managers also perceive a lack of authority for themselves attributable to both not being able to run the department in the manager's role and a lack of CAD systems development, due to others not having the courage to make decisions on investment.

7.2.2.4 Main Contributions

People's perceptions of their own main contributions within a department are summarised in table 7.4 below:

Table 7.4 **Perceived Main Contributions**

Company	Level	Activity	Activity	Activity
ShipCo 1	S (drwg)	Advise staff		
ShipCo 1	S (drwg)	Check plans	Relay problems	Log man-hours
ShipCo 2	S (des)	Supervision of work	Communication	Maintain programme
ShipCo 2	S (des)	Guide project	Checking output	Assist staff
ShipCo 2	S (drwg)	Responsibility for output	Group coordination	Motivating individuals
ShipCo 2	D (drwg) (inf S)	Advising others		
ShipCo 3	S (drwg)	-		
ShipCo 3	S (drwg)	Collating information	Group coordination	
ShipCo 4	S (drwg)	Provide appropriate information	Maintain programme	
ShipCo 4	S (drwg)	Group coordination		
ShipCo 4	S (des)	Technical aspects	Maintain programme	Choice of appropriate personnel
ShipCo 4	S (des)	Maintain coherent course	Resolving difficulties	
ShipCo 4	D (des) (inf S)	Coordination	Information gathering	Information distribution
ToolCo	S	Organisation	Maintain coherent course	Maintain programme
ShipCo 1	D (drwg)	Lay out composites		
ShipCo 1	D (drwg)	Produce unit drawings		
ShipCo 2	D (des)	Experience	Specific knowledge	
ShipCo 2	D (drwg)	Specifying pipework information		
ShipCo 3	D (drwg)	Liaison with other departments		
ShipCo 3	D (drwg)	Producing clear drawings		
ShipCo 4	D (des)	New and normal design work	Sponsoring engineer	Liaison outside department
ToolCo	D	Design/tool layout		
ToolCo	D	Task completion, on time	Ensure valid design	
ShipCo 1	CAD	Systems development	Problem solving	Maintenance
ShipCo 2	CAD	General support (including hardware support)	Fault finding and error checking (of drawings)	Applications development
ShipCo 3	CAD	Longer term planning	Understanding user requirements/selling concepts to users	Managing development team
ShipCo 4	CAD	Support users and user management	Managing user team	Planning future contracts
ToolCo	CAD	Administration of the department (including systems management)	Applications development	

Key:

S (drwg) = Supervisor (drawing)   S (des) = Supervisor (design)   S = Supervisor   inf S = informal supervisor
D (drwg) = Draughtsman   D (des) = Designer   D = Design/Draughtsman
CAD = CAD manager

A summary of analysis of the above table shows that individuals in the supervisor position perceive their main contribution is to provide the monitoring and control elements within a department. As might be expected the pattern among designers and draughtsmen is that they perceive their main contributions are technical, ie. the production of drawings or information. Finally the CAD managers see their main contributions as those of motivating and controlling both the CAD system and support team, plus an element of systems and application development.

7.2.3 Enhancing Job Satisfaction

The supervisor's perception of enhancing general job satisfaction covered a wide range of areas. These can be split into a number of groups of factors, shown in table 7.5:

Table 7.5 **Factors Perceived as Related to Job Satisfaction**

Area	**Examples**
Factors related to CAD	- CAD relevant training; - greater involvement in the development of the CAD system; - greater insight into effective job planning with CAD.
Specific environment	- cosmetic enhancements, eg. lighting, ventilation, seating; - time set aside each week, or each day, for administration.
Work conditions	- better treatment of professional staff, eg. staff use times clocks, which allow no recognition that they may work longer than expected or work late to compensate for "clocking in" late; - overtime pay; - reinstate flexi-time, ie. there used to be unofficial flexi-time, but management removed this then refused to introduce formal flexi-time; - flexible holidays, eg. there used to be "floating" holidays.
Relationship with management	improve communication (see section on supervisor communication with superior)
Physical support	- assistant supervisor to carry out some of the work tasks; - extra staff for data-input.
Other support/guidance	- clearer definitions of constraints on task/area of responsibility, ie. no clear definition of what were allowed to do; - programme to guide initial phases of a project, ie. at the time of the study they had to "make [their] own way"; - stop contract engineering within the company, ie. they waste a lot of time arguing about contractual issues

One supervisor seemed to accept his level of job satisfaction, at the time of the interview, saying "a job is just a job", but later commented that training is always useful and therefore he might not have been as satisfied as first appeared.

The above groupings are not independent, with multiple interactions possible, eg. the perception of work conditions might be influenced by the level of communication between supervisors and management, in a particular company.

None of the interviewees in ToolCo expressed any specific views on job satisfaction enhancement.

7.2.4 CAD System Update Courses

CAD system update courses are not as comprehensive as initial training, but aim to inform users of relevant changes to the system, after the implementation of a new software release or hardware upgrade (CAD training will itself be discussed later in this chapter in section 7.5). These courses are important for the supervisor so that he can maintain up-to-date knowledge of the system and hence maintain contact with the primary users. Supervisors' perceptions of quality and quantity of CAD system update courses varied among the companies, such that:

ShipCo1

One supervisor (drawing) knew of one system upgrade but no relevant training. One draughtsman said they had only received written information on new functions while the other draughtsman had attended a one-day upgrade course.

Those who had not received any training did perceive the need for it or at least information to enable them to capitalise on the extra capabilities of the system provided by the new software releases.

ShipCo2

One supervisor (design) related how the CAD supervisor had attended the vendor update course and used this to train others in the company, including this supervisor. Another supervisor (design) did receive some training, while the third (drawing) was not aware of any update training being offered. The individual identified as being an informal supervisor (drawing) said that only nominated individuals (basis not known) were informed what the changes were, apart from some written details of the changes which were circulated to everyone.

The first supervisor said he thought the update training received from the CAD supervisor was too condensed, while the second rated the quality of training as adequate but there was a need to secure access to the system and consolidate what had been learnt. The informal supervisor said that although the booklet did provide information, this was not adequate, ie. it "did not go far enough".

ShipCo3

One supervisor (drawing) was aware that there had been training courses related to systems upgrades, but had not attended any. The other supervisor (drawing) had attended one of these courses which taught him how to use a piece of software which allowed control over the status of a drawing, ie. in work, approved or release modes. One of the draughtsman was aware of update courses and had attended one of these, while the other was not aware of the courses in the first place.

None of the supervisors or draughtsmen made any comments regarding a significant lack of upgrade training support for the CAD system in ShipCo3.

ShipCo4

Three of the four supervisors and the individual identified as being an informal supervisor (design) were not aware of any CAD update courses, while the fourth was, but had not attended any. The designer had attended one update course.

The designer who had attended an update course, commented that he lacked time after it to try out his new skills on the CAD system and so consolidate the learning.

ToolCo

Neither design/draughtsman were aware of any update courses, and the supervisor did not comment.

However one design/draughtsman had been shown a quick demonstration of the enhanced features, but it was only a "token gesture", while the other was only aware of the upgrade through a memo.

7.2.5 Trade Unions, New Technology Agreements and CAD

Conditions varied from company to company as to whether the various Trade Unions (TU) were involved or consulted in the introduction of a CAD system and whether they signed a New Technology Agreement (NTA), and what the later effects resulting from the different mix of conditions were, (ToolCo is a non-unionised company).

The major TU which appeared to be present in the design/drawing offices of the shipbuilding companies was MSF (Manufacturing, Science, Finance) for the designers and draughtsmen and EMA (Engineering Management Association) for the supervisory level. The designers in ShipCo1 said there was a closed shop, ie. compulsory membership, while the designer and draughtsman in ShipCo2 said the same existed there but unofficially. Only three individuals did not belong to a TU: the informal design supervisor and one designer in ShipCo 4 and the CAD manager in ShipCo 3. Out of those only the CAD manager in ShipCo3 expressed a reason for this situation, saying he felt that the company should be able to negotiate with him directly, rather than have to go through a Union.

ShipCo1

Supervisors

One supervisor did not remember any NTA signed with a TU at the time of the introduction of the CAD system. However he perceived that the Unions do support the use of the CAD system; however they see it as "just another drawing board".

The other supervisor did remember the company signing an NTA, and that the Union had pressed for the drawing office to do as much work as possible on CAD. In addition the support was still continuing, at that time.

Design/Draughtsmen

Both draughtsmen remembered that an NTA was signed at the time the CAD system was introduced. This included an increase in wages for those trained to use CAD, which was later phased out. The present perception of the Union backing of CAD was good, with concern displayed over issues such as health and safety regulations.

CAD Manager

The CAD manager's perception was that the Unions had adopted a sensible attitude towards the CAD system, not allowing it to become the responsibility of any one discipline, eg. it had not been situated such that it could only be used by designers; also rules for shiftwork were defined, in case it was decided to introduce it. The present level of support was rated as good and the Unions had made proposals on how they saw CAD being used for in the future. However as some of these proposals cross the industrial relations for loftsmen and draughtsmen, this could be problematic.

ShipCo2

Supervisors

All three supervisors and the individual identified as an informal supervisor all remembered some sort of NTA signed at the time of the introduction of the CAD system. The package agreed included an initial wage increase of 5% after training followed by a further 2% after "on-the job" experience, and a clause that once people had been trained they could not be forced to use it. This CAD allowance has now been superseded and consolidated within the general wage structure.

During the introduction of the CAD system the Union were kept well informed about progress which was communicated to the technical workforce by the draughting Union. As part of the NTA, the Union insisted on CAD workstations being situated wherever there was a Union member. Therefore all supervisors received wage rises for having CAD workstations in their section. However if management had been better briefed they would have been able to contest this and have the workstations located where they were most needed. While conditions for shift working had been agreed with the Union, at the time of the interview this had never been invoked.

The supervisors appeared to feel that generally no support was needed from the TU as the CAD system was generally accepted. The TU do ensure that new individuals in the drawing offices receive CAD training and keep monitoring the system on the health and safety side.

Overall the general consensus was that CAD had been introduced with success by both the Union and the company, especially as financial reward was used as an incentive.

Design/Draughtsmen

Both the designer and draughtsman acknowledged an NTA was reached with their Union. The designer perceived the TU had handled the introduction of the CAD system adequately and that the overall introductory process had been smooth. However in terms of TU support for the CAD system at the time of the interview he thought that the Unions should be investigating the health and safety aspect connected with it as he perceived that sometimes people can spend too long sitting in front of the screen.

The draughtsman's initial concerns were also about health aspects. They used to have "proper" chairs and screened windows, but these were no longer present at the time of the interview. Another worry that people had in the drawing offices was the effect of the CAD system on their job security. He thought the TU's could do more to monitor the conditions around the workstations, although the company could have planned the environment better when they introduced the CAD system.

CAD Manager

The CAD manager recalled that fast and accurate information about the introduction of the CAD system had been transmitted through the Union. In addition no jobs were lost as a result of the introduction of CAD. In some respects the Union attitude to the introduction of the CAD system could be classed as poor because they said they just said wanted extra wages for the users and did not consider the capabilities of the system. At the time of the study the TU's did nothing to support the CAD system and neither the company nor the TU evaluate the environment for CAD, eg. new chairs, refurbishment etc.

ShipCo3

Supervisor

Both supervisors (drawing) recalled an NTA being reached with a TU which consisted of a 5% pay allowance for using the CAD system and 2% proficiency bonus, plus the agreement that, across the board, training for CAD should be carried out within the next 2 years. This NTA was later superseded by an agreement which awarded an overall 9% pay rise.

Design/Draughtsmen

Both draughtsmen recognised the company had agreed an NTA, negotiated when they were still part of British Shipbuilders. Following privatisation, the TU agreed to drop the CAD allowance from 7% to 3½%, but had this paid to everyone eligible to use the CAD system rather than just those who were actually using it. Thus it appeared that the TU negotiated a drop in CAD allowance for their members.

One draughtsman rated the TU support of the CAD system at the time of the interview to be adequate, while the other thought they should be investigating the present and possible future effects of working with vdu's.

CAD Manager

The CAD manager was not aware of any NTA agreed by ShipCo3. However he perceived the draughting TU's had a limited view of the CAD system as a draughting system. This view needed expanding so that wider variety of individuals could be eligible to use the system.

ShipCo4

Supervisor

Of the five supervisors (including one individual identified as an informal supervisor) all recognised some form of NTA had been signed by ShipCo4.

The two drawing supervisors and the one informal supervisor (design) perceived TU support during the introduction of the CAD system to have been adequate. However the other two supervisors (design) did not think the TU had handled the introduction of the CAD system well, and possibly penalised its development through their blanket policy of banning design engineers from using CAD (although this had been lifted prior to the time of the interviews).

The perception of TU involvement was that they were "just as ignorant about the CAD system as the company". While the TU could perceive the need for training, they were not able to commit their resources to it and even if they could then the training would be no good without opportunities for consolidation of what has been learnt, which is not generally available.

Design/Draughtsmen

The designer recalled there was an NTA accompanying the introduction of the CAD system to the design and draughting offices which included salary increases both for training and using the system.

CAD Manager

The CAD manager's perception was that the TU did not care about how the CAD system was introduced, only how to get an allowance for the draughtsman. However he considered it more important for the TU to be educated about how the system would affect their members. The TU has never really looked at the effects of working with a CAD system, eg. what type of environment exists etc.

7.3 CAD Training for the Supervisor

One important area affecting supervisors perception of changes to their role with CAD appears to be the degree of training relevant to using a CAD system that they have received.

Table 7.6, shows that most supervisors received some form of basic CAD training, mainly with a group of individuals from a variety of organisational levels and disciplines. While the consensus appeared to be that these courses were average to good quality and consisted of about the correct amount of time and information, they were only basic technical courses.

Table 7.6 **Summary of Perceptions of CAD Training for Supervisors**

Company	Level	Training	Course Membership	Quality	Quantity	Aspects wrt supervisor	Perception of training	Reason for discontent
ShipCo 1	S (drwg)	Yes	Variety of possible users	Good	About right	-	Okay (at the time)[1]	-
ShipCo 1	S (drwg)	Yes	Variety of possible users	Good	About right	Yes (technical only)	Okay	-
ShipCo 2	S (des)	Yes	Variety of possible users	Good	About right	No	Okay	-
ShipCo 2	S (des)	Yes	Supervisors only	Average	About right	No	No	-
ShipCo 2	S (drwg)	No	-	-	-	-	Do not know	-
ShipCo 2	D (drwg) (inf S)	Yes	Variety of possible users	Good	About right	-	No	Too little (certain aspects of system not seen)
ShipCo 3	S (drwg)	Yes	Mixed with draughtsmen	Good	About right	No	No	Too little
ShipCo 3	S (drwg)	Yes	Developers of CAD within the company	Good	About right	No	No	Too little and too short
ShipCo 4	S (drwg)	Yes	Variety of possible users	Good	Too little	No	No	Too little
ShipCo 4	S (drwg)	Yes	Mixed with draughtsmen	Average	About right	No	No	Too little (more on system capabilities)
ShipCo 4	S (des)	Yes	Variety of possible users	Very good	About right	No	Okay (for what he wanted to do)	-
ShipCo 4	S (des)	Yes	Variety of possible users (all from design area)	Good	About right (as a first course)	No	No	Too little
ShipCo 4	D (des) (inf S)	Yes	Design engineers only	Good/ average	About right (for starters)	-	No	Too little
ToolCo	S	No	-	-	-	-	No	-

[1]But not for system after upgrade

Key:

S (drwg) = Supervisor (drawing)	S (des) = Supervisor (design)
S = Supervisor	inf S = informal supervisor

In table 7.6 the following abbreviations are used:

Course membership =	rough category of people who attended the course;
Aspects wrt to supervisor =	aspects of the course which specifically applied to the role of the supervisor in design or draughting;
Perception of training =	individual perceptions of whether they had received an appropriate amount of training for using a CAD system;
Reason for discontent =	reasons individuals felt they had received insufficient training for use of a CAD system.

Supervisor's View

Few of the training courses contained any elements which focused on the role of an individual supervising a design or drawing section, including people using a CAD system (any reference to the supervisory role appeared to be limited to technical aspects of using the CAD system, such as preparing a file for release). In addition many of the supervisors felt that they had not received enough appropriate training to enable them to use the CAD system to support their role. The duration of the training courses was too short, both for the amount of information to take in and the amount of time available to consolidate what had been learnt, plus there was a lack of further update courses to match any upgrading of the systems.

Thus, although training might be expected to enable a supervisor to have the technical skills to interact with the technology, where this training does not appear to be focused on anyone other than a primary user of a system, it is both useful and interesting as base information, but does not enable an individual, such as one in a supervisory position, to use a CAD system effectively in carrying out their tasks. One supervisor said that while the training course had been useful, there had been no mention of any "human" aspects involved in working with a CAD system.

Further while some supervisors perceived the need for future requirements of more training related to the CAD system and more in-depth knowledge about the capabilities of the system, another noted that finding time for more (or in some cases for any) training was itself problematic.

Finally one supervisor cited a case of inappropriate training where a design supervisor had been "trained for CAD the way the drawing office use CAD and so has to work on hard copies"; he therefore felt he was constantly "hassling" the CAD users for printouts so that he could make decisions involving the work done using CAD. Apparently he was unable to do this interactively with the system and so was forced to rely on requesting printed output from his staff.

Design/Draughtsmen's View

The designers and draughtsmen expressed few views regarding the amount and relevance of training for CAD received by supervisors. Those perceptions that were expressed were split between the view that the level of training had left the supervisors still "naive" about the nature of the CAD system itself.

CAD Manager's View

When questioned about CAD training for supervisors, the CAD managers recognised that while some form of training had been available, it had been of "questionable" quality. Only in ShipCo1 had the supervisors' general training on the CAD system been followed by an "occasional" tailored refresher or update course concentrating on what supervisors need to know, rather than how to do things (this is reflected in the views of supervisors recorded in table 7.6).

ToolCo's CAD manager recognised that a useful CAD training course for supervisors might include elements such as:

- an appreciation of the capabilities of the system;
- an idea of the resources available.

It would also need to provide a mechanism to enable a supervisor to decide the amount of work to be allocated to the CAD system.

7.4 Company Culture and CAD

One of the seven major issues identified as part of the Grounded Theory analysis can be described by the concept category "company culture pro-CAD ... [rather than] company culture not pro-CAD". This has three other concept categories clustering under it, two of which are also identified as being part of the seven major issues. These three concepts are:

- lack of management planning regarding CAD;
- lack of company communication;
- general management commitment to CAD.

7.4.1 Lack of Management Planning Regarding CAD

Supervisor

Table 7.7 **Perceptions of Management Planning Regarding CAD**

Characteristic	Explanation
inconsistent policy which leads to an undermining of supervisor authority;	some general decisions about a job might be left to a supervisor, only to later might find that his informal supervisory decision was countered by the management; management problem/responsibility to secure labour resources;

Characteristic	Explanation
insufficient monetary reward for job;	if people are making decisions, then they should be paid for taking the responsibility; perception that people have more responsibility than they get paid for, ie. gap to superior too big and gap to staff too small;
lack of support for technical division;	board level people grew up with company as solely production and so do not really support the technical areas as well as they could;
lack of forward vision;	management only look at short-term financial considerations;
strong middle management level;	they "call all the shots", which penetrates down to the technical area and now general morale is very low.

The results from this perceived lack of management leadership/direction included:

- loss of motivation;
- loss of trust in management;
- high staff turnover.

CAD Manager

The major perceived exhibition of management attitude was a lack of public support, leadership or show of ideas about what they wanted the CAD system to do.

Therefore CAD managers perceived that negative influence of management attitude on the CAD system could be a major cause of failure in the initial stages. The situation in one company was such that when one senior manager publicly said he did not support the CAD system, others were too scared to say that they did. Further, the politics involved in the changes that might accompany the CAD system and the state of management attitude had already influenced many people in their decision to leave the company.

7.4.1.1 Company Adherence to Procedures/Programmes

Supervisor

The function of a work programme is mainly to control how the drawings run through the sections and the company. The timing plan should aid planning of the number of man-hours required for a task and allow the optimising of manpower loadings. However in some companies this had only recently been brought into use and the criticism was that not enough time was allowed for its preparation.

Suggestions to counter this include the need for more guidance, definite structure and plan of projects. In particular at the start of a project, a plan which defines what data is needed and in what timescale could be developed for the whole company and used to monitor the project.

Work programmes were generated through three routes in the sample companies:

1. a *central or specialised planning department*; eg. a planning department which sets dates for when a specific system is needed for a ship so that the job can be manned accordingly. Some drawing programmes are designed by computerised central planning systems. However the supervisors in one company said, "the plans it [the system] produces are useless because people have not been consulted about it".

2. an *individual*; people tend to work by objectives. Once the task is roughly defined then deadlines can be set and normally the design required to complete the objective is measured according to time constraints. Projects such as "tenders" are relatively short term, so they are attended to first. Once the contract is up and running, how to achieve targets is left to the individual designer or draughtsman.

3. from a *negotiation process*; production was becoming more formal than it had used to be and so there were "set dates" to meet, which had been decided at higher level meetings, to establish the requirements and priorities. Therefore this route was perceived as becoming more common at the time of the interviews.

Another problem which might occur with the work programmes is establishing priorities. In general it is quite clear which task takes priority at any one time. But where this is not the case:

- a superior can be asked to arbitrate between tasks;
- priorities can sometimes be established according to the drawing programme;
- it may be possible to establish priorities by obvious hierarchy between projects, ie. how far down the line the project has gone;
- other organisations are very much driven by the needs of their production group (which has its own production plan) and commercial enquiries and so they are subject to very short periods of intense activity.

Other problems occur due to lax implementation of the work programmes, although one supervisor held the view that this might change with the introduction of new quality standards.

In some companies the work programme is very important, so much that in one case the supervisor's view was that a major element of his time was spent chasing the progress of the design programme.

Design/Draughtsmen

The design/draughtsmen held a more linear view on programme generation:

- when the ship is planned, different installation dates are proposed and the work scheduled to meet these dates; the supervisor informs production of the specific dates when the drawings for certain areas of the ship will be ready for them; the supervisor is thus concerned that the draughtsmen meet the deadlines.

Thus it can be seen that the work schedule for the week appears to be generated from the supervisor according to the work programmes. In one company a job planning board assigns a number to every task in the drawing office which is then marked according to how well the tasks follow the plan.

Establishing priorities appears to be a more varied activity from the design/ draughtsman perspective. It could be characterised by a "whoever shouts the loudest from the shopfloor gets the priority" mode of working. In other companies where the product is for the military, then preparation for and passing inspections by the MoD dictate the priorities within the programme.

Whereas the programme revision is often calculated on a weekly basis, it often appears not to be attended to because of the many and various "mini-crises" that have to be dealt with.

7.4.1.2 Insufficient Resources to Meet Work Programme

An important manifestation of the lack of management support for the CAD system by supervisors was the perception of the level of resources available to meet the work programme.

In general supervisors perceived that there was insufficient labour to meet the work programme, mainly as a result of the programme being developed by a technical planning office separated from the design and drawing offices. In one case the design office had shrunk to half its former size of four years ago, but was still expected to produce the same rate of output. Where there is not sufficient labour to meet the programme demand, progress falls behind the programme schedule and thus the programme becomes impossible to achieve.

These problems tend to be exacerbated through use of a CAD system. Time delays can occur when there are not enough and/or restricted access to the CAD workstations (eg. one department had a full complement of CAD workstations but the supervisor estimated they still only had an allocation of about half of what they needed). A lack of appropriately trained staff to use the system can also affect the progress on a work programme.

One response in failing to meet the programme through insufficient manpower is an increase in a supervisor's feelings of dissatisfaction with their job. Another response is characterised by some supervisors' perception that it is the responsibility of a manager to secure resources. This reinforces the perception of management failure to support the CAD system adequately.

7.4.2 Lack of Company Communication

Supervisor

The main characteristics for supervisors were the poor quality team briefings, failure to channel communication through the "line management", faulty communication patterns, and physical barriers.

One problem with communication patterns was that supervisors thought they should act along the horizontal (═════) levels of the organisation, whereas communication actually appeared to act up and down organisational levels in a "zig-zag" style (/\/\/\/\). Therefor instead of supervisors in different departments communicating directly with each other, one supervisor makes a request of his manager who then communicates the request to the supervisor in another department.

Team briefings were criticised because they appeared to be company propaganda events rather than honest attempts to keep the workforce informed. This resulted in the general feeling that meetings wasted time which could have been more effectively used. The other factor mentioned above, the physical barrier, referred to the situation where communication with a superior is hampered by the two people being in physically separate places eg. different offices.

Design/Draughtsmen

For designers and draughtsmen, problems in company-wide communication were caused more by the organisational level above that of their immediate supervisors, who they perceived neither provided adequate feedback to the supervisors (and hence their staff) nor provided them with any concrete global task definitions, eg. what image should be projected by a project.

CAD Manager

One CAD Manager did recognise the superior's responsibility to encourage a subordinate's trust. Although communication is bi-directional, the responsibility lies with the person in the higher position to instill in the person below the trust to say what he thinks and to listen to him to allow communication to exist (section 7.7.2.5 discusses communication with staff). This was something which was perceived to be lacking in the company as a whole.

7.4.2.1 Design and Production Engineering Relationship

The relationship between the design and production engineering functions can be taken as a reflection of the general level of integration within a company. In particular while the relationship between design and production engineering might be expected to be close since the latter generally follows the former in the design process, traditionally a "barrier" exists between the two disciplines (mainly due to craft distinctions, see Francis & Winstanley, 1988). However the introduction of new technologies might be able to address this through encouraging (or in some cases forcing) greater integration.

