THE IMPLEMENTATION AND INTEGRATION OF CAD/CAM IN MANUFACTURING ORGANISATIONS: A GROUNDED THEORY INVESTIGATION

Tarek Mahmoud Kasim Tantoush

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews

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June 1997

I, Tarek M. Tantoush, hereby certify that this thesis, which is approximately 100,000 words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree.

Dated: Tarek M. Tantoush

29/12/1997

I was admitted as a research student under Ordinance No. 12 in October, 1990 and as a candidate for the degree of Doctor of Philosophy in October 1990; the higher study for which this is a record was carried out in the University of St. Andrews between 1990 and 1996.

Dated: Tarek M. Tantoush

29/12/1997

I hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Doctor of Philosophy in the University of St. Andrews and that the candidate is qualified to submit this thesis in application for that degree.

Dated: Dr Fiona Wilson

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In the Name of God, The Most Gracious, The Most Merciful

Acknowledgement

"Praise be to God, The Cherisher and Sustainer of the Worlds, Most Gracious, Most Merciful, Master of the Day of Judgement ..... Who taught (the use of) the pen, taught man that which he knew not". And peace be upon prophet Mohammed as well as upon Adam, Noah, Abraham, Moses and Jesus and all their brethren apostles who, in conveying heavenly revelation, offered us knowledge in its purest, most serviceable form.

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TO MY FAMILY

ABSTRACT

New technology has received increased attention in the literature over the past two decades. Information technology's profound economic, social, political, organisational, and psychological effects have been the subject matter of numerous studies. The wide-spread use of computers in manufacturing industry is an important area for research into what may look superficially as a purely technical change but turns out to be, in effect, as much about organisational adaptation as it is about the introduction of a technology system *per se*. The latter needs to fit the host organisational setting in order to operate and deliver and the former needs to fit the technology being introduced in order to make an effective use of it. Among other important computer technology applications in manufacturing industry (e.g. robotics, CAT and MRP-I), CAD was the subject matter of numerous research efforts during the 1970s and 80s. So was CAM but to a lesser degree. For the 1990s and beyond, however, the focus of research has shifted to concentrate on integrating technologies (e.g. MRP-II and CADCAM) used in manufacturing companies and often symbolised by the generic concept of CIM Such technologies are more technically advanced in their own right but they also have greater implications for job design and work organisation. This thesis addresses the gap between precept and practice in CADCAM implementation as a technology-induced organisational integration process.

The aim of the present research is to develop a better empirically-informed understanding of integration as an organisational change process by researching and comparing ten selected UK-based manufacturing companies' experiences. The emphasis in this study is on the discovery and development, rather than testing, of theory. Therefore, the underlying theory here is grounded in the data gathered through an oriented field research, rather than tested for verification purposes following a logic-deductive literature review. A qualitative, "grounded theory" methodological approach is used to meet the set objective on the basis of a defined link between the study's theoretical and methodological frameworks. The research strategy is designed to include a longitudinal case study approach which traces the companies' historical experiences of introducing CAD and CAM systems since the early 1970s (in the ten companies) and current experiences of interfacing them to create integrated CADCAM (in five of them - termed primary cases), as well as the lack of integration initiatives (in the other five companies - termed secondary cases).

Seven tentative research questions are used to orient the field research initially. A conceptual model is then developed as a framework for the generation of theory: 20 substantive theoretical propositions on CAD/CAM and integration and, subsequently, 20 corresponding formal theoretical propositions on organisational change in general, of which 14 are presented in a hypothesis form.

The findings have implications for directing the efforts of future organisational change, particularly in the area of CADCAM integration. They should be of interest to different individuals and groups who are involved in organisational change in one way or another. Senior and technical managers in particular may find them to be of importance in managing the organisational aspects of a strategic technological change process.

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List of Exhibits

Abbreviations

AI	Artificial Intelligence
AIM	Automatic Insertion Machine
AMT	Advanced Manufacturing Technology
ARR	Accounting Rate Return
ATS	Aircraft Testing System
CAD	Computer-Aided Design
CADD	Computer-Aided Drafting and Drawing
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CAPP	Computer-Aided Process Planning
CASE	Computer-Aided Software Engineering
CAT	Computer-Aided Testing
CAW	Computer-Aided warehousing
CIB	Computer-Integrated Business
CIE	Computer-Integrated Enterprise
CIM	Computer-Integrated Manufacturing
CM	Cellular Manufacturing
CNC	Computer Numerical Control
DEM	Design-Engineering-Manufacturing
DFV	Design For Value
DIY	Do-It-Yourself
DP	Data Processing
EIM	Enterprise Integrated Modelling
EM	Enterprise Model
ESPRIT	European Strategic Programme for Research and Development in Information Technology
FEA	Finite element Analysis
FIET	International Federation of Commercial, Clerical, Professional and Technical Employees
FMC	Flexible Manufacturing Cell
FMS	Flexible Manufacturing System
GT	Grounded Theory
ICFTU	International Confederation of Free Trade Unions
IM	Integrated Manufacturing
ISO	International Standard Organisation
IT	Information Technology

JIT	Just-In-Time
LAN	Local Area Network
MAP	Manufacturing Automation Protocol (Standard)
MBA	Master of Business Administration
MIS	Management Information System
MOD	Ministry of Defence
MRP-I	Material Requirements Planning
MRP-II	Manufacturing Resources Planning
NC	Numerical Control
NEL	National Engineering Laboratory
NWO	New World Order
OSA	Open Systems Architecture
PC	Personal Computer
PCB	Printed Circuit Board
PIG	Product Integrity Group
R&D	Research and Development
SE	Simultaneous Engineering
SPC	Statistical Process Control
SPU	Special Purpose Unit
TQM	Total Quality Management
TOP	Technical Office Protocol (Standard)
VP	Vice President
WAN	Wide Area Network
WFTU	World Federation of Trade Unions

CHAPTER ONE

Introduction

1.1 Overview

The history of industrialisation in the modern world has been through three phases of development: craft production, mass production and competition age. Associated with each of these eras are distinctive types of production settings. Organisation of manufacturing has changed from one era to another, both at an enterprise and industry levels as well as within and across national boundaries, but variations have also existed within each era (see Burnes, 1996; Hoffman, 1994; Piore and Sabel, 1984).