Supervisor

The degree of liaison between these two functions varies between positive and negative within different companies. Table 7.8 describes aspects of positive and negative relationships.

Table 7.8 **Quality of the Perceived Relationship between Design and Production Engineering**

Positive	generally *quite a close relationship*;
	quite a *good rapport*;
	try to *work closely together*;
	good contact, continuous liaison, especially when the machine is being built (a ToolCo response);
Negative	*not much contact* with production engineers;
	minimum of contact between the two sections because there is a liaison section to resolve problems of production engineers which, although under-staffed, works well;
	although there is a separate production engineering department, normally *no direct contact*, because part of the draughtsman's function is to production engineer;
	large design engineering group and small production engineering group which are *administratively and managerially separate*;
	not at all close, although closer than used to be and now use an intermediary;

The types of information exchanged tended to be mainly technical information (eg. design parameters) with direct contact only occurring when problems in the build phase happened.

Where this relationship is negative it can lead to frustration (especially where one department appears to be leading the other), less effective work being done, or even open antipathy, (ie. see them as people who go their own way and then complain when it does not work) and a severe lack of mutual rcspect.

7.4.2.2 Superior's view of individual's job/role

Design/draughtsmen's perceptions of whether their superiors (their supervisor) had a realistic view of their job were elicited and are summarised in table 7.9:

Table 7.9 **Design/Draughtsmen Perceptions of Superior's View of their Job**

Company	Level	Realistic perception
ShipCo 1	D (drwg)	Yes
ShipCo 1	D (drwg)	Yes; supervisor does have realistic opinion of who is are better draughtsmen in this drawing office;
ShipCo 2	D (des)	Yes
ShipCo 2	D (drwg)	No; when job starts are many distractions (eg. advice to others) which are not taken into account;
ShipCo 3	D (drwg)	Yes; performance measured by how much work received at end of week;
ShipCo 3	D (drwg)	Yes
ShipCo 4	D (des)	Yes
ToolCo	D	Yes
ToolCo	D	Yes

Performance measures tended to be informal with the design/draughtsman expecting the supervisor to know the capabilities and expectations of an individual, and measure how much work is received at the end of a week against this.

In ToolCo performance is not measured on a daily basis, rather after couple of weeks the supervisor checks to see what work has been done.

CAD Manager

For the CAD managers, perception of his superior's view of job and tasks is also an issue. One CAD manager recognised that in a broad sense their supervisor held a realistic perception of their job, but lacked detailed knowledge and was perceived to hold the view that the CAD manager spent too much time in support (which is an unidentifiable deliverable).

Another had found that while the technical director had an understanding of their job, their immediate superior did not. The problem here was that the direct superior was only seeing the outcome of what was done and so was only cognisant of about 50% of the CAD manager's day, ie. he believed the CAD manager just "ran the system" and spent his budget.

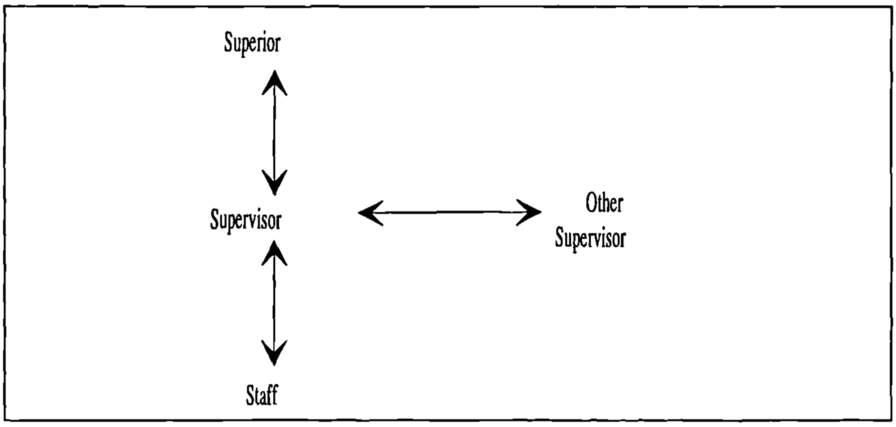
The only performance measure for a CAD manager mentioned was a quarterly informal appraisal, which was intended to monitor him according to a specific level of performance.

In ToolCo the CAD manager also found a problem in that his superior was not computer-literate. Therefore his performance could only be measured in terms of the amount of support seen to be given to users.

7.4.2.3 Communication Among Individuals

Communication within the design and drawing offices was examined both horizontally within the offices and vertically within the management structure of the organisation, focusing on the design supervisor, as represented in figure 7.1, below:

Figure 7.1 **Diagram Showing Lines of Communication Examined within Design/Drawing Offices**



The comments made about individual communication can be aggregated and divided into five topic areas, for each type of interaction:

1. general perceptions of the level of communication;

2. the type/characteristics of communication that exists;

3. problems with existing communication;

4. potential areas for improvements in communication;

5. other comments about communication.

These topics are discussed in more detail in the following sections.

7.4.2.4 Liaison with Other Supervisors

1. General perceptions of the level of communication.

Overall there is a high level of liaison which results from a good level of communication among supervisors (including ToolCo).

2. Type/characteristics of communication that exists.

The nature of contacts between different supervisors can vary between a range of characterisations, eg. informal, formal, mixed, different for different people.

An example of informal liaison is where three supervisors work in physically close proximity and so are able to "talk, and exchange some written information". Formal liaison refers to where supervisors officially exchange information (more often written than verbal). The mixed type of contact implies liaison which is informal but with occasional formal meetings (often for specific reasons, eg. where one section has overall control of the machinery space and within that are systems from other sections who therefore need to be informed of any changes). An illustration of a mixed characterisation was one where a supervisor listed his level of liaison with the other supervisors around him as ranging from very little contact with the other four design supervisors, minimal contact with one drawing supervisor and quite a lot of contact with the other drawing supervisor (mainly because this drawing supervisor controls the sheet showing each project's progress).

3. Problems with existing communication.

No major problems were detected and instead areas for improvements were suggested (see next section).

4. Potential areas for improvements in communication.

General problems might occur from a lack of coherent information flows. Therefore the company might need greater consultation at the start of a project, because otherwise the people involved might not all be "going in the same direction" and later will have to "turn the project around" and pull it back on course.

Another suggestion was for group meetings of all the supervisors (in a design or drawing office) with the superior, so that everyone knows what is happening (outside of design/drawing offices the perception is that everyone inside knows everything that is happening, therefore information is not passed around and this idea might also solve this situation).

5. Other.

In addition, it might be that as circumstances change, so too do the patterns of liaison between the supervisors, eg. in one case the liaison of three supervisors in a design office, moved from a general discussion every 2 weeks (to determine which individuals were "spare" and so could be moved to more important jobs), to a new pattern, in which, there was more individual liaisons with other supervisors (such as only when something was needed, etc.).

7.4.2.5 Communication with Staff

1. General perceptions of the level of communication.

Supervisor

Managing his staff, including information seeking and advising, is one of the major tasks for a supervisor; consequently communication with his staff is very important.

Overall the level of communication does appear to be adequate with most comments centring around problems associated with the physical separation involved in those companies which have a centralised CAD system.

CAD Manager

The CAD managers appeared to be divided between finding the level of communication with their staff either in need of improvement or merely acceptable. In the case of ToolCo the level of communication was perceived to be good, which was attributed to the small staff size which required only minimal supervision without the need for departmental meetings.

2. Type/characteristics of communication that exists.

Supervisor

Some supervisors acknowledge being more available to help people working in physically closer proximity. In addition they recognise they occasionally visit a CAD room that is physically separate and hold the perception that "if staff worked in a separate building or office with someone else's management structure or organisation then it could be more difficult because the staff would have to involve their own supervisors as technical managers" to solve any problems.

3. Problems with existing communication.

Supervisor

While supervisors recognise that a major problem in communication with their staff is attributable to the physically separate CAD office, they also accept that the responsibility for improvement lies with themselves. In a wider sense some interviewees highlighted the idea that the responsibility for a working relationship between two or more people always lies with the person holding a higher position in the organisational hierarchy.

4. Potential areas for improvements in communication.

Supervisor

One suggestion to improve personal communication concerned the provision of an area for private discussions eg. an office or secluded place where a private conversation could be held, such as for disciplining someone; at that time this had to be done in public, which was embarrassing for both parties (the supervisors recognised, however, that if a room existed solely for this purpose then taking someone in there might alert others and so also cause embarrassment.

Again the physical siting of the CAD system was cited as a potential area for improvement, ie. "much better to have someone working only a few yards away".

Another improvement suggested was for more time to be allocated to greater direct contact with staff, eg. check on people in the CAD room. However while other supervisors had also recognised this, they felt they were not able to action it because of the heavy constraints on their time.

CAD Manager

Improvements suggested by the CAD managers included seminars and meetings (for people beneath the project leaders to try and understand the conceptual ideas etc.) and a formalisation of communication so that there was less reliance on verbal communication (there was an expectation that new quality standards might rectify this).

However one CAD manager did recognise the superior's responsibility to encourage a subordinate's trust (see section on lack of company communication). This was also an aspect which was perceived to be lacking in the company as a whole.

5. Other.

Supervisor

Where one of the supervisors was relatively new to overseeing a department he expected the communication to improve as he learnt more about the job itself. Unfortunately other evidence presented here does not lend support to his hypothesis, showing that the picture is much more complicated than first appears.

One perceived consequence of less contact between supervisors and their staff was that it led to people having a greater tendency to resolve problems themselves.

7.4.2.6 Communication with Superior

1. General perceptions of the level of communication.

The supervisor's perception of the level of communication was that this was adequate overall. This was echoed by both the design/draughtsmen and the CAD manager levels (including those in ToolCo, although the design/draughtsmen also argued that given enough time most things can be improved).

2. The type/characteristics of communication that exists.

One supervisor said communication with his superior was adequate for formal or information aspects but a "waste of time" for solving any problems. Overall informal communication was rated well and using the superior to put pressure on someone of the same level if they were not giving their full cooperation. In ToolCo the communication was also perceived as being of good quality as they were perceived to be a "close contact company".

The design/draughtsmen's perception was that supervisors could get "more involved" with them, although they also acknowledged that the levels above the supervisor were also to blame for causing problems, ie. not feeding down information from the customers. Overall communication with a supervisor appeared to be the result of some need for information to sort out a problem not available directly to the individual themselves.

The CAD manager view was represented at one extreme by one CAD manager who directly communicated with (and reported) to the Technical Director. Therefore his communication with his superior was virtually nonexistent. The ToolCo CAD manager communicated with his superior via monthly report on main events, interim informal reports as requested and short informal meetings to discuss any other matters.

3. Problems.

The only direct acknowledgement of problems with communication at the supervisor level was concerning problems higher up in the hierarchy than the superior, ie. a lack of general policy direction within the company.

4. Areas for improvements.

For one supervisor this would be for his superior to change his attitude and become more open with information. For another, communication would be improved by setting aside a specific period of time to discuss general matters. But both of them claim to be very busy and finding the time for this would be difficult. Another area that could be improved is through formal written communication between the supervisors and their superiors. The information is mainly verbal and so when questions arise later, there are no records to which to refer back. Finally some superiors only communicate what they are forced to, such as when decisions are taken by their superiors, but many of these could be mentioned before a firm decision was made.

The design/draughtsmen again focus on the problems for communication involved in working in a physically separate area, such as when using a centralised CAD system. In addition the idea of discussion sessions, to discuss general problems, was suggested.

For one CAD manager, who had a particularly strained relationship with his superior communication was non-existent. Another area for improvement was for the CAD manager and his superior to hold regular meetings to encourage this greater exchange of information and try to build some mutual trust and openness.

A lack of communication resulted in a tendency to "drift" from the schedules set at the project status meetings.

5. Other.

The prevalent attitudes in the management of these companies tended to be disseminated of information on a "need-to-know" basis. A consequence of the superior not passing information to his supervisors is that often things become known from other areas, which undermines the superior's credibility and gives the impression he has been holding back. Therefore from the supervisor's viewpoint it would be better if the superior "put his cards on the table" and communicated with the supervisors.

7.4.3 Management (general) commitment to CAD

Supervisor

Overall the perception was that the past and present (at that time) degree of support for the CAD system was poor. Only in one case, ShipCo4, was the system considered to run effectively, and this was attributed to the CAD management team, rather than the company management in general.

Others recognised that support within a company was variable, some departments and individual managers supporting it better than others. As is often the case, the lack of financial resources backing public support was also commented on, which was seen as resulting in a lack of progress in the time the company had a CAD system.

Design/Draughtsmen

In the ShipCo's, as with the supervisors, the past and present (at that time) degree of support for the CAD system was not considered high, but was seen in a relatively more positive light. The past support was perceived as average and although management were seen to realise some of the potentials and capabilities available, that was because it was "difficult to get the message home to them about the truth".

The present degree of support was even considered good, with more positive views seen in individuals higher up the management hierarchy. But management were thought to have over-expectations of what CAD can do, eg. they "expect that all modifications only take a few minutes, which is not true".

In ToolCo, management perception of the CAD system was considered low because it had not lived up to expectations and so was seen as a "necessary evil". However the design/draughtsmen were optimistic that slowly they were persuading more and more people within the company of the benefits of using the CAD system.

CAD Manager

The general support for the CAD system perceived by the CAD managers in the four ShipCo's ranged from good through average to indifferent. One consequence of this was that without the resources to tackle problems, little could be achieved and so job satisfaction for CAD management was low. Further, with the lack of commitment to the system, they felt they spent more time fire-fighting than in a healthy environment which would enable people to work more efficiently.

While the past degree of support was not greatly mentioned, the degree of support at that time was considered to be adequate, but the lack of any strategy had led to a degree of stagnation. Again an optimistic note was heard in that one CAD manager perceived an increasing support of CAD, with management more aware of the amount of time spent on the system and the resulting benefits.

In ToolCo the CAD Manager perceived a significant lack of senior management general commitment to support and expansion of their CAD system. He perceived they had the false idea that a CAD system was a "one off" investment, whereas his view was "once [you] invest in new technology [you] need to keep that running or lose the benefits". His alternative was for management to "carry through" their investment in the CAD system, ie. greater investment, and estimated that if they did this productivity gains could be doubled in about 10 years. The CAD manager in ToolCo was so disillusioned with senior management attitude towards the CAD system that he subsequently left the company's employment.

7.4.3.1 Perceived Cost (In)Effectiveness of CAD

One way which management traditionally gauges the usefulness and therefore the degree of commitment deserved to the CAD system is through its estimated cost effectiveness.

Supervisor

The cost effectiveness of the CAD system can be investigated at four organisational levels:

- company - overall low because only few departments exploit the advantages;
- department - variable, depending on where and who is using it plus lack of downstream benefits (see section 7.9.8);
- job - need to evaluate for each job;
- individual - loss of CAD-trained personnel, attracted by higher wages offered elsewhere.

In addition, at the technical level there are benefits (eg. it is possible to abstract information for other uses) and problems (eg. the present drawings are more detailed than need be produced by the CAD system).

Time and speed of design/drawing production are often presented as major benefits of using a CAD system. But, at the time of the interviews, none of the supervisors could see a significant increase in either. However they did perceive the future effectiveness. One group of savings would be produced by use of simpler drawings while others might come from the discipline imposed by using the CAD system such that everyone works on the same ship 'in the same way'.

In ToolCo, the supervisor perceived that the "built-in obsolescence" of hardware meant that the three year payback period was too short for the size of outlay on their CAD system.

CAD Manager

The CAD system was perceived as an ineffective draughting tool but an effective production information generator. One CAD manager estimated that they could get more "work" from a skilled draughtsman using CAD than from two draughtsmen.

The ToolCo CAD manager agreed that their mode of use of their CAD system was unsuitable for cost effectiveness. One factor he considered important was that their use of the system at that time did not justify the depreciation on it, therefore it could not be seen as cost effective.

Overall it appears that the future cost effectiveness of the CAD systems used in each company was expected, but the perception that they were not yet using it "properly" seemed prevalent.

7.5 Benefits of CAD

The final two major issues identified as part of the Grounded Theory analysis concern the benefits and problems associated with the CAD system. Elements of these have already been presented throughout the analysis.

The major benefits associated with using a CAD system are summarised in table 7.10. The areas of benefit are split into seven areas for the purposes of analysis, but there are many interrelationships between the different areas, eg. data storage allows previous drawings to be easily reused and so enables faster production and modification of drawings.

Table 7.10 **Summary of Benefits Associated with CAD Systems in the Case Study Companies**

Area of benefit	**Supervisor**	**Design/ Draughtsman**	**CAD Manager**
Storage of data and later re-use	- drawings available for re-use; - data storage;	- 3D images promote less waste in production; *- easily use previous designs with slight modifications;*	- ability to extract information for other purposes, eg. reports, bill of materials etc.; - transfer data between drawings; - library of standard parts, shapes;
Communication	- downstream links; - data transfer; - move from production drawings to workstation drawings which show a section at different stages and how it's built-up, which is very helpful in production; *- direct links with partner organisations*	- easier data exchange;	- improved communication with other departments, companies etc.; *- improved communication with corporate partners;*
Speed	- faster drawings production (may be true for specific areas only); - quicker response to customers;	- faster drawings production; - faster drawings modification; - easy to include data from previous designs; *- easier modifications;*	- faster project completion; - less redraw of basic information; - faster drawings and information preparation; *- less man-hours per project;*

Area of benefit	**Supervisor**	**Design/ Draughtsman**	**CAD Manager**
Quality and accuracy	- higher quality and better accuracy of drawings; - *image and clarity of drawings*	- simulation used as a marketing tool; - less errors therefore less re-work; - higher quality of job because individual perceives higher job satisfaction; - *better customer presentations;* - *less design/drawing errors;*	- less mistakes in drawings; - good public relations and marketing tool;
Flexibility of individuals, design options and computer systems		- use of spatial analysis; - one individual can replace another to carry on tasks; - *explore more drawing/design options;* - *greater ease of modifications;* - *automatic "clash checking" analysis etc.;* - *availability of engineering analysis programmes*	- faster response to changes;
Interaction between people		- enhanced interaction between members of the organisation; - better "feel" for areas other than own area;	
Financial benefits	- less personnel; - replace expensive scale model with CAD model;		

NB. Normal text represents views expressed by members of the ShipCo's; text in italics represents views expressed by members of ToolCo.

One ShipCo design/draughtsman also pointed out that the implementation of a CAD system had resulted in some unanticipated beneficial uses, eg. specific tasks for the MoD that could only be done using CAD. However in at least two of the ShipCo companies, the CAD managers admitted that no empirical measure of benefits accruing from CAD had been attempted, just "gut feelings" measurement.

In table 7.10, the majority of benefits refer to organisational benefits, rather than benefits for the individual. The exception is the design/draughtsmen mentioning enhanced interaction between different members of the organisation described by design/draughtsmen. This enables them to understand better their role in the design process as situated within the organisation.

However even within the context of perceived benefits associated with the CAD system, some of the supervisors noted that CAD was not yet realising its full potential, and could perceive improvements in the future, eg. better drawing information database.

Some specific benefits of using CAD will now be explored in greater detail; these constitute the next level down in the map (see section 6.11) and represent the next level of issues which arose from the Grounded Theory style analysis:

- initial savings;
- improved presentation of work (ie. drawings, designs, marketing information, tender information);
- faster speed of product design;
- information transfer.

Each of these issues will now be examined in greater detail in the following section.

7.5.1 Initial Savings

This section reviews perceptions of initial savings associated with use of the CAD system. 'Savings' is a difficult category to define, representing different concepts for different individuals. Apparently qualitative savings are not formally measured in any of the companies. However perceptions of savings appeared to be mainly financial savings associated with a post-CAD project compared with similar project pre-CAD implementation (such as time savings from the reduced number of man-hours).

Supervisor

These reflect the areas seen in the benefits summarised earlier (section 7.8) in terms of the ease of drawing modification (including avoiding replication of work); downstream links (so that information can be continually passed down and kept up-to-date); higher quality of information (in particular to estimators, such that more accurate tender prices can be quoted) and higher quality presentations to customers; flexibility, such that the individual is able to explore more design alternatives and review more past material.

In addition the level of savings associated with CAD are seen to vary according to the stage in the design process, with greater savings arising later in the design cycle. The perception that greater savings would be seen in the future was again expressed, in particular from the future ability to "add intelligence to drawings".

Others felt that any possible early savings were negated due to the training period needed for CAD use, or 'misuse' of the CAD system (ie. using CAD only as an electronic drawing board).

In ToolCo, the supervisor thought the speed of drawing production was no quicker than on the drawing board, such that savings arose from the ability to re-use common details in different drawings or modification of drawings.

Design/Draughtsmen

The design/draughtsmen's perceptions of savings also concentrated on savings for the organisation, whether through ease of modifications and re-use of basic/similar drawings; increasing the speed that jobs are carried out (including the removal of repetitive detailing and the downstream links whether through NC tapes or to provide data for improved production).

Suggestions for the future included more effective organisation and planning of the drawings, possibly establishing downstream links (eg. for NC cutting) while intelligent models were expected to produce later benefits in production.

In ToolCo one design/draughtsman did not perceive savings from CAD, while the other saw reduced design lead times associated with the ability to work on a complete job (from start to finish).

CAD Manager

For the CAD managers, while some savings in time were made through not having to redraw completely, however time was lost due to increased time taken due to inefficient CAD procedures.

7.5.2 Improved Presentation of Work

Quality and accuracy of material for presentations and proposals, whether directly to customers or in marketing brochures was seen as consistently high (including after many modifications) by supervisors, design/draughtsmen and CAD managers, in both the ShipCo's and ToolCo. For a few individuals the high quality of presentation material was the most important benefit associated with CAD.

7.5.3 Faster Product Design

All groups mentioned faster product design, and therefore shorter product lead times, less man-hours and so financial savings. Re-use of information from past designs and the ability to investigate options quickly were also seen to contribute to time savings.

However some individuals did specify that savings were not constant but were linked to the specific section in which the design was taking place. One supervisor said that using CAD was no faster in production of drawings because the time initially saved had to be used to produce the extra detail required for CAD drawings.

7.5.4 Information Transfer

Information transfer, both between disciplines within a company and between one organisation and another (eg. ToolCo with sister companies in America and Europe) were seen as easier, faster and more accurate by most individuals.

However one supervisor perceived that the link was not yet fully operational and so information could not flow easily. While without a direct real-time link, then any late changes had to be communicated to the downstream party to maintain the integrity of the design.

Another supervisor perceived that the extra responsibility for providing information to other parts of the company reduced the overall effectiveness of the design/drawing office.

7.6 Problems Associated with CAD

The major problems associated with using a CAD system are shown below and will be discussed in greater detail in the following sections:

- anxieties associated with the CAD system;

- extra tasks associated with the CAD system;
- tasks transferred to CAD;
- mixture of CAD and non-CAD design processes;
- the move from drawing-boards to CAD;
- characteristics of using CAD;
- pressures associated with using CAD;
- unrealised downstream links.

7.6.1 Anxieties Associated with the CAD System

Supervisor

The anxieties associated with the CAD systems as expressed by the supervisors can be classified into three types of issues:

A. technical issues;
B. issues arising from the interaction between individuals and CAD;
C. issues arising from the interaction between the organisation and CAD.

A Technical issues

Technical anxieties arise from the limitations of the CAD system software and hardware, limitations of the CAD resource, factors which result in loss of savings (associated with CAD, see 7.8.1):

- work and time losses from a system not running or "crashing" (this was also mentioned by the supervisor in ToolCo);

- inability to see whole drawing on workstation screen (although some A0 sized workstations exist, none were in use in the case study companies);
- design mistakes could be automatically passed downstream, or design changes not updated for all users;
- insufficient workstations for the number of staff;
- fast rate of obsolescence of hardware.

Another, more general, technical anxiety linked into the problem of CAD obsolescence was whether some work would be lost if their information database proved to be incompatible with future CAD systems (or updates to the present system). Finally some supervisors were aware that their staff found the response rate of the CAD system frustratingly slow (this was echoed in the design/draughtsmen's own anxieties about their work-pace being set by the work-pace of the CAD system).

B Issues arising from the interaction between individuals and CAD

Table 7.11 **Issues Arising from the Interaction between Individuals and CAD**

Issue	**Explanation**
Friction	found between individuals who are pro- and anti- the CAD system and results in inefficiencies;
Lack of "understanding"	it was perceived that some of the CAD users could 'operate' the system but lacked a true 'understanding' of it;
Communication & space	with personnel in centralised CAD room, physical location of system makes it difficult to supervise/relate to people; asking for a print from design/ draughtsman often results in large amount of paperwork generated;
Isolation	in centralised CAD room the people are cushioned from the outside world, but drawing is only 10% of work and the tendency is to be "blinkered" and drop everything else; isolation of experienced individuals from the "coalface", ie. CAD, and so require extra individuals to liaise with the CAD room;

Issue	Explanation
Technical	need for design/draughtsmen to draw correct geometry because this no longer checked later in the design process;

NB. The idea that drawing is only 10% of a design/draughtsman's work is based on the idea of CAD as an electronic drawing board.

C Issues arising from the interaction between the organisation and CAD.

Two main anxieties arose here, the first is that management hold a perception that the CAD system "hides" something (eg. the belief that there is an issue drawing on the system somewhere which has not been found), which needs to be countered and the second is that there is a lack of coordination among design/draughtsmen as to which projects they allocate priority.