The craft production era originated in Britain, the pioneer industrial country. As Pollard (1965: 1) points out, the British Industrial Revolution is often viewed as the "prototype of the industrialisation process which many countries have undergone since, and others are undergoing, or about to undergo, at present". In 1850 Great Britain was known as the "workshop of the world" and was the model that the USA and other European countries sought to emulate in their attempts to transform traditional agrarian societies into urban societies based on science and technology (Bessant, 1991; Kemp, 1979). A low-cost mass production era then followed. It began in the USA and was symbolised by the factory operated by Henry Ford in the 1920s, the *River Rouge* plant (Bessant, 1991). The current competition age has succeeded the mass production era since mass production could no longer offer the right conditions for the kind of industrial flexibility needed (Piore and Sabel, 1984). It emphasises product differentiation, quality, and customer satisfaction as patterns of demand become increasingly fragmented and emphasis shifts to non-price factors, such as variety, frequency of product innovation and high-quality customer service. Globalisation of markets is another characteristic of service-oriented economies of the current competition age (see, for example, Coates, 1992; Dodgson, 1988; Hoffman, 1994). "Post-Fordism" succeeded an era of

> "..... mass consumption through standardised markets premised on mass production bureaucracies organised around low-trust relations, with changes which began to occur in the late 1970s [due to] a conjuncture of several factors [including] ..... the continuing post-1974 recession and the increased competition from Japan and other NICs." (Clegg, 1990: 209).

In a relatively recent article published in *Dundee and Tayside*, the journal of *The Dundee and Tayside Chamber of Commerce and Industry*, Michael Hesseltine (1995: 76), Britain's former Deputy Prime Minister typifies the central theme of entrepreneurial thinking in the current age, one that, in his case, is fortified by strong capitalist free-market convictions of the Conservative Party. He writes:

> "Competitiveness has become a key concept of our time, pervading the thinking of governments, industry and individuals alike. ..... Competitiveness matters to nations. If they are incompetitive, their living standards drop. They cannot sustain high standards of education, health, infrastructure or preserve their cultural heritage."

Manufacturing industry entered the decade of the 1980s in a mood of technological optimism with sophisticated advanced manufacturing technologies (AMTs)[1] to meet the challenges of changing strategic environment by virtue of enhanced competitiveness. The belief in technology as a significant element determining corporate and sectoral strategic competitiveness dominated the background to this optimism (see, for example, Dodgson, 1988; Porter, 1993; Schroeder *et al.*, 1995; Voss, 1986). Yet over a decade and a half has passed and caution about AMTs seems to be on the increase; "although many firms found improved competitive performance, the road is littered with less fortunate examples of failure and disappointed expectations" (Bessant, 1994: 237).

The question for managers is one of deriving the potential benefits of AMTs whilst avoiding pitfalls which have led to much disappointment so far. The question for researchers is one of describing what has happened with regard to user companies' experiences of AMT implementation, analysing and explaining such experiences, and, hopefully, developing empirically-informed recommendations to assist with future technology projects.

This study is a contribution to developing a better understanding of technology-induced organisational change. It focuses on the contemporary implementation of computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM) systems and the organisational processes whereby such independent technology applications are integrated in selected manufacturing organisations in Scotland.

1.2 Defining CAD, CAM and Other Relevant Concepts

In this section the basic concepts behind the acronyms "CAD" and "CAM" and two other closely related concepts will be defined.

[1] See List of Abbreviations for acronyms. Each acronym used in this thesis consists of the initial letters of a corresponding group of words which appear against the acronym and thus define it.

1.2.1 CAD

A comprehensive definition of CAD is needed for the purpose of this study, one that addresses it both in terms of its functions and constituent components. Groover and Zimmers's (1984: 1-2) provide a suitable one. It is:

> ".... the use of computer systems to assist in the creation, modification, analysis or optimisation of a design. The computer systems consist of the hardware and software to perform the specialised design functions required by the particular user firm. The CAD hardware typically includes the computer, one or more graphics display terminals, keyboards, and other peripheral equipment. The CAD software consists of the computer programs to implement computer graphics on the system plus application programs to facilitate the engineering functions of the user company. Examples of these application programs include stress-strain analysis of components, dynamic response of mechanisms, heat transfer calculation, and numerical control part programming."

Therefore, the term CAD is used to refer to those design activities that involve the use of the computer to create or modify an engineering design throughout conceptual design, analysis, information handling, detailing and modification. Such activities include graphics design, functional analysis, stress-strain analysis, heat and material balances, simulation and modelling, data analysis and cost estimating of proposed products to determine fitness of purpose and economically optimised production (Bessant *et al.*, 1985).

1.2.2 CAE

CAE is sometimes used to refer to CAD/CAM by "extending the link beyond the 'pure' design area into the latter stages of the manufacturing process." (Bessant, 1991: 164). It involves the utilisation of a CAD system for purposes beyond basic drafting and design into the various types of analysis activities involved in the formulation of nearly any engineering design project. The significance of CAD is further highlighted in the role it can play in developing computerised integration via CAE, and thus creating the base for a company-wide flexible automation project (Kaplinsky, 1984).

CAE helps designers simplify sophisticated design analyses through the use of engineering analysis techniques such as finite element analysis (FEA) and analysis of mass properties (Adler, 1889; Groover and Zimmers, 1984). An analysis of mass properties helps a designer assess properties of a solid object being analysed, such as the surface area, weight, volume, centre of gravity and moment of inertia. An FEA involves dividing the object into a larger number of finite elements with a view to evaluating its stress-strain, heat transfer and other characteristics. Consequently, undesirable object behaviour could be changed by modifying the design under evaluation.

1.2.3 CAPP

Computer-aided process planning (CAPP) allows the free flow of information from design to manufacturing through a computer network with the advantage of planned manufacturing process for product components. It is defined as:

> "A computer application which supports the development and creation of the technological plan required to produce a given part. It is an important application from a CIM perspective since it is a key interface between ... CAD and ... CAM. The resulting process plan consists of a statement of the sequence of operations necessary to manufacture the part, the identification of the machines on which these operations should be carried out, as well as the operation times." (Browne *et al.*, 1988: 22).

1.2.4 CAM

As Adler (1989) points out, a buy-out policy is more feasible in CAD than in CAM due to the greater degree of firm specificity of the manufacturing process as compared to design. CAM may also cover a much wider range of activities that are normally carried out on the production side of a manufacturing organisation. Since these might vary widely from one company to another a single definition of CAM tends to be less universally acceptable.

Nevertheless, the role of computers in manufacture is to help management monitor and control various production activities through high speed computation, mass data storage and fast retrieval, and systematic detection of errors. A consensus can be established thus far. In general, CAM involves the utilisation of computer technology in the management and control of shop floor production operations of a manufacturing company through either direct or indirect computer interfaces with the physical or human resources of a company.

CAM can be defined comprehensively as "the use of computer systems to plan, manage and control the operations of a manufacturing plant through either direct or indirect computer interface with the plant's production resources."(Groover and Zimmers, 1984: 2). CAM may cover a wide range of applications. These can be classified broadly into two categories (see Groover and Zimmers, 1984):

1) Computer monitoring and control applications:

These are direct applications in which the computer is connected directly to a manufacturing process for the purpose of monitoring or controlling the process.

2) Manufacturing support applications:

These are indirect applications in which the computer is used in support of the production operations in a factory, without it being interfaced with the manufacturing process.

In the first category the computer is used as a tool for performing human-controlled operations on the basis of the information feedback it provides through monitoring a particular productive process. In the second the computer is not physically linked to a manufacturing process but used "off-line" to play one or more support roles. These might include the provision of plans, schedules, forecasts, instructions and information for the manufacturing operations of a user company. The most widely recognised areas of CAM applications in this category include (see Groover and Zimmers, 1984: 3):

1) Computer numerical control part programming whereby control programs are prepared for use on automated machine tools.

2) Computer-automated process planning whereby the computer is used to prepare a listing of the operation sequence needed to process a given product or component.

3) Shop floor control where by the computer is used to collect factory data to establish progress of production shop orders.

It can be noted from the above exposition that defining CAM is not as straightforward a task as that of defining CAD. For a start, CAM is a less established, more complicated, and much more costly technology. Traditionally, in manufacturing industry MIS (Management Information Systems) or DP (Data Processing) departments have resumed responsibility for indirect information technology (IT) applications at a plant level, whereas engineering groups, both associated with product design and manufacturing, have had responsibility for application areas which are more directly related to the core of the manufacturing process (Browne *et al.*, 1988). Thus the term "CAM" is often used by engineers to imply only those manufacturing areas in which their core technical skills are applied[2].

Having defined the basic acronymic concepts in the technology area of concern to the present study, the chapter now proceeds to present the research problem in the following section.

1.3 Presenting the Research Problem

The assimilation of major technological innovations into organisations has been studied extensively in recent years from economic, social, political, organisational, and

[2]Unless otherwise indicated, the use of the acronym "CAM" throughout the thesis reflects an inherently engineering concept of CAM, for two main reasons: (1) the researcher's engineering training background and (2) the study's central focus on the flow of information and material processing in a product design-engineering-manufacturing (DEM) context, rather than broadening the research boundaries to include other aspects such as production planning and control management systems. As a result, the notion of integration utilised is concerned with integration within the boundaries of a manufacturing company, rather than cross-organisational integration.

Different writers on the subject use these acronyms in slightly different ways to indicate specific versions of the basic concepts by combining their elements. To clarify the position of this thesis a clarification note will probably be helpful to avoid possible confusion: when used with "CAD" in the "CADCAM" format "CAM" is to refer to an integrated system in which both elements are interfaced; when used in the "CAD/CAM" format it means that either or each of the two separately is implied but not both of them together.

strategic points of view (Forrester *et al.*, 1995; Markus and Robey, 1988; Plonski, 1989). Arguably it has become more challenging, as a phenomenon, to research in recent years because of the more dynamic nature of the organisational contexts under profound and rapid change in the manufacturing business environment of the 1990s (see, for example, Boaden and Dale, 1990; Fjermestad and Chakrabarti, 1993; Hoffman, 1994; Kovacs *et al.*, 1994; Mac Conaill, 1993; Scott-Morton, 1995). Such is the scope of current change that it involves structures of national economies, structures of individual companies, and the lives of individuals at the work place and in larger society (Hoffman, 1994).

A random survey of both academic and managerial literatures would reveal that the need for change is now almost taken for granted; "it is seen as the hallmark of the late twentieth century" (Stacey, 1993: 2). Organisation theory, for example, has long considered the topic of change to be a significant sub-discipline in its own right (Wilson, 1992). The vast majority of the literature and theorising on change, however, can be located within a "modernist" perspective (Clegg, 1990). Such a perspective is founded upon the power of reason, the search for essentials, the machine metaphor of organisation and a faith in progress and universal design (Gergen, 1992).

It is important to make it clear from the outset that concerns about the "health" of present change theory are by no means confined to researchers preoccupied with "post-modernity" as a real or imagined phenomenon, whose entire existence, after all, could be rightly questioned as an attempt to interpret current history's cultural, social, economic and political trends by (still human) experts in the imaginative field of organisation theory. Many other researchers of various academic interests and research traditions (e.g. Frost and Egri, 1991; Pettigrew, 1985; Robey and Azevedo, 1995; Wilson, 1992; Winch and Twigg, 1993) agree on the need for a more realistic theory of change. The central concern of such researchers is that idealistic assumptions of linearity and rationality often deform the reality of change in organisations as reflected in much of the literature on present change theory.

A technology is more than "simply equipment"; it is "not just pieces of hardware and software, but also [a] system based on engineering principles and composed of elements which are functionally arranged (configured) in certain specific ways" (Clark *et al.*, 1988: 13). The relevance of change theory to this study is obvious. The introduction of a "new" technology[3] can be viewed as a process of change, defined

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[3]The term "new technology" deserves some clarification from the outset to avoid otherwise possible confusion arising from shared meanings ascribed to it. Most observers agree that the most significant "new" technologies are: (1) information technology (including AMT), (2) bio-technology, (3) materials technology, (4) space technology, and (5) nuclear technology (OECD, 1988). Special =

broadly as "the alteration from one state to another" (Peppard, 1993: 274). Hence the relevance may begin to crystallise. Furthermore, the realisation of any possible strategic potential of such technology is dependent on successful implementation. This in turn will be affected to a considerable extent by the quality of the decisions that constitute the implementation process within a given set of contextual constraints. Thus the relevance crystallises further.