Design/Draughtsman

The anxieties associated with CAD, as expressed by design/draughtsmen, represent an awareness of both technical limitations and the interaction between the individual and CAD. However while many of the issues concern both the technical system and the individuals using it, almost none refer more directly to the interaction between the organisation and CAD system.

Technically oriented issues:

- general health problems such as potential damage from vdu's (deterioration of vision from excessive exposure has not been proven, but initially some companies did provide eye-examinations for computer users and recommend regular breaks);
- individual's speed of work is dependent on the performance of the CAD system;
- optical illusions in 3D views can lead to wrong decisions and possibly conceal a mistake in the drawing;

- easy to lose things through "housekeeping" problems; individuals have to put more effort into keeping own files tidy etc.;
- one ToolCo design/draughtsman perceived CAD as time consuming, because the system required drawings to be called and filed manually even when only minor modifications were being made.

Issues arising from the interaction between individuals and CAD:

Loss of work - this could be the result of forgetting to file something at the end of a session, from a system crash or from "bugs" which might be in the drawing This was also mentioned by a design/draughtsman from ToolCo, who also perceived that there was less "feel" for the overall drawing with CAD.

Perception - one design/draughtsman acknowledged that an impressive looking "sketch" style drawing with very little information in it can easily be created using CAD, which could be problematic, or could be used to impress a customer.

Isolation - of individuals is also possible (especially in the case of a centralised CAD system;

Control - both a) the user is constrained/paced by the speed of the CAD system, and b) tracking what the draughtsman does, by the supervisor, is more difficult when he is working on CAD.

Pressure and effort - appears to increase when using CAD because the individual has to be more accurate as his output is no longer re-checked before being passed on to production.

In ToolCo, one design/draughtsman perceived a machine designer using CAD was a "valuable", scarce resource for the company and therefore he would be unlikely to move up a career ladder easily.

CAD Manager

The anxieties associated with the CAD system, by the CAD managers, mainly concerned technical issues related to running the CAD system, ie. related to support by the organisation (both in financial terms and being visible about support) and related to users.

Technical - problems arose when it was unknown whether the CAD model, paper (manual) drawings or the plastic model were the 'master' copy of the design. A high degree of importance was attached to data security and the need for a regular and thorough back-up procedure. In addition because CAD is not a productive tool for creating traditional orthogonal drawings, it was thought that there was no reason to create a CAD model before creating the output.

Support - financial support is continually needed for training, installing new releases, assessment of new releases etc. In addition commitment was perceived to be "bottom to top" therefore they felt they spent a lot of time "firefighting" to keep the system running.

Users - the human element is always present, with the need for operators for a CAD system.

One CAD manager felt that while the CAD system was well operated it was not applied or used appropriately.

It is very interesting to note here that while the benefits associated with CAD mainly concerned issues that benefited the organisation, the anxieties associated with CAD mainly concerned issues that affected individuals.

7.6.2 Extra Tasks Associated with the CAD System

Supervisor

Some supervisors perceived that after the introduction of CAD their workload had increased. This was the result of both the extra administrative tasks needed for drawings control and the extra responsibility implied by the higher degree of accuracy of information now required in the drawings (mainly because the information was being passed direct to the burning table without any further checking). One supervisor also perceived that CAD involved more "thinking", ie. the need/ability to consider more things.

Design/Draughtsmen

Design/draughtsmen perceived they worked harder in a centralised CAD room because it contained fewer distractions than elsewhere. However while some repetitive tasks traditionally associated with design/drawing could be automatically performed by CAD (see section 7.8) other repetitive tasks, such as data input (ie. for parts lists), still had to be manually performed.

In ToolCo, the retrieval and filing of each model, even when making small modifications, was seen as extra work compared with pre-CAD working practices.

7.6.3 Tasks Transferred to CAD

Supervisor

Rather than "new" tasks associated with using the CAD system (as in 7.6.2), these comments refer to perceptions of tasks which would have previously been performed in the design process, but had now been "transferred" or automated by the CAD system.

The overall "correctness" of information in the model appeared to be taken more for granted, ie. the information held in the model was believed to be "true". Because the supervisor held more trust in the implicit correctness of the CAD model he acknowledged he was less likely to check drawings especially the more minor details. In the same mode the drawing standards are assumed to be incorporated in the CAD system, and therefore the drawings were not checked for this on CAD (although it is still possible that the supervisor checks over a printout).

7.6.4 Mixing CAD and Non-CAD Design Processes

None of the companies had committed themselves to completely using the CAD system and so the majority of projects used a mixture of CAD and non-CAD design processes.

Supervisor

The supervisors perceived a number of issues arising from the mix of CAD and non-CAD design processes. In general the views reflected the opinion that running the two systems in parallel was a waste of resources such as time, energy etc.

At a more individual level one supervisor in ShipCo 4 perceived that the role of a supervisor was incompatible with designing/drawing using a CAD system because, having initially been allocated full-time to working with CAD, they were later moved away. This appeared to lead to the assumption that the role of a supervisor was incompatible with using CAD.

Part of the supervisor's role is to allocate tasks to individual design/draughtsmen (see section 5.5.1), this also includes decisions on whether work is carried out using CAD or not. However some supervisors said they found making the decisions difficult because of their lack of knowledge about CAD. This was particularly awkward for those with little personal experience of using the CAD system. In addition, the separation of supervisor and staff using CAD (in the case of a centralised CAD system) caused some additional problems. Generally the supervisor stayed in the design/drawing office and said they found it difficult to spare the time to visit the CAD room. Therefore it was left to the design/draughtsman to choose to return to his supervisor to report on his progress etc., which appeared to happen infrequently.

Design/Draughtsmen

The design/draughtsmen's comments echoed those of the supervisors, highlighting the lack of clear commitment from the company towards CAD, the difficulties in communication caused by having a separate and distant CAD room and the confusion over where the "master" drawings reside, whether in the CAD model or elsewhere.

7.6.5 The Move from Drawing-Boards to CAD

Supervisor

While one supervisor perceived "no real difference" between using a drawing-board and pencil and using the CAD system, others perceived problems arising from the move from one to the other. However having stated that this switch required a corresponding switch in thinking (and the assumption that it would be more difficult for those that had been using the drawing-board for a longer period of time) it was also stated that once a person had begun using the CAD system then it became very difficult to return to using a drawing-board and pencil. In addition the lack of experience of supervisors with CAD was again highlighted, with the lack of previous experience of planning jobs with CAD contributing to present difficulties with planning decisions.

While age was also mentioned as a factor in the speed of familiarisation with the CAD system it was also acknowledged that design/draughtsmen using CAD were more "visible" in that they were more likely to be found at a workstation than a non-CAD design/draughtsman is likely to be found at a drawing-board. This in itself worries others, both for possible physical harm that may result and skills specific to use of a drawing-board that may be lost if a wholesale change to CAD use were to occur.

7.6.6 Characteristics of Using CAD

Supervisor

Some of the positive characteristics of using the CAD system have already been mentioned, such as the high quality of presentations and standardisation of drawings. However these can also be seen as resulting in a "levelling" of the design/drawing office structure and competence, which for some appears to be characterised as a loss of the "personal touch". However a different perspective on this was suggested by the supervisor in ToolCo, who perceived that this loss of personal touch was compensated for by the other benefits provided by CAD (see section 7.8).

Design/Draughtsmen

While not overly negative, the design/draughtsman's perspective was that some satisfaction has been lost by those who enjoyed drawing in pencil (although compensation comes from using the CAD system which is faster). In addition the

CAD system may limit a user's artistic biases, compared with the drawing board, and requires more number manipulation.

CAD Manager

One CAD manager perceived people's awareness that they might "mess up" using the CAD system and cause some harm. However the pressure from industry meant that they also believed that they had to use CAD "right" next time and the manager was hoping to use this to direct changes in the way CAD was to be used in his company's next project.

7.6.7 Pressures Associated with the CAD System

Supervisor

Different types of pressures were associated with using the CAD system. Some came from the system itself, such as the pressure to adhere to standard conventions, (naming drawings correctly to ensure they were stored in the appropriate place). Others came from the organisation of work around the CAD system, such as the accuracy of geometry which was now required in the drawings (since the details would no longer be checked further downstream, except by the supervisors who found this very time consuming).

Different pressures came from management who were seen as not understanding CAD and so holding unrealistic expectations. In some cases where production established the priorities for a project, the design supervisor had no control over the allocation of time for his own projects, and found that management were expecting results quicker than previously had been achieved.

However some supervisors saw that if their section was 'seen' to do a job quickly then they would always be expected to work at that faster pace, which they felt would not necessarily be the best utilisation of time.

7.6.8 Unrealised Downstream Links

Supervisor

One area of benefits in section 7.8 concerns improved communication and data exchange between departments. However barriers to these benefits are perceived to be due to the lack of planning of the most effective use of the CAD system. In departments where CAD is perceived as being an electronic drawing-board, downstream links are not considered, therefore many of the benefits of integration between different parts of the organisation are unrealised.

7.7 Access to CAD Workstations (Allocation of and Access to Resources)

Based on the results of stages One and Two of the research it was also supposed that the allocation of terminal time to users would be the responsibility of the CAD manager. Only one CAD manager claimed responsibility for this activity. One other CAD manager said that he allocated terminal time, but only after the supervisors had requested CAD time from their superiors (assistant chief draughtsmen), who had then negotiated among themselves about how to divide the total time available.

In the remaining companies, the technical managers negotiated among themselves for allocation of CAD terminal time which they in turn allocated to their supervisors. One reason given for this arrangement was that the managers had been responsible for justifying the system and requesting the budget allocation; therefore they felt they deserved ownership and authority over it. In these companies the supervisors appeared to be recovering some of the control responsibility from the CAD manager, in particular over who uses the CAD system and for which jobs.

In the stage Three sample companies, CAD system workstation access was reported as being more or less flexible, with either a) some pattern of allocation of the workstations, or b) whoever needed a screen "grabs it", with management mediating in any disputes.

Supervisor

The different strategies for allocation could be seen as:

- In ShipCo1, ShipCo3 and ShipCo4 drawing offices the workstations were allocated through a negotiation process between the CAD manager or CAD supervisors and the various assistant chief draughtsmen, who in turn allocated the workstations to the supervisors below them.

- In ShipCo1 drawing offices, the CAD manager allocated the workstations, either in response to requests from individual supervisors or according to a priority listing extracted from the work programme.

- In ShipCo2 drawing offices, the managers decided and secured CAD resources for the department, which could then be used on a "1st come, 1st served" basis. In the design offices the general manager decided the number of workstations he "felt" needed to be allocated to his department, so that whoever needed a workstation could use one (in cases of dispute the manager would be called on to arbitrate).

- In ShipCo4 design offices the workstations were allocated in direct response to requests from the supervisors, or their representatives.

Access rotas were also reported, but only in cases of high workload (where management agreed a project had an especially high priority they did not have to join in the rota). The rota system is limited, as in the case of one department where they all used the CAD system, therefore each section could only get about 50% of the access they needed.

Similarly ease of access varied from easy to difficult, depending on the total number of workstations available and how they were situated. In one company, three workstations had been recently allocated to the design offices, on a permanent basis.

In ToolCo each person had their own workstation and so allocation and access was not a problem.

Allocation of tasks and/or people to the CAD system in the ShipCo's also showed a range of choices:

- the supervisor decided whether or not the CAD system was used for a particular job (depending on the job and particular draughtsman);
- no formal decision about using the CAD system, but a concern that as much as possible was to be done using the CAD system and that work was either obviously appropriate or inappropriate for CAD.

In ToolCo, each design supervisor himself controlled whether CAD was used on a project.

Design/Draughtsmen

In the perceptions of the designer/draughtsmen the strategies for allocation of workstations were:

- In ShipCo1, there had been a period of "free for all" but the situation had returned to a number of workstations allocated to each department, by consultation between the CAD manager and the supervisors, with any spare CAD seats in the central CAD rom, open for use by any other relevant individuals.

- In ShipCo2 the CAD manager allocated the workspace and workstations to the various design and drawing office managers, after which individuals self-selected periods on a rota sheet (2 hour slots).

- In ShipCo3 a shift system was in operation (to make best use of a limited resource) therefore allocation of workstations was not required. However a rota allocating relative time on each workstation was generated each month by the CAD supervisors, although it changed very infrequently.

- In ShipCo4 the CAD manager received a set of requirements from the chief design engineers in advance of determining the allocation.

CAD Manager

The CAD manager in each ShipCo company was involved in the allocation of workstations, whereas the CAD manager in ToolCo was not (since each individual had their own workstation). The different approaches used for allocation of workstations were:

- In ShipCo1 the allocation of workstations appeared to be made by the CAD manager in isolation.

- In ShipCo2 the allocation of workstations had been "migrated" to departments such that each was allocated a specific number of screens, for which individual supervisors internally negotiated for use.

- In ShipCo3 the CAD supervisors decided in consultation with a set of drawing office chiefs.

- In ShipCo4 the CAD manager decided, in response to requests from the supervisors channelled through the Assistant Chief Draughtsmen or Chief Designers.

7.8 Suggested Organisational Changes for the Effective Use of CAD

It is also interesting to contrast the different views held by different individuals within the organisations studied as to their suggestions for improving the organisational effectiveness of design/draughting using CAD. Each is slightly different and can be seen to come from differing perceptions of design and drawing using a CAD system.

One supervisor suggested integration of the whole squad on the CAD system with the supervisor himself positioned in the CAD room.

However one of the CAD managers, in another company, suggested moving the daily running of the CAD rooms to the Operations Group and so free other resources.

Yet another view expressed by another CAD manager, in a third company, who perceived the CAD system lacked direction. This was attributed to the CAD manager, drawing office manager and design office manager all holding positions at the same organisational level and therefore no-one could properly control the system.

7.9 Future CAD systems

Supervisor

Supervisors in the ShipCo's held a range of opinions about the future for the CAD systems in each of their companies. Most concerned the future they would like to see, rather than their expectations of what would happen. The opinions can be grouped under the five headings: technical, training, people, design process and planning.

A Technical

Many comments concerned the technical elements in the longer-term future of the CAD system, centring around the formation of a model database. This would allow the CAD system to be used as an information tool which everyone could "plug into".

In parallel with this, the company would need to devote resources to developing procedures and software to ensure the proper evolution of model management techniques, eg. the facilities to do the widest range of work, both layout and calculations. It was also supposed that lead times could be reduced by setting up the system to extract information at very early stages, eg. automatic materials listing.

Other comments reflected some of the problems associated with the CAD system and how these might be solved, such as the need for more workstations and the laborious nature of non-computerised analysis calculations for the ship (which could be much more effortlessly computed using the model).

One proposed change was to 'nest' details on the next project, saving time and making better utilisation of the capabilities of the CAD system but the supervisor remained sceptical of whether the system could technically "cope" with this.

B Training

Some supervisors perceived the need for further training in the use of the CAD system, especially for the more sophisticated aspects of the system, eg. 3D modelling (especially useful in the engine drawing office).

C People/Individuals

Having trained individuals to use the CAD system, the company must then ensure that they retain the CAD-trained personnel. They could look at ways to keep people with the company after training, such as pay rises, or demonstrate there is a future for them, eg. career path, within the company.

D Design process in the organisation

One possible development was to abandon the full scale physical model, still used for most major presentations, in favour of a CAD model. However it was supposed that customers, such as the MoD, would need to see a comparative example before it would start to change because the CAD model had yet to "prove" it could match the physical (5th scale) model.

Another supervisor perceived that the future should include a re-organisation of the company such that the CAD system could be used effectively. This would involve a long term plan in which the CAD system is integrated into the design area so that everyone is familiar with it and can use it, as opposed to the small areas of development which characterised the development at that time, ie. short sharp exercises followed by periods of inactivity.

E Planning

Planning for the future of the system would require a review to evaluate its current utility and lead to a decision on whether to replace or integrate it with other systems.

It was also thought that project planning could be improved. This could take the form of planning prior to the drawing phase, such as what could be drawn in bulk, what could be used from previous projects, etc.

Design/Draughtsmen

Again perceptions about the future of the CAD system, by the designer/ draughtsmen, can be grouped under a number of headings.

A typical comment on the general state of the CAD system and its future was along the lines of "if the company is going to follow ... the lives of computer-aided drawings then it should keep up to date and make sure it is suitable". This can be seen to represent the design/draughtsmen's acknowledgement of the importance of the CAD system to their work and the need for continual evaluation and progress.

A Technical

Change in working practices from the past have already been seen. The design office used to produce arrangements from drawings and the modellers would produce the model from this, so that arrangements for the design office could be developed.

Updates to the hardware were mentioned as something the company needed to maintain at a current level eg. colour plotter and/or other analysis packages that are developed or replacing black and white screens.

The need for the company to commit itself to a major updating and upgrading of a library of standard parts was also perceived as necessary in the future.

B Training

Not mentioned by this group of interviewees in the ShipCo's.

However the design/draughtsmen in ToolCo did suggest that the future might see them training some of the older and more experienced designers to use the CAD system, and thus take advantage of their design skills and knowledge.

C People

One suggestion to improve resources was to have the "right" number of CAD trained people in design office so that they could meet their targets, especially because they were working to a shorter timescale than ever before.

D Process

As suggested in the supervisor section, one design/draughtsman suggested that the company should be looking towards the use of 3D models on the CAD system.

E Planning

Planning can refer to both projects and the CAD system.

- Where it refers to projects, the thinking was that the company should examine planning for future contracts so that it may improve upon the planning that had been done for previous projects.

- Where planning refers to the CAD system, the idea was for the company to investigate a long term plan for the CAD system such as how to improve it and possibly moving towards using the system in other areas, eg. production.

Individuals in both the ShipCo's and ToolCo suggested that a shift system in the design and drawing offices would make better and more cost effective use of the workstations, but accept it would also entail a large salary increase for it to work.

It was also widely recognised that one of the important elements in future changes for the CAD system would be a higher degree of managerial involvement in design/draughting and the CAD process.

CAD Manager

A Technical

Suggestions for future technical changes to the CAD system include:

- Modifying the model so that the form and content of outputs can be defined such that the traditional orthogonal views can be replaced with isometric views.
- Interface the CAD system with the other company information systems, eg. to produce parts lists automatically, etc.
- Turn the CAD system into an information tool such that it becomes very "transparent" and if something needs to be done on it then anyone is trained to use it.

B Training

Not mentioned by any of this group of interviewees.

C People

The CAD managers mentioned that the company would benefit from educating line managers to use the CAD system in the future.

In addition they said they would like to see a dedicated CAD group set up within the CAD area (given that they would first have to remove TU barrier). This would contain experienced efficient CAD users who could handle multi-disciplinary tasks, working on a process from start to finish.

D Process

It was thought that other benefits might accrue from applying the CAD system earlier, eg. from the initial design of a contract, as well as widening its range of applications.

Another set of changes proposed were in the working practices, so that they would take advantage of the benefits of the system, especially for the draughtsmen. One CAD manager went further than this suggesting the automation of the draughting process as a way to improve draughting productivity.

E Planning

Strategy for the CAD system, eg. long term, of up to about five years, was considered both important and lacking in many of the companies. Without strategy it was felt that "things tend to just hover". In particular one CAD manager targeted investment in the development of a CAD system to support the build of a ship as being an important focus.

In ToolCo it was felt that the senior management were no longer committed to expansion of the CAE facility (and subsequent to the interviews this CAD manager left the company).

F CAD department

One set of comments about the future of the CAD system, from the CAD managers, concerned the associated future of the role of the CAD system department. In the ShipCo's this was for them to become more involved in the production of technical information and to be given some responsibility to ensure tasks are completed according to the time plan.

In ToolCo the CAD manager recommended that a dedicated CAD department should be created, which would contain a main manager with supervisors to take care of the applications.

7.10 Chapter Summary

Following the analysis style developed using the Grounded Theory approach and Cognitive Mapping (chapter 6), the data was presented using five of the seven major categories/issues (figure 6.3). The structure of this chapter reflects these five categories in the first five major sections, such that:

7.2 supervisor's perception of changes to role;
7.3 CAD training for a supervisor;
7.4 company "culture" and CAD;
7.5 benefits of CAD;
7.6 problems associated with CAD;

with the other two major categories closely related to and therefore presented as subsections 7.4.1 and 7.4.2 of section 7.4. The last three major sections reflect some other interesting issues suggested by the data. In all the sections, where appropriate, the data from the three groups of interviewees (supervisors, design/draughtsmen and CAD managers) were presented separately and, where appropriate, the data from ToolCo's interviewees was also highlighted or presented separately.

Although the relatively small sample for each interviewee group size does not enable broad generalisations, there appears to be no great differences between the responses from individuals working in ToolCo compared with the responses from the individuals working in the four ShipCo's. The implications and further interpretations of the data analysis are presented in chapter 8.

CHAPTER 8
DISCUSSION AND CONCLUSIONS

8.1 Introduction

This study has continued from where Dawson (1986) finished his thesis, questioning whether the introduction of new technology (computer-based) in other industries from the one he had studied (British Rail) would create similar new supervisory positions. This study has examined large scale mechanical engineering companies, especially in the ship-building sector, and found that full design computerisation has yet to be achieved. The organisations are themselves in a state of flux and are continually evolving formats for the supervisory function.

Rather than attempt to define the clear-cut answer for these organisations, this chapter will explore the set of considerations which need to be taken into account in improving the design function (including a CAD system) and thus the design supervisory role.

8.2 Overview of the Findings

Much of the literature on computer-based new technology has examined the process of implementation but failed to go further and investigate the consequences of longer term operation and use of the same technology (although it is recognised that only in recent years has new technology been in place long enough to allow these studies to be attempted).

Dawson identified four major stages in the process of computerisation: a) decision to introduce; b) choice and design of the system; c) implementation and initial operation; d) routine operation. This study has concentrated on the latter stages and in particular on the last stage, ie. "routine operation". However computerisation is not a neat, easily categorised process, as is reflected in the complex picture seen in the results.

Many practitioners, company members involved in the management and running of a CAD system, and researchers make the assumption that through the process of ongoing operation, a system will "settle down" and problems (including any connected with design supervision) will be resolved (the same situation is likely to be seen with the introduction of most computer systems). But this ignores the continual process of change and transition which also occurs, such as turnover of staff, changes in the general company context and especially in the area of computerised technology, in which hardware and software are becoming obsolete at an increasingly fast pace.

This process of change is further complicated by the differing perceptions and assumptions of individuals embarking on the process, eg. the differing perceptions of the content and effect of an NTA by different individuals within the same company.

Computerisation can show effects at a number of different levels, ranging from the individual to the business sector (cf. Curtis et al. 1988):

- business sector, eg. shipbuilding
- company
- design/draughting office
- department/section
- individual.

At the lowest level, and intrinsic to all computerisation, the individual is concerned whether his own needs are being met in the operation process.

Therefore any change process has to take account of the needs of the individuals concerned, ie. for it to be important to them people have to see the relevance and advantages of change to themselves, such as enhancing their own skills or performing less repetitious/mundane tasks. While individuals can see the need for training and are often receptive, problems arise due to the lack of support from management, both during and after the training period. Specifically, the needs of the supervisor's role are often totally neglected, or only partially met through training.

In some cases the technology, rather than the organisation or the individuals within it, is blamed for not meeting the needs of the supervisor. In this way the organisational problems can be avoided and attributed to the "new" technology. This implies that no matter how much the technology is adapted, tailored or changed then many of the organisational problems such as those faced by supervisors will not improve.

Moving from a general discourse on new technology to more specific cases this section will focus on CAD systems, as seen in the companies investigated in this study.

Because the introduction of CAD systems in British shipbuilding was initiated by an external source (namely the nationalised body, British Shipbuilders), the choice and initial design of the system was limited (see section 6.5.1). The results of this limitation still have effects, such as where a CAD system often runs alongside the existing "manual" system.

One approach in design might be a fundamental shift in the way of thinking when working on a CAD system, as compared with the thinking involved in design or draughting work on a drawing board. The way in which designs are constructed is very different on the drawing board compared with CAD systems; therefore it is reported that a different approach is needed (drawing board design can be categorised as "piecemeal" compared with CAD operation which is more integrated, especially with the use of storage databases). Use of a CAD system includes the potential for linking to other computerised systems, which also might affect the patterns of thinking employed (ie. design for productivity issues involved in direct links with CAM, CNC machines etc.).

This is compounded by the physical environment of a CAD system (the need for subdued lighting, carefully controlled air conditioning, positioning of the CAD workstations etc.) which appears to be almost intrinsically opposed to the traditional environment of the design or drawing office (ie. naturally light, airy places suitable to more extensive social and work interaction).

The potential impact of CAD on both draughting and design is complex, subject to many more factors than merely the introduction of a new and more complex tool. In some organisations design often seems more able to accept and work with CAD, whereas in others, draughting seems better able to incorporate CAD into their working pattern. Where CAD is seen as the first step in integrating the manufacturing process, ie. CIM, the integration of the technology is a physical possibility but this says nothing about the more complex task of integrating the individuals within an organisation. In some cases the traditional craft barrier between design and production is still in evidence and itself needs to be addressed.

One case clearly shows how the CAD manager sees the design department as accepting him and the CAD system, whereas the drawing office perceive him as a threat (and by implication the CAD system too). He cites what he sees as the reasons for the drawing office management's antagonistic perceptions,

> "They see him (the CAD manager) as doing something which they (the drawing office) do not understand yet; senior people listen to him; he is an outsider in a technical department, with power and he

is someone who will not bend to their historical ways of doing things and will fight them".

These comments illustrate the interaction of a number of factors relating to the CAD manager and therefore to the CAD system:

i) mainly a lack of understanding and degree of distrust on the part of the drawing office;
ii) the CAD manager's perceived influence with more senior management;
iii) a perception of the CAD manager as a change agent;
iv) distrust of perceived "power" attributed to the CAD manager, including:
   - refusal to accept the "norms" of the situation;
   - readiness to defend his opinions.

The "pure" design supervisor appears to find working with CAD a very confusing situation. Whereas most designers or draughtsmen appear to have been adequately trained to work with CAD, there is a definite lack of supervisory training. As yet no one has tackled the problem of how to deal with the effect of CAD on secondary users, ie. those who do not work with CAD themselves but work directly with primary CAD users (eg. supervisors of CAD users).

Another set of problems occurs when CAD workstations are situated in a centralised area separate from the main design/drawing office. In this situation the supervisor is physically separated from his subordinates and often experiences a concomitant sense of psychological distance from him. This is exacerbated when the subordinate turns to the nearest expert for advice, namely the CAD manager.

Wider issues concerning the nature of the organisation and the need for awareness by managers of the possible paths that CAD might lead to also need to be addressed. The remainder of this chapter discusses the issues mentioned in this section in greater depth and looks at possible options for future research.

8.3 Management Strategies for CAD

The main aim of this research was to elicit information about the changes in organisational roles and structure in the design office with the introduction of CAD. One area of interest was whether or not management had a medium term plan for change.

From the case studies a range of approaches were identified but for many companies, setting up the roles of CAD manager and support team was the *only* planned organisational change. However management generally tended to adopt strategies that lie on a continuum between two extremes:

- to minimise change resulting from the introduction of CAD;
- to use the introduction of CAD as a catalyst for introducing more widespread and radical organisational change.

Thus in one company illustrating minimal change, management planned to keep the organisational structure as stable as possible and maintain the same work patterns as pre-CAD implementation. In this approach CAD is viewed merely as an "electronic drawing board", which must not be allowed to trigger a new generation of "overhead" specialists.

A number of process industry companies have had computer-aided design in some form for a number of years, eg. numerical systems to aid calculations. Therefore they have been able to adopt a more flexible and evolutionary approach in which modern CAD is merely the latest "new technology" to be accommodated.

In stage One, of this research, one organisation was already structured into small project groups (eg. four to six individuals) which seemed to have been readily able to reorganise their activities at the "informal level", to accommodate the CAD system. In another company, management chose to introduce the CAD system cautiously, initially just at a pilot level. This strategy ensured that there would be only minor disturbance to the whole organisation (although full scale adoption of a CAD system might be very different).

By contrast, in other companies the introduction of CAD has been associated with more radical organisational changes. In one shipbuilding company the introduction of CADCAM had resulted in the redundancy of the activities of a department adjoining design. The traditional loftsman role was to lay out the outlines of the ship's plates full size, using his expertise to correct any inaccuracies in the drawings. With the greater accuracy provided by using the CAD system, this skilled work was no longer needed, and the decision was taken to integrate the lofting department into the drawing office, despite the traditional craft barriers. This change was accomplished with relative ease through foresight and planning by arranging for the loftsmen and draughtsmen to be trained *together* on the new technology and be based in the same area.

However in stage Three, both the design supervisor and design/draughtsman highlight this "pressure" to produce more accurate geometry without the "safety net" of later checking by a third party, as a major stress factor associated with CAD.

A major aerospace company appeared to use CAD as a catalyst for introducing changes to organisational changes and working practices. These included the change from traditional role to a matrix organisation structure, the formation of integrated design teams, and the declaration to all company employees of company targets and accountability of individual managers.

Other cases where CAD has provided the stimulus for major change have been described in the literature (eg. Majchrzak et al., 1987). These changes cannot be labelled as purely technology-driven but form part of a wider company strategy for organisational development.

8.4 Planning Change

Recognition by management that significant organisational change is likely to be needed when CAD is introduced is supported by the philosophy of the socio-technical school (see section 2.4.8). This views a work system as consisting of both *technical elements* and *human/social elements*. The aim in designing a new or improved work system is to achieve compatibility between these two types of elements, so that both of their functional requirements are optimised. Therefore when a new technology such as a CAD system is introduced, the social system needs to be modified in order to find this optimal balance again.

This does not imply "technological determinism", that is the (new) technology demands a specific social system which has been customised for it. On the contrary, a range of social systems can be designed around a particular technology, and managers can exercise "strategic choice" (see Child, 1987) in deciding which social system best meets their foreseeable objectives (including achieving committed and effective performance from their staff).

For a smooth change to occur in the social system, the technology itself can be used as a catalyst or "unbalancing agent". A recent survey in the UK concluded that organisational change was more likely to be accepted and accomplished smoothly when it was associated with the introduction of new technology (Daniel 1987). The author's interpretation was that management investment in new technology was perceived as representing confidence in the company's future; those workers directly associated with the technology would benefit if they cooperated in adopting the necessary changes in work patterns. The "losers" were more likely to be the indirect and lower skilled workers who had little power to resist change. By contrast, much more resistance was identified where organisational change had been introduced *without* any "justifying" technological change.

Thus planned change depends upon management's objectives. If they wish to make low investment, taking a cautious and exploratory approach to investigating the implications of the new technology, then little planned change will be necessary and CAD systems may well be used only as "electronic drawing boards". Its potential for providing much greater benefits may therefore be missed.

This provides an opportunity for the organisation to begin to explore CAD and may lead to further investment in it. However without appropriate planning and recognition that more major changes might need to take place, this later evolution of CAD might still fail to capitalise on the benefits of CAD. This appears to be the stage that most of the case study companies had reached. They had a limited perception of the wider implications of CAD and their already significant investment.

In contrast, management may wish to radically alter the performance of the design function in terms of the quality and quantity of its output, its relationship with other functions and its efficiency. A major investment in CAD, with all the associated changes in work patterns and the necessary training programmes, can provide the opportunity to bring about a step change. There will be turbulence and instability within the company for many months, so the risks and potential for serious business setbacks are high. Consequently forethought, planning and continual monitoring of the implementation process are important elements in achieving a successful changeover (although other factors might hold equal importance, depending on the specific context in which the change process occurs).

The case study information confirms the previous view that managers in general plan effectively for the investment in technology and the training of users, but *do not* recognise the wider implications of changing supervisory roles and responsibilities.

8.5 A Changing Role for the Supervisor

Dawson and McLoughlin (1988) have also highlighted the problematic situation for the supervisory system associated with the introduction of and working with CAD. The high degree of complexity surrounding this situation does not lend itself to the production of easy "solutions". Moreover some "pure" supervisors seem reticent to admit to any changes in their role caused by this implementation and long-term use, while others see slight variations in specific tasks eg. a greater amount of paperwork generated by working on the CAD system.

One of the major problems appears to be not the addition or use of the CAD system itself but the continued equivocal role that members of the supervisory system play within the organisation itself, ie. often they are neither part of the management structure nor part of the general staff.

An alternative view is offered by socio-technical theory (section 2.4.8), which advises the generation of semi-autonomous work groups and so "solves" the question of the role of the "pure" supervisor. However supervisory functions are still carried out (eg. in representation of the group to the outside world); therefore this view side-steps the problem rather than tackles it directly.

A major part of the supervisor's role concerns the motivation of his staff (activity A7, table 5.3, section 5.5.1). One key factor affecting *their* job satisfaction was the nature of the task and the inherent "interest" contained within it. Introducing a CAD system into the design process allows some of the more repetitive (hence low interest) tasks to be automated. Accordingly because the remaining tasks have greater interest for the designers/draughtsmen, they are more likely to have greater personal motivation and to require less explicit "supervision" than previously. Hence the supervisor's role may become more heavily biased towards technical aspects of the design process. However as shown in the case studies, it is the perception of work done with the CAD system which frames whether the design/draughtsmen find their work more interesting. Not all repetitive tasks are appropriated by the CAD system, and possibly some new "boring" tasks are created. Therefore the greater motivation posited above is only one possible outcome from using CAD, as is the proposed possible change in emphasis in the design supervisor's role.

As already mentioned, difficulties occur when the technology is seen as a "fix" to solve the problems resulting from the equivocality of roles within the organisation itself. One organisation's management expressed the feeling that as the organisation evolves and matures, the equivocality of the "pure" supervisor role would disappear, of its own accord, with time.

This could be a result of the argument that as designers/draughtsmen are trained in using CAD, from early stages of their career, and are promoted to supervisory positions, the present problems with lack of training and skill differentials will naturally disappear. Therefore these new design supervisors:

- will not have to be concerned the impact of initial CAD implementation;
- will themselves be CAD-trained and have experience of using the CAD system, as operators;
- will appreciate its limitations and therefore will be better able to appreciate the problems subsequently expressed by their subordinates;
- will have available a range of examples where the capabilities of CAD have been successfully applied to relevant typical design problems;
- will exist in an environment of greater familiarity with CAD;

- will have software and hardware which is more reliable and has greater compatibility with other computer systems within the company.

This is an appealing idea, but does not consider the above mentioned inherently unstable supervisory position. In addition senior managers' awareness of research, such as this study, may help them to plan effective social changes in their organisational systems. The basis for expecting the equivocality of the pure supervisor role not to disappear 'naturally' comes from the following:

- future supervisors are still liable to be in the same position faced by present supervisors, ie. holding the responsibility for the group output but without the true management authority to ensure the work is done (described by some writers as the "man-in-the-middle" scenario);

- continuing developments in hardware and software may cause the supervisors to lose touch with the capabilities of the CAD system if they are not using it continually;

- present design supervisors with limited CAD capabilities will still be in the organisation;

- much general design supervisor training is currently left as "on the job" learning from their predecessor; therefore the future supervisors will tend to inherit the problems of today's supervisors;

- few, if any, large design organisations have fully converted to using a CAD system, and many will try to retain a mixed manual/CAD system. Problems which occur include, where to keep the master copy of a design (ie. on paper or on the CAD system), mixing the lighting requirements for manual and CAD systems, mixing the design processes surrounding the two systems, etc. Factors which have prevented full conversion to a CAD system include:

- people's distrust of the CAD system hardware and software (possibly generated during the initial introduction of the CAD system, before it was fully functional and all the "bugs" were removed);

- unsuitability of the CAD system for some parts of the design process, ie. the CAD system might well be unsuitable for conceptual design (see Pugh S, 1991), whereas other drawing packages which can link into CAD systems such as DesignView™ (by ComputerVision) might improve this.

The mixed system may not be a transitory state, but one in which the potential of the social organisation and the potential of the CAD system can be exploited. This contrasts with the drive towards complete computerisation in the design and drawing offices, often associated with CIM.

8.6 Work Allocation and Monitoring

Work allocation with manual design is governed by three main criteria (Wells 1987):

- the availability of staff as previous work is finished;

- the knowledge and expertise of available designer/draughtsmen relevant to the task;

- the particular task requirements eg. high urgency, need for high creativity or specific expertise.

In general when CAD is introduced it is run in parallel with the existing manual work in the drawing office. Therefore further criteria for work allocation must be added in this dual system (also from Wells 1987):

- the availability of time on the CAD system and work station(s);

- whether the task is suited to CAD or not, ie. whether CAD would be used effectively;

- how important it is to have the job in the CAD database, eg. if the work is expected to be reused or modified, or if a customer or associate requires CAD information, then CAD should be used, but if no such benefits can be seen then the effort and commitment to using CAD for the full life of the project may not be justifiable.

However since CAD terminals are usually shared among several sections, and experienced users are dispersed among the sections, the responsibility for work allocation may be passed from the design supervisors to the CAD manager (from the supervisors' role activity A3 to the CAD manager's activities B5 and B14, see section 5.5.1, tables 5.3 and section 5.5.2, table 5.4).

The evidence from the questionnaire companies (stage Two) was that various levels of the design supervisory system retained the responsibility for B5 in about half the reported cases but that responsibility for B14 was mainly with the CAD manager or supervisor. From the case studies further factors emerged that became overriding for work allocation. These often formed an important part of the strategy for introducing a CAD system:

- Organisations whose strategy was to reduce manual design to a minimum in the medium term, endeavour to put all their new work on CAD.

- Some companies select a single major project to be designed using CAD, as a "pilot project".

- Some companies allowed the design supervisors the responsibility of deciding whether to use CAD or not, but provided guidelines about the types of project that were best suited to CAD.

The question of CAD sharing among sections appeared to be answered by allowing either the CAD manager or someone in a more senior position, eg. a senior supervisor or the drawing office manager, to set priorities for use of the available terminals. In this way the status of the first line supervisor was maintained since he retained most of the decision-making process and appeared able to adapt to this new CAD environment. However if the CAD manager was given the job of work allocation rather than merely terminal allocation, the design supervisor's role was diminished, a situation which could and probably did cause friction between the two positions.

In stage Three only one draughting supervisor reported being responsible for logging the man-hours worked by his staff, both on the drawing board and on CAD. Although hours worked on the board had been included in the activity A5 (monitoring), the expectation was that the CAD manager would be responsible for time worked on the CAD system (see activities B5 and B14 - job and terminal allocation - in the CAD manager's activities list; table 5.4, section 5.5.2).

However one task which apparently has passed from the CAD manager's role was the allocation of jobs to CAD. All the supervisors interviewed said that they were responsible for job allocation within their section (in consultation with their manager and according to the priorities of the design programme). In four of the companies the supervisors said they were also responsible for deciding whether or not CAD was used on a particular job. In the fifth company, the supervisor in draughting decides who uses CAD within his section but, in design, the designer himself makes the decision about whether CAD is used for a particular piece of work.

Thus it appears that the full integration of CAD into the design process has yet to stabilise, within a general organisational context. Part of this stabilisation process is the continuing development of the design supervisory and CAD managerial teams and roles.

8.7 The CAD System Layout and Implications for Work Organisation

The positioning and layout of the CAD system was cited in all the case studies as being of major importance to the developing work relationships. This represents another example where management fails to anticipate the non-technical implications of new technology. There are two main options for the location of the CAD system open to management:

i) workstations situated in a centralised CAD area (separate from the main drawing office);

ii) workstations distributed around the present drawing office.

The literature describes technical, environmental, 'man-machine interface' and other factors in favour of a centralised layout, as follows in table 8.1 (based on information in Preston et. al. 1984, Smith 1985).

Therefore managers were strongly encouraged to create a *central* CAD facility, physically divided from the rest of the design office. However there were some serious implications for work organisation.

Potentially the most important factor, at least during the learning phase, was the need for an operator to consult the CAD support team about using the system. For

Table 8.1 **Factors Supporting a Centralised CAD Area**

i)	To achieve environmental control for both people and equipment: • Lighting is especially important. The screen reflects ambient light; therefore local, reduced, indirect lighting under the control of the operator is recommended. This requirement conflicts with that for bright lighting needed for the drawing boards in the regular drawing office. • Other factors include control of dust, noise, temperature, humidity and electrical interference.
ii)	To minimise installation costs.
iii)	To maintain security against unauthorised access and sabotage.
iv)	To make maintenance as easy as possible (dispersed equipment is less easy to monitor).
v)	To make budget and cost control as simple as possible.
vi)	To achieve a maximum learning rate by focusing trainer attention and minimising outside disturbances.
vii)	To optimise the use of trained manpower and facilities (this represents a new "criterion" for work allocation - to be discussed later).
viii)	To enforce standardised procedures for projects and database management on the CAD system.

this the workstation needs to be situated near the CAD support team offices (a telephone call is considered far inferior to face-to-face contact). Without the immediacy of physical proximity, psychological distance between the operator and their supervisor often occurs (see below for more discussion of this issue). Thus the operator may well have considerably more contact with the CAD manager and his staff than with his design supervisor. A centralised layout also allows the operators to discuss problems and help each other. However, other human and social factors support a decentralised CAD facility:

- A centralised CAD system forces the designer/draughtsman to work away from his design supervisor and within the potentially strong influence of the CAD manager and CAD support team. Thus the design supervisor's control over the operators' performance, technical input, training, etc. is reduced.

- An "elite" group of CAD operators may be created who are isolated from their 'manual' colleagues; thus new artificial boundaries are formed that may constrain work allocation decisions.

Most of the communication problems between the design supervisor and his subordinates came from this separation and the accompanying view that "out of sight is out of mind". In addition the design supervisor loses track both of the level of competence reached by the operator on CAD and of the current attributes of the system itself. This situation is exacerbated by the CAD manager, who possesses the greater CAD system expertise and tends to take over some of the responsibilities of the first line supervisor.

One solution to this centralised/decentralised layout debate, seen in a shipbuilding company (stage one), was a compromise between the two choices. Although the work stations were distributed around the drawing office, they were in clusters of four or five in a central 'island' between rows of drawing boards. In this way an adequate physical environment for the CAD workstations could be provided without losing social contact with the sections.

Another company was experimenting with moving some of the screens from the centralised area into the sections in the drawing office itself, hoping that this would remove some of the psychological barriers that had built up. The CAD manager believed that the screen relocation had only become possible through the then recent introduction of "anti-glare" screens into the CAD accessories marketplace. He expected that "when he (the design supervisor) has got the work station in his area and he sees that it's sitting idle too much, he will soon have to put some work onto it!" This may represent the deterministic view that the technology should be used, whatever the context, which ignores the question of whether it is appropriate to use the CAD system at this point in the design process.

In the latter cases it became clearer that the most suitable configuration may change over time. A central CAD installation may be desirable during the implementation phase to encourage information exchange between users during their initial training and consolidation phases, and to minimise external distractions. After this initial phase, the CAD system becomes accepted and "visible" within the design process and the pool of competent users grows. Following this, additional workstations can be located around the design and drawing offices and fully integrated within the work groups area. In this way a small central area is retained (for training, systems development etc.), but most of the CAD technology is dispersed and does not interfere with the natural work groups.

8.8 CAD Training for Design Supervisors

All companies recognised the need to train their designers and draughtsmen to use CAD. Generally the strategy was to send the CAD manager and support team away to be trained by the CAD system vendor. After their return they trained some leading designers, some small percentage of designers and eventually a proportion or all of the remaining designer/draughtsmen (depending on the policy of the individual company). Some of the more 'advanced' CAD companies are now setting up CAD training sections within the main training department. However in the literature, only minimal reference has been found to the training of first line supervisors.

In the sample companies, three general approaches to training the design supervisor to use a CAD system were seen:

1. The approach that no training on CAD should be given to design supervisors because they were perceived to be 'non-users' of CAD, in the same sense that they do not do manual drafting. This ties in with the philosophy that CAD is merely an "electronic drawing board". Therefore the

only way a design supervisor can work on a drawing with his subordinate was by writing on a printout taken from the CAD system.

2. The approach that although the design supervisor does have some contact with the CAD system, extensive training would be wasted since anything learnt would soon be lost without the further practice associated with continual use. Therefore a minimal CAD "appreciation" course was all that was needed, possibly lasting as little as one day.

3. The approach that it would be useful for the design supervisor to be able to use CAD. However he should not be forced to accept training. Therefore even when CAD training was offered to everyone in the design office, several companies found that very few design supervisors requested a place. The design supervisor was often a middle-aged man (45+ years), a design expert experienced in company methods, products and technology, but not regarded as "management material" and having very little knowledge of computers or their benefits. Consequently he viewed himself as "too old" to train on CAD, would be too sceptical of computers (the perception of CAD as "that damned machine") or was wary of losing his status in the drawing office because his performance on the CAD system might be weak.

Note that these approaches to CAD training for supervisors *may* only be a transient phase in the first few years of a CAD system being introduced; in time, experienced CAD designers would be promoted to supervisory grades and would have the necessary technical skills. What remains to be seen is whether:

- the job specification will be changed to require them to maintain those skills;

- or whether they themselves will choose to maintain their skills or allow them to fade as they settle into the traditional role.

8.9 Experience with CAD and CAD Skills

The case studies showed it is becoming more and more difficult for design supervisors to remain as non-users of CAD. As their subordinates gain experience and become familiar with CAD, a 'skills differential' often develops between subordinate and supervisor, resulting in a perceived loss of status by the supervisor.

Problems also arise when the supervisor has to assess the performance, ability and training needs of his subordinates; he has no personal "yardstick" against which to measure them. If the supervisor cannot access the operator's files, he is forced to request prints periodically (although many people still prefer to discuss the design on a hard-copy anyway). He appears to find it very difficult to estimate the drawing times needed for planning and control. Furthermore if he is not a regular user, the supervisor cannot have any real understanding of the limitations and benefits of the system or be able to recognise inefficient use. Therefore with this differential in knowledge there are accompanying problems in supervisory relationships as well as sub-optimal use of the system. This situation is exacerbated when the drawing programme is generated by a department outside of the design/drawing offices, who also have very little knowledge about CAD and who often assume that it produces the productivity improvements cited by CAD vendors. Thus the design supervisor can find himself in the position of trying to drive work using CAD, so that designs and drawings can be produced faster, and unable to easily modify the work timing programme to take account of any failures to meet it.

Just as companies do not have ideal organisational models to move towards, so they do not have a clear view of the role of the first line supervisor with CAD systems and consequently are unable to develop appropriate training. There is a need to develop training in both technical and supervisory aspects of CAD for supervisors, appropriate to the organisation they are situated within.

8.10 Applying the Structural Model of Technology to CAD Systems

8.10.1 Introduction

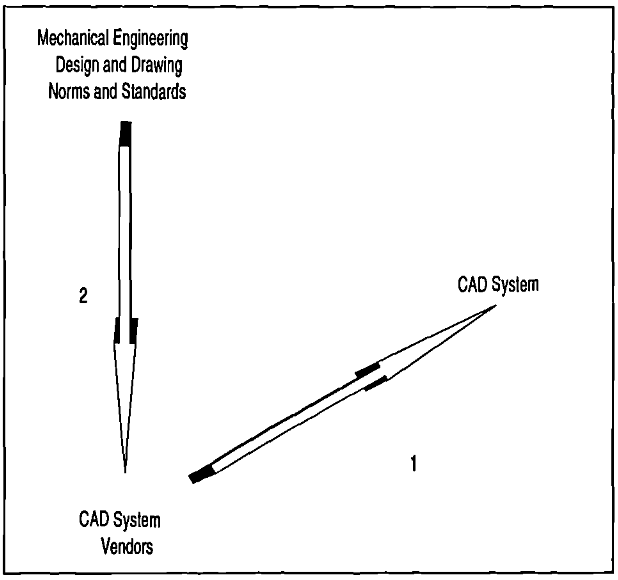
A summary of Orlikowski's (1991) application of Structuration Theory to technology has been presented in chapter 3 (section 3.5). This was then used as a framework within which to examine the introduction and running of CAD systems in the case study companies.

8.10.2 Initial Development of CAD

From the general studies of CAD systems, and in the five companies examined in this thesis, it is clear that the systems were not, on the whole, developed for specific purposes, except those "institutional properties" associated with design in general (although the caveat would be that in the case of relatively large scale customers, such as one of the sample companies where the vendors cooperated closely in tailoring the system more to the specific needs of the company).

Therefore development engineers within the vendor company (ie. human agents) produced the CAD system (the technology; arrow 1, figure 8.1). The basic requirements for the CAD system would have been informed by the general

Figure 8.1 **Initial Development of CAD**



institutional properties of mechanical engineering design and draughting, eg. accepted design and drawing knowledge, norms and standards (structures of signification; arrow 2, figure 8.1).

Generally users are not involved in this early stage of development of CAD systems. However in ShipCo 2 (see section 6.6) members of the company were involved in development of software to enhance and tailor the CAD system for use in shipbuilding, prior to the main implementation. In particular a group of supervisors were seconded to this development team in order to capitalise on their experiences (however this is not necessarily participative design; rather it is tailoring the existing CAD system which has already been institutionalised)

8.10.3 Institutional Use of Technology

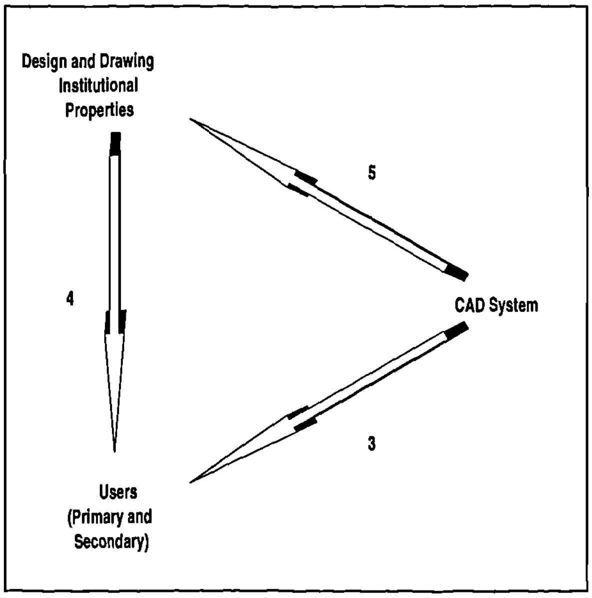
The diffusion of CAD systems is variable, spreading farther in some companies than in others, and in a mixture of physical configurations, ie. centralised vs. distributed systems (in addition a variety of degrees CAD "maturity" may be seen in companies other than in the sample and in the more general literature, as described in chapter 2). However at the time of the study, use of the CAD system had not yet become mandatory in any of the companies examined.

In using a CAD system, design and drawing work may be mediated by the assumptions and rules built into the system. Where CAD is viewed as a medium of human action, it can be seen to both constrain and facilitate the users (both primary and secondary). CAD vendor developers, or in-house developers, often build in quality standards, rules for geometry, standardised layout of drawings etc. This can also be seen in the drawing processes using a CAD system, which are themselves quite radically different and sequentially constrained by the system, compared with the use of paper, pencil and drawing board (Cooley 1987, Rosenbrock 1983).