One can happily share strategy scholars' (e.g. Fjermestad and Chakrabarti, 1993; Porter, 1983; Schroeder *et al.*, 1995) enthusiastic argument that a successful strategy for change is vital. Nonetheless, one has to qualify this position by adding that a "good" strategy *per se* is insufficient for a successful implementation of a change process because the success of the former is contingent upon how the latter has been managed in practice within the constraints of a given situation; "the secret of success is to create success" (Fjermestad and Chakrabarti, 1993: 261). Of course, a strategy-formulating process is necessary for an effective management of technological change. It is argued, however, that that should be managed simultaneously with a careful consideration of the social relations elements, particularly the "distribution of power" within it and "the political tactics that can be employed in shifting the balance in favour of change" (Nutley, 1991: 223). Parallel organisational change and development to enable effective implementation of new technology is crucial (Bessant, 1994). Again, therefore, the relevance of change theory to the implementation of technological change is further consolidated.

When it comes to integration of CAD and CAM systems the organisational implications of change become much more profound than when single applications are introduced. As Arcelus and Wright (1994), for example, point out, the implementation of a computer-integrated manufacturing (CIM) strategy is partly dictated by characteristics that are unique to each adopting firm. Social scientists' perspectives on organisational design, particularly after the "socio-technical systems" design tradition (Emery and

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= programs designed to advance R&D and facilitate new applications of such technologies are promoted in many countries around the world.

In their distinguished article 'Management in the 1980s', Harold Leavitt and Thomas Whisler (1958:42) called information technology "new" because "one did not see much of it until World War II, and it did not become clearly visible in industry until a decade later. It was also "new" because it could be differentiated from the then dominant managerial philosophies such as Frederick W. Taylor's (1911) *scientific management*. As Clark (1989: 5) points out, however, the term "new technology" can be confusing in the literature. It is used in two different ways: first, to describe a technology that is relatively newer than established one (e.g. "An electronic typewriter is a new technology to an organisation or individual if it replaces a mechanical typewriter"), and/or to denote the most advanced level of mechanisation or automation at a certain moment in time with reference to a particular task or set of tasks.

In this thesis the term is mainly used to imply the second meaning but the first will be resorted to on a few occasions, in which case this should be clear from the appropriate context in which the term appears.

Trist, 1960; Rice, 1963; Trist and Bamforth, 1951), suggest that organisational issues should be managed in parallel with technical issues (Bessant, 1994; Bessant *et al.*, 1985; Susman and Chase, 1986; Symon and Clegg, 1991). In terms of an integrating technology such as CADCAM, technical integration should be mirrored by organisational integration if its full potential benefit is to be realised (Child, 1987).

However, what makes strategy formulation, and more significantly its implementation, exceptionally challenging at present is that such change is evolving within manufacturing organisations which are themselves changing in at least four ways (see Abernathy and Utterback, 1975; Browne *et al.*, 1988; Coates, 1992; Hoffman, 1994; Schoeder *et al.*, 1995):

1) Competition has become more intense due to globalisation of markets.

2) Emphasis on cost reduction and efficiency improvements has lost ground to flexibility, responsiveness, niche markets and customer satisfaction, particularly in high-growth industries such as pharmaceuticals, electronics, and medical equipment. In these areas competitive advantages often manifest themselves in accumulated knowledge more than in the physical marketed products.

3) Technological advancements have changed many work methods in business conduct terms.

4) Conventional hierarchical organisation structures ruled by command and control corporate cultures have come to be questioned more seriously than at any time before by a generation of "computer-literate" managers aspiring for initiative, creativity, and empowerment (Hoffman, 1994).

Various IT applications provide an opportunity for businesses to improve their efficiency and effectiveness (Thong and Yap, 1995). IT may potentially help manufacturing companies improve their flexibility and responsiveness to customers through computerising their product design, engineering and manufacture functions, which are the key activities of many manufacturing companies. Computerising such functions, through the application of technologies such as CAD, CAE and CAM systems, is widely believed to be useful to a manufacturing business but integrating such systems can be much more rewarding - both technically and economically.

Over the past twenty years or so, computers have become widely employed in all phases of a product design-engineering-manufacturing (DEM) cycle. A substantial growth in the use of computer systems has been witnessed during the 1980s and 1990s throughout a wide section of the manufacturing industry (see Scott-Morton, 1995).

Despite a phenomenal growth in the utilisation of such "stand alone" technology systems, however, DEM (Design-Engineering-Manufacturing) processes in the majority of manufacturing companies are still exchanging data and design decisions much as they did a century ago, with paper drawings and reports (see Boaden and Dale, 1990: 305; Gunson and Boddy, 1989: 41). Integrating a DEM process through the interfacing of CAD, CAE, and CAM systems is much more challenging, from an organisational point of view, than introducing a single stand alone system (Bessant *et al.*, 1985). At the same time, organisational challenges to integration appear to be much more difficult to overcome than financial and technical problems.

Although a somewhat "idealistic strategic perspective" on integrated CADCAM or CIM would promise a "competitive edge" through reducing costs, improving quality, enabling variety production, reducing product introduction times, and improving delivery reliability, the reality in many manufacturing companies is different (Forrester *et al.*, 1995). Against this background it is quite reasonable to expect an important question to arise concerning the gap between the "potential" and "real" impacts of such advanced integrating technology (or what Bessant [1991] terms its "promise" and "reality") for manufacturing industry which has become as much a processor of information as it is of materials.

The role of social sciences research in describing, explaining and guiding technological and organisational change is crucial, especially in the present phase of the history of manufacturing industry. The present phase is one of unparalleled interconnectivity between systems, with interactive effects that are not only system-wide but have an impact on matters of organisation form and configuration. Contemporary technological mutation is a phenomenon that deserves to be studied from an organisational perspective because it influences organisational structures, cultures and values, just as much as it is itself influenced by such organisational characteristics.

It is important to investigate technological change from perspectives other than "pure" rational economics. While the argument about adoption may often be couched in economically rational terms, the decision to change and the implications of so doing are rarely, if ever, as tightly prescribed. Hence, a broader and more subtle lens is required, one that looks closely into the interior life of the organisation in question. The need to better understand the organisational, and thus social, implications of integrating CAD and CAM necessitates further research into the type of work organisation that is inherited from the previous era and whether or not it is suitable for the present one. To what extent can CADCAM changes enter into an organisational form that predates them? What aspects do they tend to have the most impact upon, and why?

> "It is now apparent that technological change is closely associated with not only economic, but also social, legal and cultural changes whose interactions is complex. .... In this sense, technology can be defined as a social process which by meeting real or imagined needs changes

the needs just as it is changed by them. Society is changed by technical change, and technical change is shaped by society." (OECD, 1988: 117).

Therefore, the present research is a contribution to addressing the gap between theories of change and the practical reality of technology-induced change in organisations adopting and integrating CAD and CAM technologies in their operations.

Technology promises made by salesmen and found in the technical literature will be investigated in the light of selected companies' experiences of implementation and integration. In the present thesis the starting point arises from a concern that, despite obtaining the most sophisticated technology available to support its DEM process, a manufacturing company may fail to deliver its anticipated benefits. So an organisational solution has to be found whereby the technology should meet exactly the technical requirements of the production system into which it is incorporated. At the same time, the organisation should be developed in such away that allows the technology to be used in such a way such that its potential pitfalls are avoided and negative organisational side effects minimised. Technology-organisation interrelationships and the managerial challenges of understanding and addressing them are central to the present research question.

In short, it is argued that for a better understanding of technology-induced organisational mutation it is crucial to utilise a research design that is as longitudinal and grounded in the social "fabric" of the organisational settings concerned as possible in order to build a thorough understanding of the interaction between the causes and effects of change. The research seeks to develop an empirically-informed set of theoretical propositions and hypotheses that derive their validity from an understanding of the process of organisational change accompanying technical change. Central to defining the research problem within the context of this approach is a desire to identify the technical, organisational, political, and economic factors at play in the acquisition of organised knowledge and techniques, rather than superficially on how it is managed as a purely linear, rational managerial task.

1.4 Purpose of the Study

As Creswell (1994) points out, a focus for a study could emerge through a literature review, be suggested by colleagues, researchers or supervisors, or be developed through practical experiences. The focus for the present research emerged during a postgraduate course in *Manufacturing Systems Engineering* attended by the researcher. The course was broadly designed for practising and recently graduated engineers to develop skills in optimising the application of various computer-controlled systems in manufacturing processes. The researcher developed considerable interest in the human and organisational issues associated with automation as it appeared that these, rather than technical issues, were behind numerous disappointing experiences - some might say failures - of new technology projects in industry.

The utilisation of AMT, it seemed, necessarily required a more thorough understanding of these issues than the average engineer-by-training would possess. Ideally, technical knowledge, it appeared, would stand a much greater chance of successful diffusion in a manufacturing organisation when complemented by sociological knowledge. Thus the idea for this study was born.

The study started by synthesising a set of questions regarding the implementation and integration of CAD and CAM systems. Seven tentative research questions were identified as important in providing an orienting conceptual framework for the investigation in the selected sites prior to approaching field work in these sites. These are:

1) Why do manufacturing companies acquire CAD and CAM systems?
2) How do manufacturing companies design/use CAD and CAM systems?
3) How do manufacturing companies introduce, maintain and develop CAD and CAM systems?
4) What are the outcomes of the implementation of CAD and CAM systems in terms of pre-identified objectives ?
5) What are the impacts of the implementation of CAD and CAM systems on manufacturing organisations?
6) Why does a manufacturing company seek (or decline) to integrate CAD and CAM systems?
7) Where applicable, how does a manufacturing company manage the integration of CAD and CAM systems in the context of its accumulative experiences in this area of technical change?

These are not "research questions" in the conventional sense of the word. In a way, their significance to the research process is provisional, as will be explained in detail in Chapter 3. Answering them *per se* will be one of the basic objectives of the research. The ultimate purpose of the research, though, is to contribute to the generation of empirically-informed theoretical propositions and hypotheses on the implementation and integration of CAD and CAM. The aim is one of theory creation by virtue of an inquiry that is deeply embedded in the organisational settings concerned, rather than a literature-premised formulation of "logico-deductive" theory.

Chapter 3 will explain in detail how these questions are used in the methodological framework of the present study in the light of a carefully defined relationship between theory and methodology. It will also clarify the terms relevant to the methodological approach chosen and the rationale behind it in relation to the objectives of the present research.

1.5 Relevant Literatures

One challenge that faces researchers in any study which ranges across different areas of knowledge, like the present one, is to isolate the relevant literature. There is a wide range of available theoretical and empirical work that could be used in a number of direct and indirect ways. The study focuses on a specific type of change process that concerns a well-defined area of technology application. Yet, the fields of academic interest which the study touches upon are multiple indeed.

Therefore, various literatures will be relevant to varying degrees, some of which become more relevant than others at various stages of the thesis. These can be grouped as shown below, starting with the most relevant literature area concerning CAD, CAM, CADCAM, CIE and CIM:

* The specific literature on CAD, CAE, CADCAM, CIE, and CIM application management in industry and implications for work organisation (e.g. Adler, 1989; Dean and Snell, 1991; Kovacs *et al.*, 1994; Lee, 1989; 1991; McLoughlin, 1990; Patankar and Adiga, 1995; Winch *et al*, 1991).

* The engineering literature on AMT, automation and computers in manufacture (e.g. Bessant, 1991; Boubekri *et al.*, 1995; Browne *et al.*, 1988; Groover and Zimmers, 1984).

* The engineering and management consultancy literatures addressing practising managers (e.g. Boaden and Dale, 1990; Peppard, 1993; Plant, 1995; Scott-Morton, 1995).

* The literature on innovation, technical change, and management of change (e.g. Beatty and Gordon, 1991; Beatty and Lee, 1992; Bessant *et al* , 1985; Frost and Egri, 1990; Pettigrew, 1990; Stacey, 1993; Tapscott and Catson, 1993; Van de Ven and Poole, 1995; Winch and Twigg, 1993).

* The literature on technology strategy (e.g. Arcelus and Wright, 1994; Fjermestad and Chakrabarti, 1993; Mueller, 1993; Porter, 1983; Schroeder *et al.*, 1995).

* The work and organisation studies literature (e.g. Child, 1977; 1987; Clegg, 1990; 1994; Perrow, 1984; 1986).

* The literature on research methodology (e.g. Creswell, 1994; Glaser and Strauss, 1967; Strauss and Corbin, 1994; Yin, 1984, 1987).

Whilst the thesis is concerned narrowly with CAD, CAE, CADCAM and CIM, it would not seem to be appropriate methodologically to restrict it to the first group of literature. Neither is it helpful, theoretically and empirically, to neglect the huge body of knowledge which addresses, in different ways, matters pertaining not only to technology, organisation and technical change, independently, but also to the complexity of relationships between them. These are themselves subject to multiple perspectives. For example, organisation theory offers several perspectives in analysing an enterprise in conjunction with its environment, size, structure, hierarchy and control, power dynamics, strategies and performance, among other things.