At the same time there are many benefits associated with CAD systems, such as the flexibility and ease of modification of a drawing, ability to explore quickly alternative solutions, integrated analysis, etc.

There are many examples of the CAD system acting as both an enabler, and constraint, on human action. Similar scenarios may be seen when the human agent is a secondary user, ie. a member of the design supervisory system (arrow 3, figure 8.2). Again the CAD system constrains and facilitates the actions of design supervisors.

Figure 8.2 **Institutional Use of CAD**



Most supervisors perceive the benefits to their role attributable to using a CAD system, such as:

- improved quality of presentation;
- quality and accuracy of data;
- availability of drawings for re-use;
- speed of drawing production;
- responses to customer needs.

They also perceive the problems or constraints, such as:

- drawings too detailed for CAD;
- large amount of paperwork still generated;
- need to check geometry;
- lack of coordination in and among departments, such that not all departments use CAD;
- communication and space.

The physical location of the workstations was also perceived to be an important variable, and open to a degree of flexibility. A centralised system, while desirable from social and maintenance perspectives, appears to often separate and isolate a supervisor from his CAD user (designer/draughtsman). Although the supervisor *could* visit the CAD room, or the user *could* visit their superior, neither do. The supervisor feels that it is not they who should go to his subordinate, and the user is more easily able to resolve any practical problems through consulting contacts in the CAD room, either fellow users or a member of the CAD support staff (often the CAD manager).

In the case of distributed CAD systems, it may be that the company is trying to force the supervisor to use (or allocate his staff to use) the CAD system by physically positioning the workstations in their section, eg. one individual in a company expressed the idea that a supervisor would then be "embarrassed" if the workstation in his section was not seen to be regularly used. However some of the beneficial social aspects of the centralised system, such as the high degree of informal learning, are now lost. The question which then arises is who may legitimately use a workstation in any particular area, ie. whether "anyone" can use an unoccupied workstation anywhere in the company, or what the restrictions might be. Thus it is clear that design and drawing office institutional properties are able to exert a high degree of pressure on the action of users when interacting with a CAD system (arrow 4, figure 8.2).

Historical factors within a company are potentially of great importance. Where CAD was introduced at different time periods in different parts of the company, it appears to have been accepted differently, eg. where introduced in design first, drawing offices view CAD as the property or "plaything" of design (therefore design has the legitimate right to CAD and dominant control over its development), and vice versa. In this way the introductory process and its consequences contribute to, and sometimes reinforce, the existing "structures" in the relationships between departments.

The CAD system may be perceived as constraining the work of individual users, through dictating ways of constructing and integrating drawings. Although views do vary and where some people complain about the lack of "human touch" or individual style in the output, others compliment the system on enabling a consistently high quality of output, even after many modifications, therefore moving the focus away from "just pretty" drawings to high quality design. Since, at the time of the interviews, CAD was not the only tool used in the companies for design and draughting (a situation unlikely to change quickly) it probably was not yet completely institutionalised, thus a variety of perceptions were still held.

However it is possible and quite likely that at some point in the future the CAD system will become the "taken-for-granted" tool, ie. institutionalised, for use in design and draughting (arrow 5, figure 8.2). New recruits to the companies are expected to be knowledgeable about CAD and in some cases users have already moved away from companies because their CAD skills add value on the job market. In one company the CAD trained personnel were being lost because other companies offered better pay for CAD skills and experience.

In this way, once the use of the CAD system has become commonplace, this can itself influence the company's institutional structure. It is likely that the acceptance of CAD will be a gradual process, rather than a discrete stage. The change in attitude towards the CAD system will probably be different for different individuals, according to which aspects of the CAD system they find most useful or in which part of the company they work, ie. whether in design or draughting.

Expressed in terms of the structural framework, the CAD system represents a powerful resource and set of rules, applied and manipulated by people in a particular company in their daily working. In this way the CAD system also contributes to each company's structures of signification, domination and legitimation.

8.10.3.1 Structure of Signification

The CAD system directs the way tasks are interpreted and work carried out through its embedded knowledge, eg. concepts and procedures, physical configuration. Some examples of this are: in the CAD room one supervisor perceived that the user is cushioned from the outside world and tends to "drop" other tasks. However he also perceived that drawing is only 10% of their work and so saw the users as being blinkered. In addition the output from the drawing offices, in some of the companies, is no longer checked by a later external department and goes straight to production. Therefore either the user or, more generally, the supervisor has to check the accuracy of a drawing before it can be 'signed off'. This inability to see the whole drawing is frustrating for users and their supervisors; the supervisor has to learn how to estimate time and plan jobs in his section when subordinates are using the CAD system, although there was very little past experience on which to base any judgements. The move from producing production drawings to "workstation" drawings, may be directed so that it uses and takes advantage of such things as libraries of stored and standard parts stored in the central database.

8.10.3.2 Structure of Domination

The CAD system contributes a resource which is used to control the work of users and supervisors. Although used to differing degrees in each department, within each company, the CAD systems were initially designed by a vendor and then modified/tailored and implemented by a specific CAD development/support team in each company. Therefore in each company the CAD systems contains in-built assumptions, features and standardised procedures through which unobtrusive, and not so unobtrusive, control over the nature of work and coordination of users and their supervisors may be exercised. The debate over the use of a CAD system as an instrument of management control has already been examined (see chapter 2).

One conclusion that can be drawn from this debate is that there is potential for the CAD system to be used as an instrument of management control, thus re-enforcing the structure of domination. Where the human agents (users and supervisors) actively utilise and appropriate the CAD system, they unintentionally reinforce the institutionalised control imposed on them through the technology. Unknown to them[1], use of the CAD system reaffirms the company's system of domination, eg. in one company initial releases of a drawing had the word PRELIMINARY and a specific logo automatically added to it, if released by a certain level of user; once the drawing was issued in full, then further changes were only possible through the CAD manager.

However it is also clear that the many departments do not solely rely on the CAD system to accomplish their tasks, and some do not use it at all. In this way the choice is made by the human agents not to use the tool, or possibly not to use the tool in the authorised manner. There are many examples of a CAD system used only as an "electronic drawing board", which results in a level of undermining of the company structure of legitimation. This is particularly relevant to the supervisor

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[1] Although it may also be argued that in some situations, eg. wage negotiations, some users do comprehend the use of technology as an instrument of control and seek to re-negotiate the power relationship more in their favour, such as through Trade Unions etc.

who generally has the responsibility for allocating tasks to be done using the CAD system. If the supervisor views the system as an "electronic drawing board" then it is more likely that the user will pick up on this, and only tasks relevant to this mode of use will be attempted on CAD.

8.10.3.3 Structure of Legitimation

CAD systems contribute to structures of legitimation through sanctioning a particular way of working (in design and draughting and possibly affecting work practices further down the line too) and propagating a set of norms of acceptable professional social practice. Theoretically, through encouragement (ie. company policy to use CAD for as much as appropriate or possible) or in some cases directly ordering the use of CAD, the company implies that the CAD system is the only legitimate tool in design and draughting. Further, the rules embodied in the CAD system incorporate some norms about the appropriate criteria and priorities that may be applied to design and draughting, and the manner in which it is to be carried out. However management "backing of" or commitment to use the CAD system was perceived, at all levels, to be relatively poor. In some cases supervisors, designer/draughtsmen and CAD managers were more concerned with communicating to management the legitimacy of using CAD for design draughting work and the adequate provision of resources, eg. one supervisor said, "management make 'nice noises' but there has been a lack of resources devoted to CAD and lack of progress in the time the company has had CAD". Comments from design/draughtsman included, "[management] realise there are potential and capabilities, but that's all", "difficult to get the message home to them about the truth"; "management do not push CAD enough, ie. there is too much free hand in how the drawings are produced".

8.10.4 Ongoing Interaction with CAD

In general, CAD systems have been introduced to the sample companies by their managers from an idea germinated by British Shipbuilders that it was necessary for the company to compete in the industry. Other benefits assumed appear to be the marketing aspect, including high speed of response to customers, and the technical aspects of increased efficiency of drawing/design production, quality and increased integration with downstream departments.

While the systems were initially designed by external vendors in a separate institutional context, and then tailored by in-house development teams, at the time of the study they were mainly used by supervisors and designers/draughtsmen who had had no involvement with the CAD system development process. In some cases the supervisors and users, even CAD managers, had not yet been employed in the company at the time of the introduction of the CAD system and so had no direct experience of the early stages of the implementation process.

Orlikowski (1992) found, in her case study, that this situation encourages passivity and a results-oriented perspective which discourages reflectiveness. The same appears true of the sample cases, in which positive aspects of CAD can be categorised as mainly "technical" improvements benefitting the organisation, eg. increased speed and quality of output, downstream links etc., and a general acceptance of the system as it stands.

However many of the supervisors and designers/draughtsmen had strong perceptions of a lack of involvement in the implementation process and the later effects of this, ie. many supervisors perceived a lack of sufficient training, unrealistic expectations, fear of the technology, lack of direction with respect to CAD, etc. Similar perceptions were expressed by those supervisors and design/draughtsmen who had joined the companies after the initial introduction of

CAD and appear to originate from the strong influence of their respective peer groups.

Human agents are both knowledgeable and reflexive, and therefore have the potential to affect the controlling influence embedded within the technology. Recognition of the "constructed nature" of the technology appears to be the major factor influencing the degree to which people are able to modify their use of technology. This in turn relies on people recognising the mediating role of technology and their ability to perceive some alternative situation or schema, while also having a sufficient level of motivation to achieve some change.

However people in organisations can become caught in cognitive traps, in which action is constrained by false assumptions, taken-for-granted beliefs, unquestioned operating rules etc. (Morgan (1986) uses the metaphor of Plato's "psychic prison"). The way out of this "prison" is to become aware of it and to question the strengths and weaknesses of the assumptions that shape how organisations view and deal with the world. This is not to ignore the view that cognitive stasis may be the product of a more conscious force (eg. specific individuals or groups may have vested interests in sustaining one pattern of beliefs rather than another, or people may seek stability in their views about the world etc.) or that the organisation exists in a wider context, which has its own logic and momentum. Therefore awareness of the role of the unconsciousness or changing consciousness may not be enough to bring about the desired change in the organisation or society.

In the case of CAD systems, none of the companies examined had yet achieved the state of "seamless" integration, ie. where the distinction between a tool as a means of production and the activities and outcomes they facilitate becomes invisible. As this distinction becomes more obscured, and CAD systems more taken-for-granted, so supervisors' and users' abilities to reflect on them and act without or beyond them will decrease. In some respects this is already what some people are working towards, and can be seen expressed in opinions of CAD as "just another tool" supporting the design process, but not affecting it.

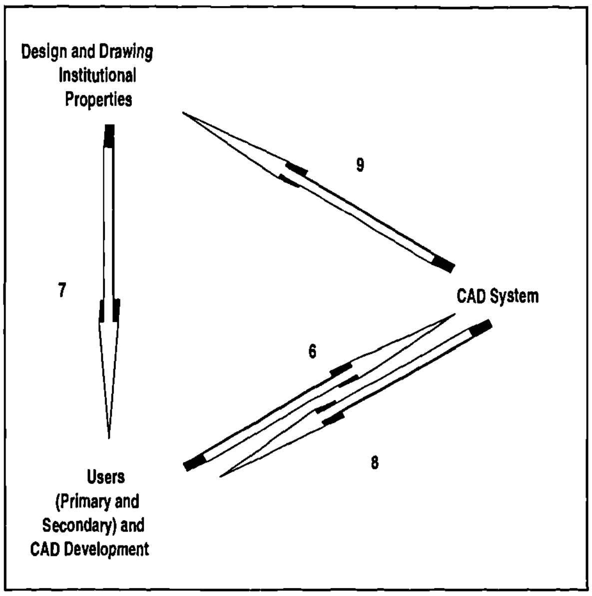
Given the active nature of human agents, through the process of dialectic control, if people can, or continue to, recognise that technology is interpretively flexible, they retain their ability to modify their interpretation and use of it, and so counter the apparent determinism of technology.

Design supervisors are still learning how to work with CAD and how to supervise their subordinates who are working with CAD. Some recognised their own lack of training, whether in general person-management skills, or skills specific to supervising people using the CAD system, eg. "not the functional side of CAD, but administration and particular ways of doing things with CAD...use of words/acronyms related to CAD...[an understanding] of what they are asking the men to do".

Some supervisors thought that it was incompatible to be using the CAD system and acting as a supervisor simultaneously, and the company should ensure that each department either use the CAD system for all work, or not at all. However this is seen as restrictive, in that CAD is perceived to be more appropriate to some tasks than others (although this could be dealt with by re-design or development of the system) and therefore it is not easy to not split departments between those that should or should not use CAD.

In the sample cases, the users (both supervisors and designers/draughtsmen) and the CAD development team appropriate the system to execute their tasks, whether for design, drawing, analysis, software development etc., through their ongoing interaction with the CAD systems (arrow 6, figure 8.3).

Figure 8.3 **Ongoing Interaction with CAD**



This appropriation of the CAD system is influenced by the company's institutional context (arrow 7, figure 8.3) while the interpretive schemes, norms and resources embedded in the CAD system mediate (both facilitate and constrain) the user's and CAD development team's action and perceptions of reality (arrow 8, figure 8.3).

Through using the CAD system to perform design and drawing tasks, the institutional properties of the organisation (ie. expressed as the structures of signification, domination and legitimation) may be maintained (arrow 9, figure 8.3).

Where the users choose to modify their interaction with the CAD system, and so deviate in their appropriation of it (arrow 6, figure 8.3), they may undermine the interpretive schemes, norms and resources embedded in it. If powerful enough, this may lead to a transformation in the institutionalised properties of design/drawing, through modifying some features of their structures of signification, domination and legitimation (arrow 9, figure 8.3). This possibly might lead to a change in management strategy, which might also entail a change in the CAD systems itself, or the way that it is used (arrow 7, figure 8.3). Some supervisors, for example, choose to refuse to use CAD directly or allocate tasks to be done using CAD, thereby constraining management which stops them from pushing a complete changeover to the CAD system, ie. the concept that the system will not truly become accepted and appropriated until it has proved its worth. That cannot be done until people use the CAD system more effectively; this may be characterised as an evolutionary positive feedback loop, extremely susceptible to environmental factors.

This in turn might change the form and/or function of the CAD system (arrow 6, figure 8.3). Once established this would again become institutionalised and again condition the work of the users (arrow 8, figure 8.3) and reproduce the institutional properties originally found in design and drawing offices (arrow 9, figure 8.3). Carrying on the above example, supervisor resistance (whether passive or active) might lead to a change in management strategy, which could have some consequent effects on re-formulation of the organisation of the design and drawing offices, other related departments, appropriate supervisor training or some recognition and awareness of the difficult position of the supervisor (which enables and encourages greater acceptance and use of the CAD system).

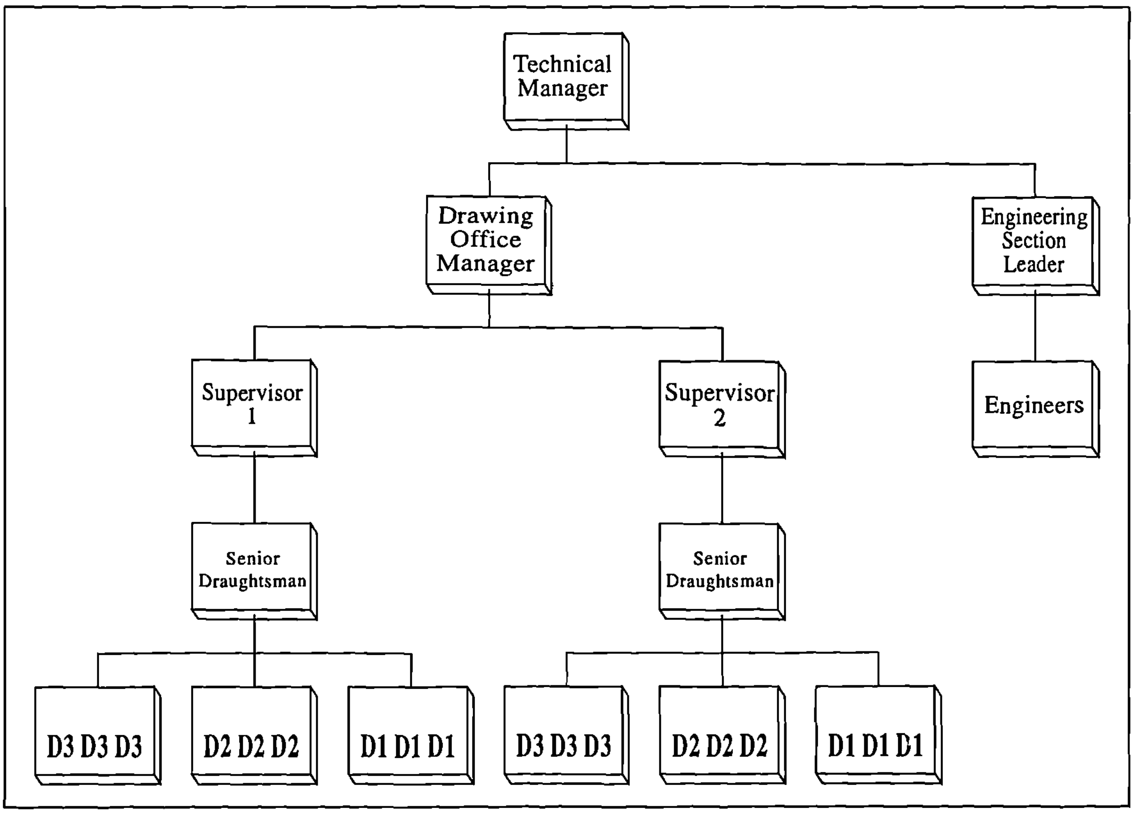
Other more simple scenarios might be just as effective. One supervisor expressed the opinion that his job satisfaction would be enhanced by being given the opportunity to become more actively involved in the development of the CAD system in his company.

Thus the interaction between users, the CAD system and the institutional properties of design and drawing offices can be viewed as an ongoing dialectical cycle, continually being produced and reproduced, over successive periods of time.

8.11 Future Supervision and Work Structures with CAD

As has been shown in the previous sections there are many different and interacting factors which are involved in the running of a CAD system. One which causes problems is the degree of role conflict which arises between some design or draughting supervisors and CAD managers. Therefore this section explores one possible organisational structure which might begin to approach this problem (while still recognising that it is set in a multivariate and complex context; this work was first presented in Brooks and Wells 1989).

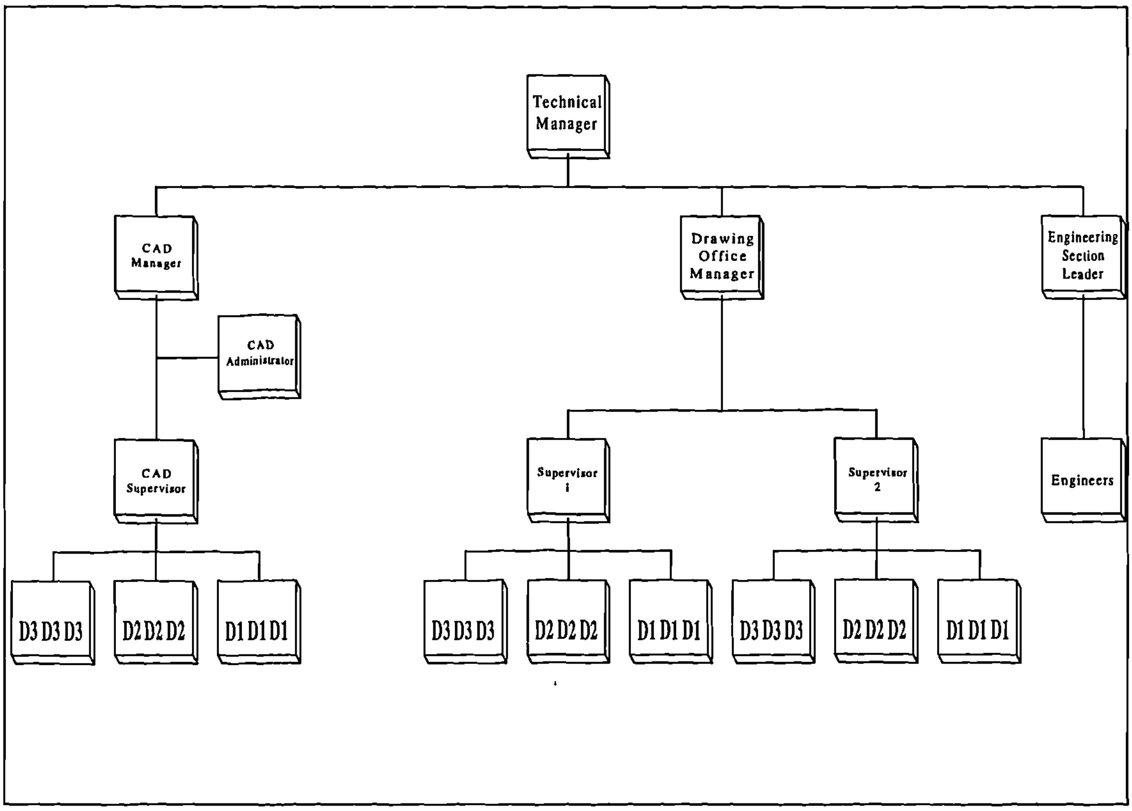
Figure 8.4 **Pre-CAD Design/Drawing Office**



Figures 8.4 and 8.5 show generalised organisational structures in a drawing office seen before and after CAD system implementation. The only change is the sideways addition of the CAD manager and line support team. As shown in section 5.6.3, a large proportion of activities considered to be part of a CAD manager role

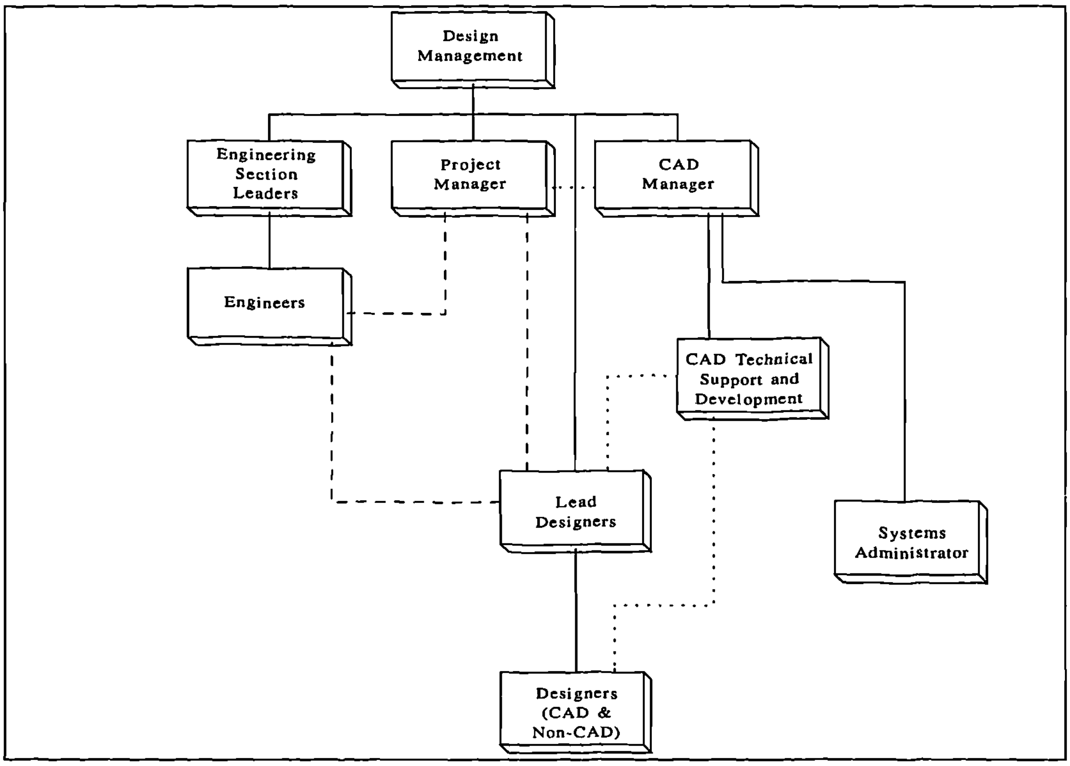
are in fact carried out by a Computer Operations Group remote from the design function.

Figure 8.5 **Post-CAD Design/Drawing Office**



One solution might be a supervision and work structure which appears to overcome many of the problems discussed so far. It represents a model towards which managers *may* want to plan movement. The assumption is that the activities comprising the supervisory system described in section 5.5.1 still need to be carried out, but they may be dispersed to new or existing roles in the design function (possibly minor functions may even be passed to the CAD system itself), so that the traditional first line supervisor role disappears.

Figure 8.6 **A Proposed New Organisation Structure**



Key:- solid lines represent line responsibility; dotted lines represent CAD support links; dashed lines represent responsibilities in the matrix design organisation.

The new model is shown in figure 8.6. This model assumes that the CAD system is fully integrated into the design function, and is being used close to its full potential (probably development to this stage will take some years).

The main roles in this model are discussed below:

Design Management - a single person in a smaller organisation or a hierarchy of senior managers in a larger organisation. He is responsible to the board for providing a design resource to meet the needs of the company.

Project Managers - individuals responsible to design management for the execution of specific projects. They will negotiate for resources from design management, handle all project-specific communications with upstream and downstream departments, and control and report on project costs and timing.