The literature is "vast" (Winch and Twigg, 1993). It can only be considered here as it enters into the main focus of this study. Nevertheless, some key studies on integrated CADCAM implementation will be selected and discussed in detail in Chapter 2. This will identify where the present research stands vis-a-vis the specific relevant literature.

1.6 Delimitations and Limitations

The study narrowed in scope as it progressed. Delimitations have to be acknowledged. The potential disadvantages of the study should be recognised as limitations caused mainly by time and resource constraints. The limitations can be summarised in six points as follows:

1) From the outset, the scope of the research had to be narrowed from one which could potentially address new technology as such in a broad sense of the word, through to one which was confined to IT as a particular area of new technology, albeit of a vital importance, and, eventually, to its present CADCAM-delimited form.

2) As the study progressed into its later stages it identified three major axes around which to conceptualise the change process of CADCAM integration (Chapter 6). These revolved around the technical, economic (or business) and organisational aspects of change. The study began with a very broad-based perspective; it developed by identifying these and then concentrating mainly on the organisational and technical aspects. It could thus be classified as a socio-technical study. Although the business aspects were consistently recognised, they did not gain the same degree of attention as the other two. It would have been beyond the scope of an organisational study to have done so. The focus was narrowed so that the organisational element would become the study's central focus of attention. Thus it ended up with the highest degree of emphasis. The technical and economic issues associated with CADCAM change were no less important theoretically but this was another delimitation of the study. To research the technical and economic elements thoroughly as well would have required another study - not a better one or a worse one, not more or less important, but one equally as valid while totally different in its approach, perspectives, methods and literature.

3) Priority was given to work organisation rather than job design issues in developing the theoretical propositions because the research focused on CADCAM as an essentially integrating, cross-functional technology. It was not possible to proceed evenly in both directions. Whenever a conflict appeared to occur priority was given to organisational analysis. One should not imply through such prioritisation that concerns about job design were less important theoretically; it was a matter of deciding on priorities, whilst not neglecting the organic interrelationship assumed between the two areas of theoretical interest. One could think of their interrelationship as in terms of a huge tree representing organisation theory, in whose branches were rich materials for research into job design issues.

4) The empirical aspect of the study was based only on ten in-depth case studies. The sampled companies included a rather broad range of companies within Scotland's electronic/electrical industry. Therefore, the scope for hypothetically-based generalisation was limited in the light of the qualitative research approach used. Initially, a quantitative dimension was intended to supplement the study towards the end of the research period on the basis of the qualitative data analysis resulting from the case studies. Quantitative measures would have been constructed. This, however, proved to be too ambitious; it was undoubtedly too much to attempt within the confines of a single doctorate. It was rather unrealistic given the time and resource constraints; the qualitative analysis was, indeed, an extremely time-consuming process. Had it been a research team's effort this would have stood a much greater chance of being achieved. It should be said, nonetheless, that for the future a combined research design would create a greater scope for generalisation of the findings and the theory generated[4].

5) The research design excluded industrial sectors other than manufacturing. There were three reasons for these exclusions: first, CADCAM, in essence, is a manufacturing technology to be found predominantly in manufacturing organisations. Second, the constraints of the local economy suggested the electronics industry because it was a recently emergent industry, one that replaced ship-building, coal-mining, heavy engineering and other older industries in Scotland. The third reason was a methodological choice whereby the study's theory generation objective required a case study research design anchored in concrete organisational settings. This requirement restricted, to a considerable extent, the researcher's freedom of movement to and from the research sites due to the relatively high frequency of visits conducted. This should be recognised as another delimitation of the study: qualitative research is more labour-intensive, time-consuming and demanding than survey work - but it also develops far

[4]This point will be discussed in more detail in Chapter 3.

more insight, especially important for research into a relatively recently observed phenomenon.

6) The study was confined to Scottish-based sites. Although these varied in terms of ownership (e.g. some of them being British and others American-owned), they were all Scottish-based. This deprived the study of any broader scope of analysis whereby the roles of other national and cultural influences could be assessed in a comparative context.

1.7 Significance of the Study

The study has significance at both the theoretical and the practical levels. Firstly, its theoretical importance can be summarised in the following points:

1) The structured methodology which the study developed facilitates a systematic investigation of technology-led organisational change and a deeper understanding of the varied effects and outcomes of such a process. Such methodology is designed to constitute a step forward towards an impartial assessment of both the existing and the potential effects of a certain application area of new technology in the face of a plethora of marketing-oriented literature, newspaper articles, television programs, and consultant writings on the subject, much of which is of speculative nature and based on little or no empirical evidence or unexplained methodologies.

2) Combining a grounded theory (GT) methodology with a longitudinal research process enables the study to offer an in-depth interpretation of the process of implementing and integrating CADCAM systems. Such an inquiry (and, thus, interpretation) draws its strength from the ways in which its insights are embedded in the organisational settings researched. The development of theory that relates to integrating technologies, such as CADCAM and manufacturing resources planning (MRP -II), will benefit from contributions that bring new qualitative elements capable of addressing the cross-functional impacts of such technologies. Unlike stand alone technologies such as CAD or robotics, integrating technologies create a greater need for embedded theorisation that relates to organisational, not just job, design skills. Generation, rather than verification, of appropriate theory aims to improve visualisation of how real integration processes influence work organisation at present, and in what possible ways they can affect companies in the future. A better understanding of integration, through the study's conceptual model, will deepen our understanding of the nature of the host of factors involved (e.g. environment and market forces), which the model accounts for, as well as the linkages between them.

3) Further theory development can be guided by the answers provided to the seven tentative questions of the research. Such development can be taken far beyond the substantive limitations of the grounded theory and formalised by virtue of theoretically-oriented, generalised abstraction. The theoretical implications that derive from the research cover a relatively wide range of issues of concern to current sociology and organisation theory. The research aids the future development of hypotheses that can further more structured empirical research. In this respect, the present study seeks to create a space in which other forms of theoretical cultivation might subsequently flourish. Vital questions can be devised and hypotheses formulated to this effect. For example, why do organisations acquire new technology? How and why do different organisations set about implementing it? How is the implementation process managed under different contextual conditions? What are the possible various impacts of such technology (i.e. its "implications", "consequences" and "effects" [Ang and Pavri, 1994])? And what are the dynamics of the processes and interactions whereby it comes to be integrated into a host organisation and how, consequently, the host organisation's structure, operation, and culture come to be affected? The emphasis will be on conceptualising integration as an advanced stage of a technological (and organisational) change process whose roots can be traced to the earlier implementation of constituent sub-systems (e.g. CAD and CAM). One of the main concerns of this study is the issue of how a specific company's approach to integration is contingent upon its past experiences relating the above questions.