Lead Designer - the biggest change from traditional models. A lead designer is someone who is an experienced designer and experienced CAD user. A significant proportion of his time continues to be spent on his own design work using CAD; therefore he maintains a high level of CAD competence. Part of his time however is spent supervising designers (both CAD and non-CAD) - probably not more than three or four individuals if he is to have sufficient time for his own work. He is thus in a prime position to monitor the performance of the designers, to make technical input from his own experience and to motivate them - in short, to act as their line manager.

His line responsibility upwards is to design management, but he and his group, along with engineers and lead designers in the same or other disciplines are allocated to a project manager, as part of a matrix organisation. The CAD workstations are dispersed, probably as small clusters immediately adjacent to three or four lead designers and their groups.

Designer - this role (whether or not he is a regular CAD user) would remain largely unchanged, except that the anomalies in his relationship with his supervisor and the CAD manager would no longer remain. His day-to-day support and assessment would come from his line manager (the lead designer). If he needed any training, development or user-support beyond that supplied by the lead designer himself, then it would be the lead designer's responsibility to see that this was provided from the CAD support group. Furthermore, since the lead designer has his own design work to do, he has no reason to hold back a more experienced designer below him who is able to take on more responsibilities (for instance, collecting his own input information, negotiating directly with other parties on elements of his project and doing most of his own checking). This contrasts with the traditional first line supervisor who probably would have resisted such erosion of his role.

CAD Manager - the same role as described in chapter 5 but with some of the more strategic activities shared with senior design managers and some of the more routine or detailed activities assigned to a system administrator reporting to him, or to a Computer Operations Group outside the design function. He is responsible to design management for the effective operation of the CAD system and for proposing strategies for its future development.

System Administrator - again a role already described, consisting of the more day-to-day activities of the CAD manager activity list. In a small organisation two people could not be justified as CAD overhead. The CAD manager's role could be dispersed, with the more strategic elements being taken over by design management, or by a specialist engineer part-time, and the training and planning elements being taken by the system administrator. An alternative might be for some or all of the routine system tasks to be passed to a system operator in the data processing department. It is felt that most design managers would want to retain all responsibility for CAD training and user support within the design function.

This structure appears to remove many sources of conflict (potential or actual) that have been identified in the relationship between traditional first line supervisors and the CAD manager/system administrator. This is because the conflict originates with the supervisor not being able to use the CAD system competently and not being encouraged to try. A further attraction is that this structure appears to be more open to allow career development. An experienced and successful lead designer might well be able to progress to project manager or indeed to CAD manager depending on the capabilities and preferences of the individual. This freedom contrasts with the non-user supervisor in a CAD environment whose job has become so eroded that he is unlikely to be able to perform in a way that invites promotion (but is it possible that there is a promotion route open to him, if he is already classed as "supervisor only" material).

It is possible that elements of this structure are already in use and indeed the concepts may already have been superseded in some highly integrated companies. If such a structure already exists before a CAD system is introduced, then it might be much more robust to the introduction of CAD than the formal, traditional non-matrix organisation structure (in addition Winch, 1983, argued that matrix organisation complements CAD/CAM technology, under certain market conditions).

At the same time this model provides many avenues for further development of the individual, either in the CAD management area or in more traditional design areas. The role of lead designer has some similarities with that of 'charge-hand' or team leader in the production environment, as a replacement for the non-working foreman (a role widely discussed as having changed radically since the 1960's).

While this model does deal with the specific issue of role conflict in design supervision, no claim can be made that it is the only, nor the best, solution. Matrix organisations are known to be problematic (see Davis and Lawrence, 1978), especially since they rely on high levels of commitment and clear understanding of the nature of matrices by both the individuals within it and the management monitoring it.

Alternative structures to the one proposed above are also possible. Most supervisors were probably promoted for their technical expertise since their supervisory abilities were unproven. If his supervisory role is reduced, the supervisor could now be encouraged to take a greater role in the daily running of the CAD system. This might then allow the CAD manager to extend his role in developing the CAD system; thus a future role scenario might be:

Design/Draughting Supervisor	- technical expert, - CAD operations management,
CAD Manager	- development of CAD system, - CAD training.

This would also encourage a much closer liaison between the supervisor and CAD manager.

Examining the supervisory structure in the design function with CAD has highlighted the importance of flexibility of individuals (that is, their ability to adapt to new situations). For the organisation to evolve and move forwards, it needs to encourage a company culture which:

- recognises flexibility;
- regards change as a normal and ongoing event;
- also includes a management which acknowledges factors that might limit change.

Within the design function the introduction of CAD does not demand adjustments in the social system but, for optimum use and to realise full potential, it implies a degree of flexibility and adaptation by both the organisation and the individuals within it (see Structuration Theory, section 8.11). There are limitations imposed by the hardware and software at any particular time eg. the physical environment needed for a CAD system, the complexity of commands required to produce images of relatively simple objects etc. However the flexibility referred to implies an ongoing evaluation of CAD, including new opportunities presented by technological innovations.

8.12 The Research Questions Revisited

This section will provide some answers to the research question posed at the beginning of this thesis (section 1.3):

1) What activities define the role of the design function supervisor?

Based on the design supervisor role questionnaire (as detailed and explored in section 5.5) the main activities can be said to include:

- to evaluate the design brief and to define the content/format of the output information required;
- to assess the resources (technical and human) available and to plan the allocation of those resources;
- to gather input information (including knowledge from his own expertise), to monitor the performance of his subordinates and to identify needs for any further inputs;
- to motivate, support and advise his subordinates and to check their final output;
- to identify and implement developments and improvements for his group and in the relationship between his group and upstream and downstream groups.

2) Are training needs for design function supervisors, where CAD is present, recognised? How is CAD training for design function supervisors carried out at present? Are there specific programmes; if so, what are the details?

    - The training needs for design supervisors have been greatly underestimated. In particular the specific functions of the CAD systems which might be most useful to the supervisor have not been identified. Therefore, out of the CAD training provided for design supervisors, none is able to focus on the aspects of the system which are important to them.

- Part of the problem derives from the method of general supervisory training which traditionally has been "on the job" training, ie. learning from previous or other supervisors. However with the advent of the CAD system this style of training is no longer possible (because previous supervisory skills are no longer a sufficient guide for the next generation of supervisors). Little structured formal training for supervisors exists and so cannot easily be adapted for use in training them to use the CAD system. Equally few supervisors have had experience of "formal" training and tend to resist any attempts to introduce it.

- It is also likely that the lack of CAD training is indicative of management's attitude towards both CAD systems and supervisors. While specific CAD training programmes could be suggested, these would not be able to tackle the underlying problem posed by the design supervisory role itself.

- One theme running throughout this thesis is that there are choices available when introducing and running a new technology, such as the choices available in the development of the supervisory system within design. Choices include: whether to devolve supervisory activities into some form of semi-autonomous work group (although little evidence indicating this type of development was seen in the empirical data, this is the central idea underlying the new design organisation proposed in section 8.13); or to develop a specialist supervisory role (such as Dawson and McLoughlin's (1988) "information manager" role); or another style of enhancement to the existing set of roles (possibly the most likely short-term option because it involves the least degree of organisational change).

3) What benefits might be usefully gained from a company adopting a "structured" as opposed to an "unstructured" approach to training? What other forms of training are available and how might they be more effective?

- One possible template for a CAD training course for supervisors was posited by the CAD manager in ToolCo, who recommended the inclusion of both an appreciation of the capabilities of the system and an idea of the potential resources available. It would also need to provide a mechanism to enable a supervisor to decide the amount of work to be allocated to the CAD system, an aspect which was discovered to be difficult to gain experience in.

4) What changes are perceived by the design supervisor with the introduction of a CAD system?

- The design supervisor may perceive himself as being edged out of key areas of his role by the CAD manager; this leads to role conflict. The CAD manager may perceive the non-CAD supervisor as a block to the effective implementation and running of the CAD system, whilst the supervisor may perceive the CAD manager as bringing in new technology that undermines his role.

- The design supervisor may feel alienated from his own subordinates who appear to find it easier to adapt to CAD. As their experience and skills increase, a 'skills differential' opens up leading to a weakening in the relationship between them. This is further aggravated when the subordinate turns to the CAD manager for help with technical as well as user-support problems.

5) What are the major stress factors experienced by design supervisors?

- Supervisors might experience stress as a result of factors both directly and indirectly associated with CAD.

- A CAD system is generally assumed to require a special physical environment which can most easily be provided by locating it in a central area. Although there are economic and managerial control advantages to this arrangement, the physical separation of the user from his design supervisor tends to lead to an equivalent psychological separation. This often results in the design supervisor abdicating some of his responsibilities to the CAD manager and his support team.

- This erosion is further reinforced where the first line supervisor is a non-user of CAD. Without this knowledge, his relationship with his designers and draughtsmen can be seriously impaired. Because there is no clear view of his role, there is no basis for designing training programmes for him.

6) As a secondary user of CAD, might design function supervisors experience any change in attitude towards the system as a result of this research (or from any other factors)?

- It is possible that shortly after the interviews, the particular supervisors spoken with did become more reflective about their position, and attitudes towards the CAD system, but it is unlikely that this would have had any significant effect. However that the results published so far have already been cited does indicate that this research is recognised within the academic arena, and therefore the possibility of transfer to industry still exists (although the rate of transfer from academia to industry continues to be notoriously slow).

7) What perceptions of the human-computer interface are held by design supervisors?

- Direct experiences such as frustration with not being able to see a complete A0 drawing or worries about the possible harm from the display units.

- Indirect experiences through their staff, such as frustration from the slow response rates or anxieties about the work-pace being set by the CAD system.

8) What activities define the role of the CAD manager?

Based on the CAD manager role questionnaire (as detailed and explored in section 5.5) the main activities can be said to include:

- developing strategies for CAD system support and CAD training;
- reports on the progress of the CAD system and assess vendor updates;
- deciding job allocation for the CAD system;
- monitoring and investigation of relevant new developments for CAD;
- planning and leading training for designers and draughtsmen to enable them to make appropriate use of the capabilities of the CAD system;
- monitoring and assessing the daily running of the system, and identifying and satisfying any development needs;

- investigating and solving system problems and implementing system updates;
- providing general *technical* support for and allocating terminal time to users;
- developing, implementing and maintaining company standard conventions and user libraries;
- controlling periodic housekeeping of the system and arranging system maintenance.

9) What interactions take place between design function supervisors and CAD managers?

    - As shown in chapter 5, the design supervisor is primarily concerned with delivering the design output information needed to meet the design brief whereas the CAD manager is primarily concerned with the effective and efficient use of the CAD system. In the case study analysis (chapter 7) design supervisors still show different perceptions of the CAD system. These range from differences in the perceived reasons behind the introduction of the CAD system to concepts of benefits from and problems with the CAD system. Where the CAD managers adopt an organisationally oriented viewpoint, the supervisors are more concerned with controlling their part of the design process and managing the individuals below them.

10) What effects does the implementation of a CAD system have on designers, draughtsmen and design supervisors' perceptions of design and top management?

    - One effect is to raise the profile of top management in making decisions which are seen to affect non-managerial staff. While the literature debates the merits of the thesis of computer new technology as a control mechanism, individuals using this technology are aware of the higher visibility using CAD confers on them.

11) What changes (both formal and informal) might be seen after the implementation of a CAD system?

- Whether or not to use CAD becomes a key factor in decisions about work allocation, and responsibility for these decisions often has to pass from the first line supervisor to the CAD manager.

- Individual designers/draughtsmen take on more responsibility when using the CAD system, particularly in the cases where the geometry from their drawings is passed directly to production.

12) What can be learned from the change process?

- Very few organisational changes are planned or recognised by management as accompanying the introduction of CAD. Often the only change is the creation of the CAD manager/systems administrator roles to provide technical support, systems development and training. However CAD *can* be a catalyst for larger organisational changes, providing visible justification for these changes and developments.

- Problems with the role of the first line supervisor revolve around him *not* being a regular, competent, up-to-date user of CAD. Therefore an organisation structure which appeared to overcome many of the problems identified above was presented. Much of the 'traditional' role of the supervisor is passed to a *lead designer*, whose activities are split between working on his own design tasks as an experienced CAD user, and supervising the work of a small group of subordinates. The interrelationships between a lead designer and the CAD manager and his team are much more compatible than those identified with the traditional CAD non-user supervisor. The premise is that management will be able to use this model (with appropriate adjustments for individual organisations) as a basis for studying their long term organisational development programme.

8.13 Opportunities for Future Research

There are many ways in which the work discussed in this thesis might be used to seed future research.

8.13.1 Direct Extensions of the Present Research

The present research does provide some valuable insights into the use of CAD and the supervisory system within the companies studied. However, due to various factors, the overall sample size is such that only tentative qualitative results could be explored. Therefore there are a number of ways in which this research could be directly extended.

First to conduct further interviews such that the present findings can be confirmed and/or expanded. Given the present sample size, this could be done by,

- gathering information from a much larger sample of supervisors, designers/draughtsmen and CAD managers, including individuals from as many different design and drawing offices as feasible;

- or extending the set of interviews in all directions, up and down and along the organisational hierarchy, eg. design/drawing office managers, analyst/planner/concept developer, production engineers, manufacturing engineers etc.

Second to extend the set of interview survey sample companies to encompass both other mechanical engineering industries, eg. aircraft, motor vehicles, white goods etc., and to other industrial categories such as electronics, architecture etc. Thereby using the in-depth analysis of the ship industry as the starting point of a much wider look at the use of CAD and the longer-term introduction of computer technology within industrial organisations.

Thirdly to extend the range of computer system types examined both within design, eg. pcb, gis etc., and outside, eg. MIS, EIS, large scale database systems etc. Thereby allowing comparison between the specific technology within CAD and other comparable new technologies.

8.13.2 Refinement of the Role Activities Questionnaire

A set of role activities has been developed for design supervisors and for CAD managers. However, while useful in the context of this research, it could be improved by circulating the role questionnaire to a much wider audience so that a more accurate picture of the activities involved in the supervisory system and CAD management could be obtained.

Another development might see the role questionnaires taken outside the present industry such that commonalities in the roles and over different working situations could be identified, perhaps leading to more generic definitions.

8.13.3 CAD Maturity Measure

Throughout this study the focus has been on the "up and running" CAD system that has been in place for more than five years. However (apart from one basic definition, see section 2.4.9) no real measure of the maturity of any new technology system has yet been developed. Therefore to examine CAD and other new technology systems, within their work contexts, with a view to developing some set of performance indicators which include a measure of maturity might also be another development arising out of this research.

8.13.4 Action Research on CAD

The material gathered in this study involved looking at CAD systems which were currently running and had been so for about five years. Therefore the perceptions of the implementation process elicited had to be post-hoc remembered impressions.

While useful, a more action oriented study might collaborate closely with a company from the early stages of CAD implementation. In this way the researchers could both observe the process and talk with people as perceptions change. In addition there might be opportunities to use and confirm the knowledge expressed in this thesis and to provide advice on the most appropriate steps to be taken.

8.13.5 Further Theoretical Frameworks

Structuration Theory (see section 3.4) is still in its infancy as a research tool (and is itself the subject of continued debate) and therefore might provide an avenue of profitable further research. One such study might explicitly explore the supervisor/CAD/institution triad in order to contribute to the design of the next generation of CAD systems, such that they might capitalise on and support the abilities of design supervisors.

8.14 Key Issues

The key issues that have arisen as a result of this research can be looked at from both an industrial and an academic perspective.

Academic	Industrial
The management strategy adopted with the introduction of a new technology is a *choice*, from a range of options lying on a continuum from minimal to wholesale change.	Management can and should plan for change within the organisation - whether to adopt a cautious and exploratory approach bringing small benefits in the short term or a more major investment to accrue potentially higher benefits in the longer term, each can be successful with the correct and appropriate planning.
Different perceptions of the same subject by different members of an organisation, namely the reasons behind the introduction of the CAD system.	Some management individuals hold the expectation that any problems connected with a CAD system will disappear in the future when the system reaches a stable state, but this ignores the process of continual change which exists - therefore people need to include an awareness of this change in their strategic plans thereby actively managing the process.

Academic	**Industrial**
Problems/needs of supervisors subsumed into the CAD system; really is a "red herring" **but** also means problems don't just disappear no matter how much the CAD system is tailored/changed.	Change needs to be related to the needs of the individual within the organisation - where the supervisor is concerned this should initially be directed towards resolving the equivocality still inherent in the role, before any of the complex new technologies can be fully exploited.
Shift in thinking required for the move from traditional drawing boards to CAD, eg. construction of designs more complex whereas editing and reproduction easier, or piecemeal versus integrated working environments.	Any system, such as a CAD system, should be chosen and introduced as appropriate to that organisation, rather than from an outside directive - therefore a CAD system appropriate to the needs of the shipbuilding industry should be chosen and this information should be made available to the rest of the organisation.
Different social environments seen as a result of the different physical environments, in the move to CAD.	Because of the way in which CAD is often seen as having purely technical implications so the CAD manager is perceived as someone not to be trusted and outside the existing picture of the organisation - if seen early on this is easy to avoid, however it is more difficult to rectify later in the process taking much greater time and effort to counter these initial impressions.

Academic	**Industrial**
Potential impacts of CAD very complex and can be, or perceived to be, a symbol of other changes, eg. changes in craft demarcations such those seen between design and production, CAD as a first step towards integrated automation.	Lack of appropriate training for design supervisors - this can easily be remedied by carefully designed training programmes which satisfy the early and ongoing needs of the supervisor as well as satisfying the needs of those around him.
The role of the supervisor is difficult to specify and often assumed without any proper knowledge of what that implies; further the supervisor can be pivotal to the continued success of an organisation providing the liaison point between the various levels of management and the rest of the workforce;	The physical layout of the CAD workstations is an important factor in its adoption and use, and a degree of choice exists between centralised and dispersed system structures - however while the centralised layout might be useful for initial use, the more mature CAD system might best be served by a small centralised system for continued enhanced learning, with a dispersed system for the everyday workings of the design function.

APPENDIX I

Costs and Benefits of CAD, (Primrose, Creamer & Leonard 1985)

COSTS

Initial costs

Hardware;
Software;
Installation (including building alterations);
Consultancy costs (may include customising software);
Inhouse project team (may include customising software);
Database development;
Operator training;
Lost time during transition (may include subcontracted work).

Running costs

Maintenance contract;
Insurance;
Running costs (ie. electricity);
Consumables;
Software updates;
Training updates (ie. for new staff);
System management;
Labour shift premium (if two-shift operation is introduced).

BENEFITS OF CAD

Drawing office savings

Reduce the number of existing draughtsmen;
Avoid recruiting additional draughtsmen;
Reduce clerical labour in the drawing office;
Reduce or avoid sub-contract design work;
Take on sub-contract work;
Eliminate model making by use of 3D design;
Reduce outside graphic design work (for marketing service departments, publicity etc.).

Increase sales from reduced delivery times

Reduce design/documentation time for customers' orders;
Improved drawing quality reduces production delays (eg. easier assembly);
Eliminate incorrect ordering of components, thus reducing production delays.

Increase sales from other causes

Company can quote more reliable delivery dates;
Faster and better presented quotations;
Company image improved by having CAD;
Orders would be lost if company did not have CAD design facility;
New products can be introduced more quickly.

Reduced stock levels

Improved drawing reduces lead times, hence reduce work in progress;
Component standardisation allows a reduction in finished stocks;
CAD may avoid ordering unwanted components;

Reduced production costs

Improved drawings/documentation reduce production costs (eg. easier assembly); reduced scrap and rework;
Production efficiency improved by eliminating "stock outs";
Component standardisation enables larger batches to be produced;
Design optimization reduces production and material costs.

Cost control

Unprofitable orders eliminated by improved estimating;
Inhouse cost control improved by better estimating and quotations.

CADCAM link

The purchase of separate systems for N programming avoided by CAD;
Linking NC programming to CAD reduces programming costs;
CAD aids company-wide information system;
CAD avoids the need for other expenditure, eg. expanding the drawing office building.

APPENDIX II

Tables A1 to A4 (source Majchrzak et al. 1987)

Table A1 **Summary of Research on the Impact of CAD on Job Changes**

Author	Sample	Finding	Job Dimension
Norton (1981)	Operators and managers	Less rountinity for designers; more routinity for operators	Routinity
Newton (1984)	Operators	No change in autonomy	Routinity
Wingert et al. (1981)	Managers	Less routinity	Routinity
Majchrzak et al. (1985)	Engineers and draughters	No change in predictability of job	Routinity
Majchrzak et al. (1985)	Engineers and draughters	No change in degree of reciprocal interdependence	Workflow
AIDD (1983)	Operators	More need for communication skills	Communication
Majchrzak et al. (1985)	Engineers and draughters	More use of coordination models	Communication

Table A2 **Summary of Research on the Impact of CAD on the Formalisation of Procedures**

Author	Sample	Finding
Majchrzak et al (1985)	Engineers and draughters	More formalization in job duties
AIDD (1983)	Operators	More formal procedures for releases, signatures on drawings and log books

Table A3 **Summary of Research on the Impact of CAD on Organisational Structure**

Author	Sample	Finding
Schaffitzel and Kersten (1985)	German companies	More use of structural interfaces between design and manufacturing
Majchrzak et al. (1985)	Engineers and draughters' perceptions	No relationship between CAD use and perceived decentralization

Table A4 **Summary of Research on the Impact of CAD on Worker's Job Reactions**

Author	Sample	Finding	Reaction
Barfield et al. (1986)	Review of human factors research	Increased stress	Stress
Newton (1984)	CAD and non-CAD draughters	No change in somatic complaints	Stress
Majchrzak et al. (1985)	CAD users	Less autonomy, more identity; mediator role of workplace	Job perceptions
Norton (1981)	CAD operators	Mediator role of management	Job perceptions
Johansson (1986)	CAD designers	More meaningful work	Job perceptions
Newton (1984)	CAD and non-CAD draughters	No change in autonomy	Job perceptions
Johansson (1986)	CAD designers	Mediator role of workplace	Job satisfaction
Newton (1984)	CAD and non-CAD draughters	No change	Job satisfaction
Majchrzak et al. (1985)	CAD users and non-users	No change	Job satisfaction

APPENDIX III

INTRODUCTORY LETTER FOR A COMPANY

Laurence Brooks

New Tel. (051) 794-4776

LB/cs1

Dear

I am very much looking forward to visiting you on ... at about 12.00am. As I said on the telephone, my research topic is the impact of CAD on the organisation and management of the design function and in particular on the role of the first line supervisor.

I have prepared a few notes to give you some idea of the areas I would like to discuss. In particular there are some specific items of information such as organisation charts and outline CAD system specifications which it would be helpful to have available for the meeting. Obviously I do not expect we will have time to cover all the areas mentioned in the notes, and possibly some may be irrelevant to the context of your organisation.

Thank you very much for your cooperation.

Yours

(Laurence Brooks)

enc.

INTRODUCTORY NOTES FOR A COMPANY

Main Purposes:-

1. To examine the impact of CAD on the company as a whole e.g. design and manufacturing performance and changes in time scales, organisational changes, new roles developed, etc.

2. To look briefly at how CAD was introduced, and the parts played during the introduction by the various levels and functions in the design organisation.

3. To examine the effects CAD has had in the design function, on the organisation within it, on design working relationships and the relationships to the other parts of the company. To gauge the level of CAD penetration and future expectations about its use.

Background:-

i) Outline of the organisation structure, of the company and of design within it (particularly design group sizes, distribution of tasks and responsibilities, grading system etc.).

ii) Outline of the current CAD system specification.

iii) CAD support staff e.g. administration, training, development etc., and how they interact with the design staff and management?

iv) The physical layout of the design function and its implications for supervision and interaction.

v) An outline of the work carried out by the design organisation: source of inputs and recipients of outputs, extent of CAD use in this work.

Introduction Of CAD

What were the original motivations behind the introduction of CAD? Who carried out the original feasibility work (internal or external to the organisation)? Were there any particular pressures which led to CAD being introduced?

What factors caused the particular CAD system to be chosen? How was the system introduced - physical preparation (e.g. lighting), appreciation and skill training (to all or selected groups, a single short course or stage-by-stage)? What organisational changes were planned?

What practical problems were encountered? What reactions were shown by the staff?

With hindsight what would you have done differently?

Current Working Methods

How is the design work split between "manual" and CAD - by the type of project, or some other factor? What factors are used to estimate job design times, both in the manual and with CAD?
How has the organisation changed with the introduction of CAD - size, structure, grades, formal/informal tasks, pay scales etc.?

What changes has the job of the designer undergone with CAD - in terms of skills acquired/lost, interaction with others inside/outside the department, methods of working etc.

Further to that how has CAD affected the others in the design office, the middle management and the 1st. line supervisor? How is work now monitored , who checks progress and in what way?

What new skills has the supervisor needed to acquire? Does s/he use the CAD system - if so what training/skills were needed? Do these need updating?

In what ways do the supervisor, designer and CAD support staff interact - how do they see each others' roles, what projections for future integration of these jobs have been made?

Current/Future Views Of CAD

Has CAD lived up to the expectations you had for it? What extra benefits does CAD have that you didn't anticipate before introduction.

What type of changes do you see for the future for your use of CAD?

What would be your ideal organisation structure and work relations and what constraints prevent you adopting these?

INITIAL VISIT INTERVIEW SKELETON

[1] Organisation

[1.] How was the organisation structured before?
[1.0] How is the organisation structured now?
[1.1] What changes are planned to the present structure?
[1.2] How does the CAD systems manager fit in?
[1.3] Perceptions of CAD around the company (eg. automated vs. manual)
[1.4] How will pay/reward systems change; also promotion policies etc.?
[1.5] Is the management structure and style appropriate?
[1.6] What changes are being seen between functions, depts. and levels?
[1.7] The question of functional vs. multi-disciplinary groups?
[1.8] What can be learnt from present changes?

[2] Technology

[2.0] Total change to CAD or just a project trial?
[2.1] Software developments particular to that company i.e. tailoring, in-house software, parametric etc.?
[2.2] Technical support of designers?

[3] Product

[3.0] At what stage is CAD brought into use?
[3.1] What are the implications of this?
[3.2] Has CAD affected product design?
[3.3] What savings come from using CAD?
[3.4] Link to CAM later?

[4] Supervisor Role

[4.0] What is their reaction to CAD?
[4.1] What training/development is given?
[4.2] How much involvement did they have in the implementation of new tech?
[4.3] Do they get adequate feedback directly and through others?
[4.4] The managers reaction to CAD?
[4.5] Are the job goals and peoples' expectations clear?
[4.6] Do the above provide a degree of challenge?
[4.7] How is the supervisor involved in identifying and dealing with problems and difficulties?

COMPANY FOLLOW-UP INTERVIEW SKELETON

[1] Job History and Role

[1.0] Age?

[1.1] Basic education?

[1.2] Technical training?

[1.3] Industrial experience?

[1.4] Length of service as a supervisor?

[1.5] Describe a typical day/week

[1.6] What training/development is given?

[1.7] How much involvement did they have in the implementation of new tech?

[1.8] Do they get adequate feedback directly and through others?

[1.9] Are the job goals and peoples' expectations clear?

[1.10] Do the above provide a degree of challenge?

[1.11] How is the supervisor involved in identifying and dealing with problems and difficulties?

[1.12] What is their overall reaction to CAD?

[2] Technology

[2.0] What hardware and software do they have at present?

[2.1] Total change to CAD or just a project trial?

[2.2] Software developments particular to that company i.e. tailoring, in-house software, parametric etc.?

[2.3] Technical support of designers?

[2.4] Management attitudes to CAD?

[2.5] The technical future? eg. what would it be good to introduce in terms of the technology?

[3] Product

[3.0] What was the motivation to bring in CAD?

[3.1] What savings come from using CAD? - projected and whether those figures are valid?

[3.2] At what stage is CAD brought into use?

[3.3] What are the implications of this?

[3.4] Has CAD affected product design?

[3.5] Link to CAM later?

[4] Organisation

[4.0] How is the organisation structured now? - including the size of the design office in general, what %'age of this is on CAD etc.

[4.1] Is the management structure and style appropriate?

[4.2] What changes are being seen between functions, depts. and levels?

[4.3] The question of functional vs. multi-disciplinary groups?

[4.4] Worker involvement in the implementation of CAD?

[4.5] Parent company influences?

[4.6] Changes for people with CAD?

[4.7] Perceptions of CAD around the company (eg. automated vs. manual)

[4.8] Training for operators of CAD?

[4.9] How will pay/reward systems change; also promotion policies etc.?

[4.10] What can be learnt from present changes?

[4.11] What changes are planned to the present structure?

ANALYSIS OF THE DESIGN SUPERVISOR ROLE

Present job title ....
Present job grade .... Age.........

In order to further this research project, I need to have a clearer picture about the jobs actually done by key personnel in the design office. Therefore a picture of the main tasks thought to be the responsibilities of a design supervisor (section leader) has been put together. However, up to this point, this is only supposition. Therefore please go through the analysis and circle the appropriate number relating to your job in your company.

If your answer is **A** please use the comments column to indicate how frequently (eg. daily, weekly, monthly) and whether the job makes up a major or minor part of your job.

If your answer is **B** please use the comments column to give the job title of the person who does do the job.

The Role of the Design Supervisor

	A I do this job	B Someone else does this job	C This job is not done in this company	Comments
1. To take the DESIGN BRIEF information given to him and use his expertise to define the content and format of the OUTPUT information required from his design group, and the internal and external standards it must meet.	A	B	C	
2. To assess the capabilities of the RESOURCES (technical and human) already allocated to him to achieve that output in the required timescale and to seek further resources if necessary.	A	B	C	
3. To plan the ALLOCATION of those resources to meet the work demands.	A	B	C	
4. To gather the necessary INPUT information for the members of his group to begin work, adding relevant knowledge from his own expertise (some of this gathering may be carried out by the subordinates themselves).	A	B	C	
5. To MONITOR the performance of his subordinates for content and quality,obtaining specialist advice if necessary to allow this to be carried out. Reporting progress, periodically, to project and design management.	A	B	C	
6. To identify needs for further inputs from inside or outside the design organisation necessary to achieve the design objectives. This is probably the most important technical part of the supervisor's role in creative design, where he feeds in his own experience and knowledge as the design develops.	A	B	C	

	A I do this job	B Someone else does this job	C This job is not done in this company	Comments
7. To MOTIVATE his subordinates by showing interest and encouragement, giving support and advice, ensuring that the objectives are clear and, if needed, dealing with disciplinary problems.	A	B	C	
8. To CHECK the final output of the subordinates before the information is passed to downstream departments.	A	B	C	
9. To plan and implement DEVELOPMENTS and improvements to the general performance of his group by identifying training needs (on and off the job), considering opportunities for increased responsibilities (eg. wider or more difficult technical areas, self-checking, partial supervision of more junior designers) and developing more efficient and effective procedures and work methods.	A	B	C	
10. To examine developments and improvements in the relationship between his group and upstream and downstream groups eg. better attitudes, better communications.	A	B	C	

ANALYSIS OF THE CAD MANAGER ROLE

Present job title ....
Present job grade ....   Age.........

In order to further this research project, I need to have a clearer picture about the jobs actually done by key personnel in the design office. Therefore a picture of the main tasks thought to be the responsibilities of a CAD manager has been put together. However, up to this point, this is only supposition. Therefore please go through the analysis and circle the appropriate number relating to your job in your company.

If your answer is **A** please use the comments column to indicate how frequently (eg. daily, weekly, monthly) and whether the job makes up a major or minor part of your job.

If your answer is **B** please use the comments column to give the job title of the person who does do the job.

The Role of the CAD Manager

	A I do this job	B Someone else does this job	C This job is not done in this company	Comments
1. Developing a strategy for the implementation and expansion of CAD in the design function encompassing hardware, software and user capabilities.	A	B	C	
2. Strategic planning for the spread of CAD training - decisions concerning which departments and which members of those departments are to receive CAD training.	A	B	C	
3. Periodic reporting to management about the progress of the CAD system and development of the volume of work for which CAD is used.	A	B	C	
4. Assessing vendor updates eg. new software issues, and preparing capital expenditure justifications and budgets.	A	B	C	
5. Deciding which jobs are most suitable for use on the CAD system - this could be decided on a job-by-job basis or by applying a set of guidelines developed from experience of initial pilot projects on CAD.	A	B	C	
6. Monitoring and investigating relevant new developments in the CAD marketplace as a source of information for planning the general direction for development of the system hardware and software.	A	B	C	

	A I do this job	B Someone else does this job	C This job is not done in this company	Comments
7. Planning the content and timing of the various stages in training in order to develop designers and make appropriate use of the capabilities of the CAD system.	A	B	C	
8. Carrying out the training programmes and initial user development.	A	B	C	
9. Monitoring and assessing the day-to-day running of the system, and identifying development needs eg. increasing memory size as system utilisation increases, meeting new and emerging design needs.	A	B	C	
10. Developing macros and subroutines for parametric design, repetitive design elements and analysis etc.	A	B	C	
11. Investigating any system problems and liaising with the vendor about these "bugs". Providing the necessary feedback to users.	A	B	C	
12. Implementing system updates.	A	B	C	
13. Providing general technical help to users.	A	B	C	
14. Allocating terminal time to users (and between sections)and reserving time for training eg. controlling a booking system. One case study company visited had a poster-sized sheet of paper on the CAD administrator's office wall which contained a month's calendar for each terminal in the section and this was used as the reservation/booking sheet for the whole organisation.	A	B	C	
15. Developing, implementing and maintaining company standard conventions eg. document naming and numbering conventions, drawing layout conventions. In addition, developing and implementing user libraries, user defined commands, user-defined tablets etc.	A	B	C	
16. Performing the daily, weekly and monthly housekeeping, archiving, dumping, reporting of utilisation etc. of the system.	A	B	C	
17. Arranging for and monitoring the system maintenance.	A	B	C	

APPENDIX IV

LIVERPOOL UNIVERSITY

Designer/Engineer Interview

Thank you for agreeing to take part in this interview.

My name is Laurence Brooks, I am a researcher in the Industrial Studies department of Liverpool University. This interview is part of a 3 year project looking at designers/engineers and computer-aided design.

As you know CAD is a powerful new technology which is no longer all that "new". This interview aims to find out how you and your company have adapted to CAD. Whether it has had the dire consequences some people predicted it would have or if it is indeed the useful tool that others said it would be.

The interview structure begins by looking at your background, training and general job characteristics. This is followed by a look at your training to use CAD, usage of CAD and general attitudes towards it. It finishes with a general section looking at the attitude of the Unions towards CAD (if any) and your general view of the future of this company and how CAD might be best exploited within that.

Some of the questions ask for your own personal views and I would first like to assure you that all the questions are asked in confidence. As well the interview structure is going to be used in a wide variety of companies. Therefore some of the questions might refer to practices or use terminology not exactly correct for your company. If this happens please try and answer the question far as possible. In addition please do not hesitate to ask if you do not understand a question.

cLiD

Interview Structure Skeleton

I.Designer/Draughtsman/Engineer's Skeleton

First I want to ask you a few questions about your job history and your job in general.

A. Job History and Career

A1 Male 1 Female 2

A2 What is your formal job title?

A3 What was your age last birthday? ____

A4 In chronological order please tell me which educational and technical qualifications you have attained since you left secondary school?

School Certificate/Matriculation	1
CSE's	2
GCE's/"O" levels	3
GCSE	4
"A" levels	5
Degree	6
ONC	7
HNC	8
HND	9
Apprenticeships,	
1. Trade - 4/5 yrs + City & Guilds	10
2. Student - 4/5 yrs + HNC/HND	11
3. Graduate - 2 yrs already with degree	12

A5 Before joining this company, briefly, what industrial experience have you had?

Company	Position	Activities	Years

A6 Do you perceive opportunities for further promotion in this company?

Yes 1 No 2

If YES

(a) Will you apply?

(b) Where will promotion take you?

If NO, what do you feel about this?

B. Training

This section is titled training and looks at the general training you have received.

B1 Have you ever had any general (non-CAD) training with this company?

Yes	1	No	2

If YES,

(a) How long was the training?

One day	1
One Week	2
Spread out over a period of time	3

(b) What type of training was it?

Formal, classroom based	1
Specific on-the-job, peer learning	2
Self-instructive	3
Systematic development by your superior	4
Other	5

(c) Approximately when was the training?

Before you took up this position	1
At the same time as taking up this position	2
Under a year after you took up this position	3
1 to 2 years after you took up this position	4
2 to 4 years after you took up this position	5
Over 4 years after you took up this position	6

(d) Can you remember any aspects of the course which you found particularly useful?

(e) In your opinion how useful has this training been?

Essential	1
Very useful	2
Useful	3
Not useful	4
No use at all	5

(f) What areas would you like further training in, if any?

If NO, Do you think any form of general training should be introduced for new designers, and if so on what subjects?

C. Job Role

This section is titled job role and aims to find out a bit about your job characteristics.

C1 How many other designers work in your section? ____

C2 How many other designers work with you on a project? ____

C3 How many other designers work with you under your supervisor?

(a) at present ____

(b) in general ____

C4 What other work do you do apart from actual design? eg. special administration tasks.

C5 How much of your time does this other work take up?

C6 Are there any structured elements in your timetable for the week?

Yes 1 No 2

If YES, what are they?

Regular meetings with your supervisor	1
Regular meetings with other designers	2
Meetings with others (who?)	3

C7 Who deals with the allocation of work within your section?

Your immediate superior	1
Other, who?	2

C8 Could you briefly describe **how** you work out your timetable/work schedule for the week?

You decide for yourself	1
You decide together with others	2
You are told	3

If YOU DECIDE YOURSELF or WITH OTHERS, what criteria do you use and how?

In the same way every week	1
In a generally structured way	2
Depending on the circumstances for that week	3
Other	4

If YOU ARE TOLD,

(a) How is it done?

Orally	1
Written	2
Other	3

(b) By whom?

C9 Do you have one project or many projects at a time?

One project only	1
Many projects at one time	2

If MANY AT ONE TIME,

(a) Are they running

Sequentially	1
Simultaneously	2

(b) With multiple projects, how do you establish priorities?

C10 What do you receive when starting a new job, and from whom?

A full design specification on paper	1
A rough outline on paper	2
Verbal and written information	3
Other	4

C11 Is any discussion involved in starting a new job?

Yes 1 No 2

If YES,

(a) With whom?

(b) What type of topics are discussed?

C12 What information do you feed back to your supervisor? *eg. project progress*

C13 How frequently is this information exchanged?

C14 How could communication with your supervisor be improved?

C15 What type(s) of information do you exchange with other designers in........

(a) your section?

(b) the design office?

C16 In general what are the most important pieces of information you receive?

C17 In general what are the most important pieces of information you pass on?

C18 What do you feel is the most important activity you do in contributing to the performance of your group?

C19 Looking at your job overall what activities would you say are the "core" activities of your job?

C20 How do you think your supervisor measures your daily performance?

C21 How does he make it known to you?

From his reactions to you	1
He tells you directly	2
Some sort of written informal appraisal	3
A written formal appraisal	4

C22 How does your supervisor monitor your overall, rather than detailed, progress?

Formal appraisal system	1
Informal chat about progress	2
Self-appraisal system	3
Other	4

C23 How regular is this monitoring?

Monthly	1
Every (x) months	2
Biannually	3
Annually	4
Other	5

C24 In your opinion what does your supervisor think are the main activities which occupy your time?

C25 In your opinion what is your supervisor most concerned about in your performance?

C26 What hours do designers work?

C27 Has this been changed at all by the introduction of CAD?

Yes 1 No 2

If YES, in what ways?

D. Job Satisfaction

D1 Looking at your job overall what do you find satisfying?
(if NO, are they actively unsatisfying?)

Your basic pay	yes/no	unsatis
Job security	yes/no	unsatis
Opportunity to exercise .... autonomy/management control	yes/no	unsatis
The variety of job tasks	yes/no	unsatis
Feeling of personal development	yes/no	unsatis
Opportunity to progress along .... some career path	yes/no	unsatis
Dealing with variations and .... unexpected situations	yes/no	unsatis
Opportunities to make .... your own decisions	yes/no	unsatis
Working with other designers, ... design office staff, supervisors etc.	yes/no	unsatis
The amount of responsibility .... you are allowed to take on	yes/no	unsatis
Work interest (technical)	yes/no	unsatis

D2 What other aspects of your job do you find satisfying?

D3 What other aspects of your job do you find dissatisfying?

D4 What could your supervisor do to make your job <u>more satisfying</u>?

D5 What could your supervisor do to make your job <u>more effective</u> for the company?

D6 Are there any aspects of your job that you feel could be carried out by someone else?

Yes 1 No 2

If YES, what are these and by whom?

D7 Do you feel that there are some other tasks which should be incorporated into your job, which aren't there at present?

Yes 1 No 2

If YES,

(a) What type of tasks are these?

(b) Why do you think these would be better incorporated into your job role?

D8 In what specific instances has your supervisor praised you? (both formally and informally)

D9 In what specific instances has your supervisor reprimanded you?

D10 Were you with this company when CAD was introduced?

Yes 1 No 2

If YES,

(a) What was your role?

Same as at present	1
Other	2

(b) Was there any involvement of the designers in the implementation of the CAD system?

(c) Were you involved in any way?

Yes 1 No 2

If YES, in what way?

D11 Do you think there was enough involvement of the designers, in general in the implementation of the CAD system?

Yes 1 No 2 Don't know3

If NO, what should have been done about this?

D12 Were the supervisors involved in the implementation of the CAD system?

Yes 1 No 2 Don't know3

If YES, was there enough involvement of the supervisors (section leaders) in the implementation of the system?

If NO, do you think this noninvolvement in the implementation phase has had any effect on the way the system is used today?

D13 Did you express any concerns, raise any significant matters?

Yes 1 No 2

If YES, what were these?

E. Computer-Aided Design and the Supervisor (Section Leader)

E1 What do you think were the main reasons behind the company's <u>original</u> decision to bring in CAD?

E2 Were these reasons explained to you?

Yes 1 No 2

If YES, when?

If NO, would it have made things easier if they had been explained to you?

E3 Do you know whether the CAD system was evaluated using a financial basis or some other way?

Yes 1 No 2

If YES,

(a) what was it?

(b) Was the evaluation on a short or long term basis?

Short 1 Long 2 Don't know 3

If SHORT, are there any plans to look at/cope with the longer term future?

If LONG, then what are the future plans?

E4 What financial (if any) savings do you think come from using CAD?

E5 In practice what do you think are the actual benefits or advantages which come from using CAD.....

(a) for the designers?

(b) for the company?

E6 What are the main disadvantages, risks or problems of using CAD?

E7 Do you think CAD has affected the way you design?

Yes 1 No 2 Don't know3

If YES, in what way?

E8 Has the role of your supervisor changed with CAD?

Yes 1 No 2 Don't know3

If YES,

(a) What changes have occurred?

(b) What ways has it made the supervisor's job harder?

(c) What ways has it made the supervisor's job easier?

E9 What do you see as the role of the CAD manager (CAD support team)?

E10 In your opinion what is the "working relationship" between the supervisor and the CAD manager?

E11 Can you please estimate the CAD background, maturity of use and satisfaction of the people working in your section.

Who	Training			Frequency of use			Ability	Satisfaction
Job Title	No Cad	Basic CAD	Adv CAD	Occ. Use	Reg. Use	Ded. Use	Comp. USe	

E12 In your opinion how well do design management support CAD?

Very well 1
About average 2
Not at all well 3

E13 What is your view about the way management has handled the introduction of the CAD system?

E14 Has your supervisor been given any training on CAD?

Yes 1 No 2 Don't know3

If YES,

(a) What kind was it?

(b) Was it at a high enough level or not?

(c) What is your supervisor's opinion of the CAD training given to him?

If NO, do you think it would benefit them to be given some basic training on CAD?

Yes 1 No 2

F. Training for CAD

F1 Have you been trained to use the CAD system?

Yes 1 No 2

If YES,

(a) How long ago?

Within a year	1
1 to 2 years ago	2
2 to 4 years ago	3
Over 4 years ago	4

(b) Who was the course for?

Designers only	1
Designers & their supervisors	2
A mixture of possible users	3

(c) How were you trained to use CAD?

Outside course x days	1
Inside course x days	2
Sitting with someone else using the system	3
Self-taught	4

F2 What is your opinion about the quality of this CAD training?

Good 1 Average 2 Bad 3

If AVERAGE or BAD, what should be done about this?

F3 What is your opinion about the quantity of this CAD training?

Too much	1
About right	2
Too little	3

F4 Did any of the course(s) discuss how to work with your supervisor when using CAD?

Yes 1 No 2

If YES, how useful was this aspect?

Essential	1
Very useful	2
Useful	3
Not very useful	4
Not at all	5

If ESSENTIAL, VERY USEFUL or USEFUL what particular aspects were these?

F5 Since the training course have there been any further development/update courses?

Yes 1 No 2

If YES,

(a) Have you attended any of these?

Yes 1 No 2

(b) How adequate was the quality of these courses?

Good 1 Average 2 Bad 3

If AVERAGE or BAD, what should be done about this?

(c) How adequate was the quantity of these courses?

Too much	1
About right	2
Too little	3

F6 Overall do you feel that you have received the correct amount of training for using the CAD system?

Yes 1 No 2

If NO,

Too much 1 Too little 2

(a) What was wrong?

Training too short	1
Training too long	2
Too simple?	3
Too complex?	4

F7 What type of computer training do you think would most benefit you?

G. Extent of CAD Use

G1 How high would you estimate your own proficiency on CAD in relation to other designers?

Top 25%	1
Middle 50%	2
Bottom 25%	3

G2 How long has it taken to reach your current level of proficiency following initial training

G3 In an average week how often do you use CAD?

G4 In an average day, what percentage of your time is spent using CAD?

0 to 5%	1
5 to 10%	2
10 to 30%	3
30 to 50%	4
Over 50%	5

G5 Within your company who allocates the use of the workstations?

G6 What type(s) of project is CAD mainly used for?

G7 How confident do you feel about CAD?

Very confident	1
OK	2
Little confidence	3

G8 How would you like to change towards CAD?

H. General

H1 Are you a member of a union?

Yes 1 No 2

If NO,

(a) Why not?

(b) Are your colleagues members of any Union?

If YES,

(a) Why?

Greater job security	1
Greater autonomy from management	2
Other	3

(b) When did you join this union?

Within the past year	1
1 to 5 years ago	2
Over 5 years ago	3

H2 Are there any agreements eg. New Technology Agreement (NTA), signed or informally agreed with this Union about CAD?

Yes	1
No	2
Don't know	3

H3 What is your view on the way your Union has handled the introduction of the CAD system?

Good 1 Bad 2

If GOOD,

(a) Is there still sufficient support from the union?

(b) What do you feel the union should be doing to better support your position in light of the introduction of CAD?

H4 What developments do you consider it essential for management to concentrate on in order to make the most effective use of the CAD system in the future?

H5 At the present time do you see the company changing its approach to design?

Yes 1 No 2

If YES, in what way(s)?

H6 Talking about design in general, where do you see the company progressing to in the next 5 years?

H7 What do you think of that?

H8 How would you like to see your own role developed within that?

NB. Finally are there any comments on the structure and administration of this interview that you would like to make?

LIVERPOOL UNIVERSITY

Design Supervisor Interview

Thank you for agreeing to take part in this interview.

My name is Laurence Brooks, I am a researcher in the Industrial Studies department of Liverpool University. This interview is part of a 3 year project looking at designers/engineers and computer-aided design.

As you know CAD is a powerful new technology which is no longer all that "new". This interview aims to find out how you and your company have adapted to CAD. Whether it has had the dire consequences some people predicted it would have or if it is indeed the useful tool that others said it would be.

The interview structure begins by looking at your background, training and general job characteristics. This is followed by a look at your training to use CAD, usage of CAD and general attitudes towards it. It finishes with a general section looking at the attitude of the Unions towards CAD (if any) and your general view of the future of this company and how CAD might be best exploited within that.

Some of the questions ask for your own personal views and I would first like to assure you that all the questions are asked in confidence. As well the interview structure is going to be used in a wide variety of companies. Therefore some of the questions might refer to practices or use terminology not exactly correct for your company. If this happens please try and answer the question far as possible. In addition please do not hesitate to ask if you do not understand a question.

cLiS

Interview Structure Skeleton

I. Supervisor's Skeleton

First I want to ask you a few questions about your job history and your job in general.

A. Job History and Career

A1 Male 1 Female 2

A2 What is your formal job title?

A3 What was your age last birthday? ____

A4 In chronological order please tell me which educational and technical qualifications you have attained since you left secondary school?

School Certificate/Matriculation	1
CSE's	2
GCE's/"O" levels	3
GCSE	4
"A" levels	5
Degree	6
ONC	7
HNC	8
HND	9
Apprenticeships,	
1. Trade - 4/5 yrs + City & Guilds	10
2. Student - 4/5 yrs + HNC/HND	11
3. Graduate - 2 yrs already with degree	12

A5 Before joining this company, briefly, what industrial experience have you had?

Company	Position	Activities	Years

A6 How did you get to be in your current position (supervisor/ section leader/principal engineer) with this company?

Offered promotion	1
Applied for promotion inside this company	2
Applied for promotion to another company	3
A sideways move	4

If APPLIED FOR PROMOTION ....

(a) Why?

A7 Do you perceive opportunities for further promotion within this company?

Yes	1	No	2

If YES

(a) Will you apply?

(b) Where do you think this promotion might take you?

B. Training

This section is titled training and looks at the general training you have received.

B1 Have you ever had any general supervisory training?

Yes, in-company	1
Yes, external (eg. at a local college)	2
No	3

If YES,

(a) How long was the training?

One day	1
One Week	2
Modular	3
Spread out over a period of time	4

(b) What type of training was it?

Formal, classroom based	1
Specific on-the-job, peer learning	2
Self-instructive	3
Systematic development by your superior	4
Other	5

(c) What subjects did this training cover?

(d) Approximately when was the training?

Before you took up this supervisory position	1
At the same time as taking up this position	2
Under a year after you took up this position	3
1 to 2 years after you took up this position	4
2 to 4 years after you took up this position	5
Over 4 years after you took up this position	6

(e) Can you remember any **particular** aspects of the course which you found useful as a supervisor?

(f) In your opinion how useful has this training been?

Essential	1
Very useful	2
Useful	3
Not useful	4
No use at all	5

(g) What areas would you like further training in, if any?

If NO, Do you think any form of supervisory training should be introduced for new supervisors, and if so on what subjects?

C. Job Role

This section is titled job role and aims to find out a bit about your job characteristics.

C1 How many staff are you responsible for at present? ____

C2 In general, how many staff are you responsible for?

0 to 2	1
3 to 5	2
6 to 10	3
over 10	4

C3 Does it vary according to the job?

Yes 1 No 2

C4 In general, how much contact you have with each member of your staff?