4) The conceptual model developed to analyse the research data (Chapter 7) can be utilised, with appropriate modifications, in other studies focusing on other technology applications or under different contextual circumstances.

5) The study contributes, to a limited extent and in an indirect manner, to current debates concerning the potential effects of technology on employment in the current competition age and also concerning the nature of future work at a time of heated debates on the future possibilities of totally computerised or "unmanned" factories of the future. It also touches on the nature of management, work and organisations under "post-Taylorist", "post-Fordist" conditions; on skilling, reskilling, upskilling and/or deskilling of working labour under such conditions; on flexible specialisation in employment; and on power and control issues in organisations. The thesis, thus, contributes, in broad terms, to the debate on the social benefits and costs of technological developments in the contemporary competition age.

6) The study addresses the role of change agents in CADCAM integration by focusing specifically on the effect of functionally-defined managerial specialisms (i.e. engineering vs. manufacturing), on how key change leaders' missions are defined,

assumed, constrained and also politicised (due to departmentalisation as a property of formal structure) vis-a-vis the organisational changes associated with integration.

7) The study addresses the relationship between integration as a presumably problematic change process and organisational learning, particularly in terms of the opportunities available to change leaders to learn from past experiences both of success and failure with stand alone technologies and act upon learned lessons in the implementation of CADCAM.

8) The study contributes to filling a gap in current knowledge in this area of academic interest, namely the question of why CADCAM integration appears to be inapplicable to non-integrating companies despite the fact that some of these are technically capable of achieving it.

Secondly, the practical importance of the study can be summarised in terms of the following points:

1) The research was beneficial for the companies that took part in it. The main practical benefit to these companies occurred through feedback reports on the study's findings. While the reports were addressed to senior and technical managers, a wide range of managers and employees could benefit practically from their contents because integration involved cross-functional, organisation-wide, and cross-organisation relationships. Feedback contained basic data analysis and practical recommendations to managers who played key roles in managing the introduction of CAD and the integration of CADCAM in their respective companies. They received insight not only into their own situation but also were able to contextualise that situation in terms of information derived from the literature review and the comparative analysis of organisations in the same region, against which they could compare their progress. The aim of the applied aspect of the research was to promote improved management of technology projects in the future. The benefit could be extended to companies that shared similar characteristics to those studied. Useful guidance can be derived from the recommendations concerning the factors that make for successful policy and strategy decisions. These include, for example, training requirements for technical as well as interpersonal integrational skills, industrial relations management, cost-benefit analysis and justification procedures, and the human and organisational dimensions of change.

2) The study should help technology consultants in the future to better understand the socio-political nature of organisational change; thus, it should enable them avoid assumptions of rationality and linearity that often characterise the innovation literature. Central to this will be a deeper understanding of the networks of ideological, structural

and power factors behind planning, selecting, designing, and using a proposed technology.

3) Trade unionists also have the potential to benefit from the study. Organisation-wide implications arise from integrating technologies, which give rise to new challenges in the way in which industrial relations and conflicts will be managed under changing power relations due to technical, structural, and cultural changes in the work place. The study may be practically useful to union members in reconsidering their role in technology-led organisational change, resistance to it, and the conditions under which they might rationally support it.

1.8 Layout of the Thesis

The thesis consists of nine chapters. The present chapter has introduced an overview of the study, presented the research problem, defined the overall objective of the investigation, discussed the various literatures that will be used throughout the remaining seven chapters, and identified both the strengths and limitations of the study. The remainder of this chapter will summarise the layout of the thesis in terms of the constituent chapters and their contents.

Chapter 2 will introduce the subject of CAD and CADCAM. It begins with justifying the importance of further research on the organisational implications of CADCAM implementation and integration. It will discuss the diffusion of IT in society but concentrates on the application of computers in manufacturing industry, in particular in the context of concurrent product design and manufacture. It will define CIM and seek to establish the organisational impacts of integration in general terms. Integration of CAD/CAM technologies and its implications for a manufacturing organisation will constitute the central theme of the chapter. In this connection, eight selected studies on CADCAM will be summarised and critically reviewed in the concluding part of the chapter with a view to assessing the state of current knowledge in relation to the research problem and, thereby putting the present study's contribution in context.

Chapter 3 is about the theoretical and methodological issues of concern to the study. It aims to define a specific kind of link between theory and methodology as two of the most vital areas of significance in any research. The chapter then proceeds to discuss the influential factors in choosing an appropriate methodological framework for the study. It compares quantitative and qualitative paradigms and explains why a qualitative approach is more suited to the purpose of this research in the light of its ontological, epistemological and axiological assumptions. Details of the qualitative research design will be illustrated in terms of its basic distinguishing features: GT, case study and longitudinality. Each of these features will be discussed critically to assess the suitability of the research design. The chapter also links the tentative research questions and their underlying assumptions with data. Finally, it concludes by showing and defending the validity, reliability and credibility measures of the present study.

Chapter 4 will address details of the filed work. It covers issues related to the decisions made and choices taken before, during and after the filed work. Choice of the sites to be researched and the criteria guiding such a choice will be outlined. Key details of the companies in the study and individual informants will be given. An explanation of the progress of the overall research process will also be provided, from initial sampling to data collection through a three-phase research strategy. In addition, one of this chapter's major contributions to theory development is that it will link the main interview schedule used in data collection to the seven tentative questions of the research. Another important feature of the chapter is that it spells out the details of data collection, recording, and coding. This chapter will also outline the lessons learned from the filed work as a learning process from the researcher's point of view.

Chapter 5 introduces the cases in the study and discusses each of them separately in terms of their distinguishing features in relation to the issues under consideration in this study. The cases will be divided into two groups on the basis of their respective positions vis-a-vis CADCAM integration. Each company will be discussed in terms of its DEM process and the CAD / CAM applications it uses in its design, engineering and manufacturing activities. Also, the history of technological change in each company will be briefly addressed in terms of CADCAM, with an emphasis on the organisational effects of the 1970s/80s investments in CAD and CAM systems and the consequent organisational context for further investment in integrating such systems. The chapter concludes with a comparison between the integrating and the non-integrating approaches to the utilisation of CAD / CAM as the basis on which the companies were grouped into two categories.