Several times a day	1
Once a day	2
2 to 3 times a week	3
Once a week	4
Less frequently	5
As and when needed	6
Other	7

C5 How much of your time do you spend on your own technical design work?

C6 How much of your time do you spend in advisory design work?

C7 How much of your time do you spend in other technical work?

C8 How is the rest of your working time spent and on what?

C9 Are there any structured elements in your work schedule for the week/month?

Yes 1 No 2

If YES, what are they?

Regular meetings with your superior	1
Regular meetings with other supervisors (other than in general departmental meetings)	2
Regular meetings with your subordinates	3

C10 Who deals with the allocation of work within your section?

You	1
Your immediate superior	2
Other, who?	3

C11 Could you briefly describe **how** you work out your work schedule for the week/month?

You decide for yourself	1
You decide together with others	2
You are told	3
Other	4

If YOU DECIDE YOURSELF *or* WITH OTHERS, what criteria do you use and how?

In the same way every week	1
In a generally structured way	2
Depending on the circumstances for that week	3
Other	4

If YOU ARE TOLD,

(a) How is it done?

Orally	1
Written	2
Other	3

(b) By whom?

C12 Do you have one project or many projects at a time?

One project only	1
Many projects at one time	2

If MANY AT ONE TIME,

(a) Are they running

Sequentially	1
Simultaneously	2

(b) With multiple projects, how do you establish priorities?

C13 What do you receive when starting a new job and from whom?

A full design specification on paper	1
A rough outline on paper	2
Verbal and written information	3
Other	4

C14 Is any discussion involved in starting a new job?
Yes 1 No 2

If YES,

(a) With whom?

(b) How much of that would be recorded on paper?

C15 What information do you pass on when starting a new job.....

(a) to your superiors?

(b) to your subordinates?

C16 Who does this information come from?

Your immediate superior	1
The design office manager (if different from above)	2
The project design engineer	3
Other	4

C17 How do you liaise with your superior when managing your staff?

C18 What type of subjects do you discuss?

C19 Other than project specifications what other type of written information is received from your immediate superior?

C20 What information do you feed back to your superior?

(a) How frequently is this information communicated?

C21 How could you improve your communication with your superior?

C22 What information do you receive from your staff?

C23 What information do you pass on to your staff, and how frequently is this information communicated?

C24 How could communication with your staff be improved?

C25 What type of information do you exchange with other supervisors in the design office?

C26 How do you liaise with other supervisors?

C27 In general what are the most important pieces of information you receive?

C28 In general what are the most important pieces of information you pass on?

C29 What do you feel is the most important activity you contribute to the performance of your group?

C30 In an average week, which one activity would you say takes up the majority of your time?

Attending meetings	1
Paperwork	2
Dealing with staff technical problems	3
Dealing with staff personnel problems	4
Advising other members of the design office	5
Dealing with contingencies/problems	6
Staff appraisal	7
Other	8

C31 Looking at your job overall what other activities would you say are the other "core" activities of your job?

C32 What standards exist for the design office?

Departmental	1
Company	2
External	3
Military	4
Other	5

C33 How are these standards monitored?

Ca. This next section deals with how you work with your immediate superior and with your staff and how you evaluate each other.

Ca1 How do you think your immediate superior measures your daily performance?

Ca2 How does he make it known to you?

From his reactions to you	1
He tells you directly	2
Some sort of written informal appraisal	3
A written formal appraisal	4

Ca3 How does your immediate superior monitor your progress?

Formal appraisal system	1
Informal chat about progress	2
Self-appraisal system	3
Other	4

Ca4 How regular is this monitoring?

Monthly	1
Every (x) months	2
Biannually	3
Annually	4
Other	5

Ca5 In your opinion what does your immediate superior think are the main activities which occupy your time?

Attending meetings	1
Paperwork	2
Supervising staff	3
Dealing with contingencies/problems	4
Staff appraisal	5
Other	6

Ca6 In your opinion what is your immediate superior most concerned about in your performance?

Ca7 Is there a "formal" job description for your job?

Yes 1 No 2

If YES,

(a) How often is this updated?

(b) How relevant to "real-life" is it?

D. Job Satisfaction

D1 Looking at your job overall what do you find satisfying? (if NO, are they actively unsatisfying?)

(a)	Your basic pay	yes/no	unsatis
(b)	Job security	yes/no	unsatis
(c)	Opportunity to exercise autonomy/management control	yes/no	unsatis
(d)	The variety of job tasks	yes/no	unsatis
(e)	Feeling of personal development	yes/no	unsatis
(f)	Opportunity to progress along some career path	yes/no	unsatis
(g)	Dealing with variations and unexpected situations	yes/no	unsatis
(h)	Opportunities to make your own decisions	yes/no	unsatis
(i)	Working with other supervisors, design office staff, managers etc. ...	yes/no	unsatis
(j)	Working with your subordinates	yes/no	unsatis
(k)	The amount of responsibility you are allowed to take on	yes/no	unsatis
(l)	Work interest (technical)	yes/no	unsatis

D2 What other aspects of your job do you find satisfying?

D3 What other aspects of your job do you find dissatisfying?

D4 Are there any areas which you see as being useful to concentrate on to make your job <u>more satisfying</u>?

D5 Are there any areas which you see as being useful to concentrate on to make your job <u>more effective</u> for the company?

D6 What aspects of your job do you feel should be carried out by someone else?

Type of task	By whom?	Why?

D7 Do you feel that there are some other tasks which should be incorporated into your job, which aren't there at present?

Yes 1 No 2

If YES,

(a) What type of tasks are these?

(b) Why do you think these would be better incorporated into your job role?

D8 In what specific instances has your immediate superior praised you (both formally and informally)?

D9 In what specific instances has your immediate superior reprimanded you (both formally and informally)?

D10 What was your role when CAD was introduced

Same as at present 1
Other 2

D11 Do you think there was enough involvement of the supervisors, in general (section leaders) in the implementation of the CAD system?

Yes 1 No 2 Don't know3

If NO, do you think noninvolvement of the supervisors in the implementation process has affected the way CAD is used today?

D12 At what stage in the plan were you involved?

At the feasibility study stage	1
At the beginning	2
Just before introduction	3
During introduction	4
Not involved	5

D13 In what way were you involved?

D14 Do you think this was the right time or should have been done at a different stage?

Earlier	1
Later	2

Why?

D15 Did you express any concerns, raise any significant matters?

Yes 1 No 2

If YES, what were these?

E. Computer-Aided Design and the Supervisor (Section Leader)

E1 What do you think were the main reasons behind the company's <u>original</u> decision to bring in CAD?

E2 Were these reasons explained to you?

Yes 1 No 2

If YES, when?

E3 Do you know whether the CAD system was evaluated using a financial basis or some other way?

Yes 1 No 2

If YES, what was it?

E4 Was the evaluation on a short or long term basis?

Short 1 Long 2 Don't know 3

If SHORT, are there any plans to look at/cope with the longer term future?

If LONG, then what are the future plans?

E5 Do you know what were the projected figures for increased efficiency with CAD?

Yes 1 No 2

If YES,

(a) What were they?

(b) Are these figures valid?

Yes 1 No 2

E6 What savings do you think come from using CAD?

E7 Is CAD cost effective?

E8 Do you think CAD has affected product design?

Yes 1 No 2

If YES,

(a) The design process?

(b) The physical product being designed?

E9 Has the job of the supervisor changed with the introduction of Computer-Aided Design equipment?

Yes 1 No 2 Don't know3

If YES,

(a) What changes have occurred?

(b) What ways has it made the supervisor's job harder?

(c) What aspects of CAD are especially helpful to your job as a supervisor?

E10 In practice what do you think are the actual benefits or advantages which come from using CAD, for the company?

E11 What are the main disadvantages, risks or problems with using CAD?

E12 What do you see as the role of the CAD manager (CAD support team)?

E13 How does your role relate to that of the CAD Manager?

E14 Can you please estimate the CAD background, maturity of use and satisfaction of the people working around you (please include all subordinates, superiors and other supervisory staff)?

Who	Training			Frequency of use			Ability	Satisfaction
Job Title	No Cad	Basic CAD	Adv CAD	Occ. Use	Reg. Use	Ded. Use	Comp. USe	

E15 What is your opinion about the quality of CAD training given to your subordinates?

Good 1 Average 2 Bad 3

If AVERAGE or BAD, what should be done about this?

E16 What is your opinion about the quantity of CAD training given to your subordinates?

Too much 1
About right 2
Too little 3

E17 What would you say are your subordinates opinions about the CAD training given to them?

Very good
Good enough
Could be better
Need more training
Awful

E18 In your opinion how well have design management supported CAD?

Very well 1
About average 2
Not at all well 3

E19 What is your view about the way management has handled the introduction of the CAD system?

E20 Has your immediate superior been given any training on CAD?

Yes 1 No 2

If YES, what kind was it?

E21 What is your opinion about the quality of CAD training given to your superior?

Good 1 Average 2 Bad 3

If AVERAGE or BAD, what should be done about this?

E22 What is your opinion about the quantity of CAD training given to your superior?

Too much 1
About right 2
Too little 3

If NONE, do you think it would benefit them to be given some basic training on CAD?

Yes 1 No 2

F. Training for CAD

F1 Have you been trained to use the CAD system?

Yes 1 No 2

If YES,

(a) How long ago?

Within a year 1
1 to 2 years ago 2
2 to 4 years ago 3
Over 4 years ago 4

(b) Who was the course for?

Supervisors only 1
Mixed with designers 2
A variety of possible users 3

(c) Briefly what did the course cover?

F2 What is your opinion about the quality of this CAD training?

Good 1 Average 2 Bad 3

If AVERAGE or BAD, what should be done about this?

F3 What is your opinion about the quantity of this CAD training?

Too much	1
About right	2
Too little	3

F4 Did any of the course(s) focus on the supervisor's job in relation to CAD?

Yes 1 No 2

If YES, how useful was this aspect?

Very	1
Not very	2
Not at all	3

If VERY, what particular aspects were these?

F5 Since the training course have there been any further development/update courses?

Yes 1 No 2

If YES,

(a) Have you attended any of these?

Yes 1 No 2

(b) How adequate was the quality of these courses?

Good 1 Average 2 Bad 3

If AVERAGE or BAD, what should be done about this?

(c) How adequate was the quantity of these courses?

Too much	1
About right	2
Too little	3

F6 Do you feel that you have received the correct amount of training for using the CAD system?

Yes 1 No 2

If NO,

Too much 1 Too little 2

(a) What was wrong?

Training too short	1
Training too long	2
Too simple?	3
Too complex?	4

F7 What type of computer training do you think would most benefit you?

G. Extent of CAD Use

G1 How high would you estimate your own proficiency on CAD, in relation to .....

(a) other supervisors (section leaders)?

Top 25%
Middle 50%
Bottom 25%

(b) designers/draughtsmen?

Top 25%
Middle 50%
Bottom 25%

G2 In an average week how often do you use CAD?

G3 In an average day, what percentage of your time is spent using CAD?

0 to 5%	1
5 to 10%	2
10 to 30%	3
30 to 50%	4
Over 50%	5

G4 Within your company who allocates the use of the workstations?

G5 What type of project(s) is CAD mainly used for?

G6 What level of competence have you achieved, on CAD?

G7 How confident do you feel about CAD?

Very confident	1
OK	2
Little confidence	3

G8 How would you like to change towards CAD?

G9 What is your overall view of the CAD system?

H. General

H1 What is the relationship between design and production engineering (if they exist as separate departments)?

H2 Are you a member of a union?

Yes 1 No 2

If NO,

(a) Why not?

(b) Are your colleagues members of any Union?

If YES,

(a) Why?

Greater job security	1
Greater autonomy from management	2
Other	3

(b) When did you join this union?

Within the past year	1
1 to 5 years ago	2
Over 5 years ago	3

H3 Are there any agreements eg. New Technology Agreement (NTA), signed or informally agreed with this Union about CAD?

Yes	1
No	2
Don't know	3

H4 What is your view on the way your Union has handled the introduction of the CAD system?

Good 1 Bad 2

If GOOD,

(a) Is there still sufficient support from the union?

(b) What do you feel the union should be doing to better support your position in light of the introduction of CAD?

H5 What developments do you consider it essential for management to concentrate on in order to make the most effective use of the CAD system in the future?

H6 In your opinion does management continue to run the CAD system well?

Yes 1 No 2

If NO, what could be done better?

H7 At present do you see the company changing the way it approaches design?

Yes 1 No 2

If YES, in what way?

If NO, what do you think about this?

H8 Over the past 5 years how much has the company changed its product range?

(a) What prompted these changes?

(b) Were any of the changes connected with CAD?

H9 Talking about design in general, where do you see the company progressing to in the next 5 years?

H10 What do you think of that?

H11 How would you like to see your own role developed within that?

NB. Finally are there any comments on the structure and administration of this interview that you would like to make?

LIVERPOOL UNIVERSITY

CAD Manager/CAD Administrator Interview

Thank you for agreeing to take part in this interview.

My name is Laurence Brooks, I am a researcher in the Industrial Studies department of Liverpool University. This interview is part of a 3 year project looking at designers/engineers and computer-aided design.

As you know CAD is a powerful new technology which is no longer all that "new". This interview aims to find out how you and your company have adapted to CAD. Whether it has had the dire consequences some people predicted it would have or if it is indeed the useful tool that others said it would be.

The interview structure begins by looking at your background, training and general job characteristics. This is followed by a look at the implementation of CAD, your involvement in the training to use CAD, usage of CAD and general attitudes towards it. It finishes with a general section looking at the attitude of the Unions towards CAD (if any) and your general view of the future of this company and how CAD might be best exploited within that.

Some of the questions ask for your own personal views and I would first like to assure you that all the questions are asked in confidence. As well the interview structure is going to be used in a wide variety of companies. Therefore some of the questions might refer to practices or use terminology not exactly correct for your company. If this happens please try and answer the question far as possible. In addition please do not hesitate to ask if you do not understand a question.

cLiC

Interview Structure Skeleton

I. CAD Manager/CAD Administrator's Skeleton

First I want to ask you a few questions about your job history and your job in general.

A. Job History and Career

A1 Male 1 Female 2

A2 What was your age last birthday? ____

A3 What is your formal job title?

A4 In chronological order please tell me which educational and technical qualifications you have attained since you left secondary school?

School Certificate/Matriculation	1
CSE's	2
GCE's/"O" levels	3
GCSE	4
"A" levels	5
Degree	6
ONC	7
HNC	8
HND	9
Apprenticeships,	
1. Trade - 4/5 yrs + City & Guilds	10
2. Student - 4/5 yrs + HNC/HND	11
3. Graduate - 2 yrs already with degree	12

A5 Before joining this company, briefly, what industrial experience have you had?

Company	Position	Activities	Years

A6 Were you involved with CAD before you came to this company (either using or managing it)?

Yes 1 No 2

If YES, in what ways?

A7 How did you get to be in your current position (CAD Manager/ CAD Administrator/CAD Support team member) with this company?

Offered promotion	1
Applied for promotion inside this company	2
Applied for promotion from another company	3
A sideways move	4
Other	5

If APPLIED FOR PROMOTION ....

(a) Why?

A8 Do you perceive opportunities for further promotion?

Yes 1 No 2

If YES, will you apply?

B. Training

This section is titled training and looks at the general training you have received.

B1 Have you ever had any general (non/CAD) supervisory/ managerial training?

Yes 1 No 2

If YES,

(a) How long was the training?

One day	1
One Week	2
Modular type	3
Spread out over a period of time	4

(b) What type of training was it?

Formal, classroom based	1
On-the-job, peer learning	2
Self-instructive	3
Systematic development by your superior	4
Other	5

(c) Approximately when was the training?

Before you took up this position	1
At the same time as taking up this position	2
Under a year after you took up this position	3
1 to 2 years after you took up this position	4
2 to 4 years after you took up this position	5
Over 4 years after you took up this position	6

(d) Can you remember any particular aspects of the course which you found useful?

(e) In your opinion how useful has this training been?

Essential	1
Very useful	2
Useful	3
Not useful	4
No use at all	5

(f) What areas would you like further training in, if any?

If NO, Do you think any form of general supervisory training should be introduced for new CAD Managers/CAD Support team members, if so on what subjects?

C. Job Role

This section is titled job role and aims to find out a bit about your job characteristics.

C1 In general, how many staff are you directly responsible for?

0 to 2	1
3 to 5	2
6 to 10	3
over 10	4

C2 How many staff are you responsible for at present? ____
(if different from in general)

C3 Are you indirectly responsible for any other staff?

Yes 1 No 2

If YES, who?

C4 In general, how much contact you have with each member of your staff?

Several times a day	1
Once a day	2
2 to 3 times a week	3
Once a week	4
Less frequently	5
As and when needed	6
Other	7

C5 Do you spend any time on your own technical design work?

Yes	1	No	2

If YES, what sort of work is this?

C6 Do you spend any time in advisory design work?

Yes	1	No	2

If YES, with whom and about what?

C7 What activities take up the majority of your time?

C8 Are there any structured elements in your timetable for the week/month?

Yes	1	No	2

If YES, what are they?

Regular meetings with your superior	1
Regular meetings with other managers	2
Regular meetings with your subordinates	3
Regular meetings with design staff	4
Other	5

C9 Could you briefly describe **how** you work out your timetable for the week/month?

You decide for yourself	1
You decide together with others	2
You are told	3

If YOU DECIDE YOURSELF or WITH OTHERS, how is this done?

In the same way every week	1
In a generally structured way	2
Depending on the circumstances for that week	3
Other	4

If YOU ARE TOLD,

(a) How is it done?

Orally	1
Written	2
Other	3

(b) By whom?

C10 Is your work governed by the projects (design specs.) working their way through the design process or do you work according to a more general strategy?

C11 How do you liaise with your superior when managing your staff?

C12 What type of subjects do you discuss?

C13 What type of written information is received from your immediate superior?

C14 What information do you feed back to your superior, and how often is this done?

C15 How could you improve your communication with your superior?

C16 What information do you pass on.....

(a) to your superior?

(b) to your subordinates?

C17 What information do you receive from your staff, and how frequently?

C18 How could communication with your staff be improved?

C19 What type of information do you exchange with supervisors in the design office?

C20 In general what are the most important pieces of information you receive?

C21 In general what are the most important pieces of information you pass on?

C22 How do you think your immediate superior measures your daily performance?

C23 How does he make it known to you?

From his reactions to you	1
He tells you directly	2
Some sort of written informal appraisal	3
A written formal appraisal	4

C24 How does your immediate superior monitor your progress?

Formal appraisal system	1
Informal chat about progress	2
Self-appraisal system	3
Other	4

C25 How regular is this monitoring?

Monthly	1
Every (x) months	2
Biannually	3
Annually	4
Other	5

C26 In your opinion what does your immediate superior think are the main activities which occupy your time?

Attending meetings	1
Paperwork	2
Supervising staff	3
Dealing with contingencies/problems	4
Programming/writing macros	5
Other	6

C27 In your opinion what is your immediate superior most concerned about in your performance?

C28 In an average week, which one activity would you say takes up the majority of your time?

Attending meetings	1
Paperwork	2
Dealing with staff technical problems	3
Dealing with staff personnel problems	4
Dealing with design staff technical problems	5
Advising other members of the design office	6
Dealing with contingencies/problems	7
Other	8

C29 Looking at your job overall what activities would you say are the other "core" activities of your job?

D. Job Satisfaction

D1 Looking at your job overall what do you find satisfying? (if NO, are they actively unsatisfying?)

Your basic pay	yes/no	unsatis
Job security	yes/no	unsatis
Opportunity to exercise autonomy/management control	yes/no	unsatis
The variety of job tasks	yes/no	unsatis
Feeling of personal development	yes/no	unsatis
Opportunity to progress along some career path	yes/no	unsatis
Dealing with variations and unexpected situations	yes/no	unsatis
Opportunities to make your own decisions	yes/no	unsatis
Working with supervisors, design office staff, managers etc. ...	yes/no	unsatis
Working with your subordinates	yes/no	unsatis
The amount of responsibility you are allowed to take on	yes/no	unsatis
Work interest (technical)	yes/no	unsatis

D2 What other aspects of your job do you find satisfying?

D3 What other aspects of your job do you find dissatisfying?

D4 Are there any areas which you see as being useful to concentrate on to make your job more satisfying?

D5 Are there any areas which you see as being useful to concentrate on to make your job more effective for the company?

D6 What aspects of your job do you feel should be carried out by someone else?

Type of task	By whom?	Why?

D7 Do you feel that there are some other tasks which should be incorporated into your job, which aren't there at present?

Yes 1 No 2

If YES,

(a) What type of tasks are these?

(b) Why do you think these would be better incorporated into your job role?

D8 In what specific instances has your immediate superior praised you (both formally and informally)?

D9 In what specific instances has your immediate superior reprimanded you (both formally and informally)?

E. Computer-Aided Design

E1 What do you think were the main reasons behind the company's original decision to bring in CAD?

E2 Were these reasons explained to you?

Yes	1	No	2

If YES, when?

E3 What was your role when CAD was introduced

Same as at present	1
Other	2

E4 Were you involved in the initial decision to implement CAD?

Yes	1	No	2

If YES,

(a) How did you go about selecting a system?

(b) What other equipment did you look at?

(c) Why did you make the choice you did?

If NO,

At what stage in the plan were you involved?

At the feasibility study stage	1
At the beginning	2
Just before introduction	3
During introduction	4
Not involved	5

E5 Do you think there was enough involvement of the rest of the design office staff in the implementation of the CAD system?

Yes 1 No 2

If NO,

(a) What should have been done about this?

(b) Do you think that noninvolvement of the design office staff has affected the way CAD is used today?

E6 Do you know whether the CAD system was evaluated using a financial basis or some other way?

Yes 1 No 2

If YES, what was it?

E7 Was the evaluation on a short or long term basis?

Short 1 Long 2 Don't know 3

If SHORT, are there any plans to look at/cope with the longer term future?

If LONG, then what are the future plans?

E8 Do you know what were the projected figures for increased efficiency with CAD?

Yes 1 No 2

If YES,

(a) What were they?

(b) Are these figures valid?

Yes 1 No 2

E9 What terms have been used to measure the benefits of CAD?

E10 What results have been seen so far?

E11 Are there any other significant but non-measurable benefits?

E12 In your opinion is CAD cost effective?

E13 In practice what do you think are the actual benefits or advantages which come from using CAD, for the company?

E14 What do you see as being the main disadvantages, risks or problems of using CAD?

E15 Do you think CAD has affected product design?

Yes 1 No 2

If YES,

(a) The design process?

(b) The physical product being designed?

E16 Has the job of the supervisor changed with the introduction of Computer-Aided Design equipment?

Yes 1 No 2

If YES,

(a) What changes have occurred?

E17 With the introduction of CAD what do you see as the role of the design supervisor (section leader)?

E18 How does your role relate to that of the design supervisor (section leader)?

E19 What is your view about the way management has handled the introduction of the CAD system?

E20 In your opinion how well have design management supported CAD?

Very well	1
About average	2
Not at all well	3

F. Training for CAD

F1 How many people in your company are trained to use CAD? ___
(what grades and how many of each grade)

F2 Out of those approximately how many regularly use it?

F3 Are design supervisors given training on CAD?

Yes 1 No 2

If YES, what sort of training is this?

The same course as everyone else	1
A course especially developed for them	2
A very basic appreciation course	3
Other	4

If NO, do you think that they should be given some training on CAD?

F4 Who is responsible for CAD training in the design office?

the CAD Manager	1
Someone else in the CAD support team	2
Separate division	3
Outside training company	4
the CAD system vendor company	5
Other	6

F5 Are you satisfied with the levels of CAD training available for designers?

Yes 1 No 2

If NO,

(a) What is wrong with it?

Too much	1
Too little	2
At the wrong level	3

(b) What should be done about this?

G. Extent of CAD

G1 How high would you estimate your own proficiency on CAD, in relation to ....

(a) other members of the CAD support team?

(b) designers/draughtsmen?

(c) design supervisors?

G2 How many workstations are in the company? ___

G3 Where are they situated?

In a central CAD area	1
In with the drawing boards	2
Dispersed around the design office	3
Other	4

G4 Within your company who allocates the use of the workstations?

G5 What type of project is CAD mainly used for?

G6 Who is responsible for administrating the implementation of updates to the system?

G7 Who is responsible for writing any macros or other supporting software needed for the CAD system?

G8 Are you responsible for the long term planning for the CAD system?

Yes	1	No	2

If NO, who is?

G9 How would you like to see CAD changed within the company?

H. General

H1 Are there any Unions within your company?

H2 Are you a member of a union?

Yes	1	No	2

If NO,

(a) Why not?

If YES,

(a) Why?

Greater job security	1
Greater autonomy from management	2
Other	3

(b) When did you join this union?

Within the past year	1
1 to 5 years ago	2
Over 5 years ago	3

H3 Are there any agreements eg. New Technology Agreement (NTA), signed or informally agreed with any Union about CAD?

Yes	1
No	2
Don't know	3

H4 What is your view on the way the Unions have handled the introduction of the CAD system?

Good 1 Bad 2

If BAD, why do you think this was so and what can be done to remedy the situation?

H5 What developments do you consider it essential for management to concentrate on in order to make the most effective use of the CAD system in the future?

H6 In your opinion is the CAD system run well?

Yes 1 No 2

If NO, what could be done better?

H7 How would you like to see CAD changed within the company?

H8 Talking about design in general, where do you see the company progressing to in the next 5 years

H9 What do you think of that?

H10 How would you like to see your own role developed within that?

NB. Finally are there any comments on the structure and administration of this interview that you would like to make?