The case write-ups which Chapter 5 provides will serve as a background reading before further data analysis and discussion in next two chapters. In this sense, Chapter 5 is the first of three chapters reporting on the findings of the study and, at the same time, providing analysis and discussion on the collected data.

Chapter 6 provides analytical answers to the tentative research questions by comparing the case studies with each other and in relation to the study's theoretical orienting issues. A conceptual dividing line will be ever present throughout this chapter between two areas of theoretical concern, namely CAD / CAM implementation in the ten cases, on the one hand, and the integration of already implemented CAD and CAM systems in five of these cases, on the other. Theory on integration will be given priority whenever a conflict appears to happen throughout the analysis and discussion of the findings, both in this and the following chapters, because of its greater theoretical relevance to the purpose of the study.

Building on Chapters 5 and 6, Chapter 7 uses a conceptual model especially devised for further data analysis and interpretation. The model will show how integration is visualised as a dynamic change process, one that is engulfed by an "internal context" of change, which is itself influenced by an "external context" of change. Both contexts are capable of producing forces for and forces against change and thus affecting a company's decision whether to adopt an integration approach or not. The model conceptualises the role of contingency variations across the integrating companies in the study, which create various conditions under which different companies' experiences of change are encountered. The external and internal factors behind such variations will be classified as either facilitating or impeding, depending on their respective effects on integration, and will be analysed in the light of the model. The outcomes of an integration process are also included in the model. Using the model as an explanatory instrument, particular attention will be given to addressing the outstanding obstacles to CADCAM integration in the experiences of the companies concerned.

Chapter 7 will also apply the conceptual model to two examples from the cases: a critical incident from a non-integrating company and another from an integrating company. It will explain some of the crucial forces and factors that prohibit and inhibit integration on the one hand and those that cause and stimulate it on the other. In so doing, it will focus on the social processes involved in CADCAM integration as an essentially organisational change.

Chapter 8 presents the theoretical conclusions of the study in the form of substantive and formal propositions as well as hypotheses. These follow from the data analyses and discussions in Chapters 5, 6 and 7. In fact, they could have been incorporated into these chapters, which would have illustrated each of them in its respective contextual position vis-a-vis the corresponding data. This would have shown each of them in relation to the particular area of analysis from which it was derived. However, the decision to set up a separate chapter for the theoretical results of the study was motivated purely by a layout consideration aiming to consolidate the resultant theory by summarising it in a single, very concise chapter, rather than to disperse it over two or three chapters. Therefore, it will not make sense to read Chapter 8 without a prior reference to Chapters 3-7; in this respect, Chapter 8 could not be regarded as a totally independent chapter. That is, Chapters 3 and 4 will be essential prerequisite reading in terms of explaining how the theory was generated, whereas Chapters 5, 6 and 7 will be essential in terms of identifying the sections of data from which the theory derived.

Finally, Chapter 9 provides a concluding summary of the study and its implications. It summarises the nature of CADCAM integration as a change process in the light of the study's findings. It also reviews the tentative questions which the empirical research process began by asking, and assesses the difficulties that were encountered in answering them. The study's conceptual model will be discussed and evaluated. The roles of change leaders, senior managers, technical managers, and supervisors in the transition towards integrated CADCAM will also be addressed in this chapter in the light of the study's conclusions. The thesis has several implications for managers, consultants, trade union leaders, and researchers. These will be outlined in the concluding part of the final chapter.

CHAPTER TWO

Implementation and Integration of CAD, CAM, CIM, CIE: Implications for Manufacturing Organisations

2.1 Introduction

CAD and CAM technologies played a key role in manufacturing industry during the 1980s. Integrated CADCAM promises even greater potential benefits for manufacturing companies. This chapter introduces such technologies and discusses their integration potential and the implications for manufacturing organisations.

It begins by justifying the selection of these technologies for the present research. It then moves to highlight IT's profound impact in general and the role of computers in particular in manufacturing industry.

The next point to be examined is product design and manufacture as the main activities of a manufacturing concern. The chapter then discusses the evolution of CAD and CAM technologies and the logic of technical rationality that lies behind their diffusion. Organisational issues that are contingent upon the use of such technologies will form a most important part of this chapter, particularly in relation to CADCAM as an integrating technology. The subject of integration will be addressed in terms of its implications for technology-led organisational change.

This chapter concludes by critically reviewing some of the most relevant studies on CADCAM integration.

2.2 Why CADCAM?

The magnitude of the relevant academic literature is indicative of a massive multi-perspective interest in researching CAD (e.g. Cooley, 1981; Currie, 1989; Lee, 1989; Manske and Wolf, 1989; McLouglin, 1990; Schmidt, 1991) and CAM (e.g. Edosomwan, 1987; Gerwin, 1988; Gobeski, 1991). The literature on integrated CADCAM (e.g. Adler, 1889; 1990; Lee, 1991, Winch and Twigg, 1993) and CIM (e.g. Fjermestad and Chakrabarti, 1993; Kovacs *et al.*, 1994; Voss *et al.*, 1991) has also been substantial, though to a lesser extent.

CAD and to a lesser extent CAM have been studied from different perspectives and for different purposes. This is because they both have implications for, among other things, job design, work organisation, skilling, quality of working life, industrial relations, managerial work, strategy formulation and investment appraisal practices, as will become clear during the course of this thesis (Chapters 2, 5 and 6). CADCAM has also been researched in recent years (e.g. Lee, 1991; Winch and Twigg, 1993; Winch, Voss and Twigg, 1991). Yet CADCAM has been chosen as the technology area for investigation in this study for the following reasons:

1) Design, almost universally, occupies a key position in the operations of any manufacturing company because it is where the end product is conceptualised and fundamental decisions are made which influence the choice of manufacturing operations and the consequent production and assembly processes. For these reasons the position held by the design office is highly likely to be of key importance for the entire functioning of the company (e.g. Baldry and Connolly, 1986; Bessant, 1991; Schmidit, 1991; Teicholz and Orr, 1987).

2) Since design functions occupy an exceptionally important position in manufacturing organisations, CAD gains a distinctive significance from among a wide range of enabling technologies used by the various functional departments of a typical manufacturing company. This provides design staff with an influential bargaining power, which could imply that management would be willing to respect their interests and wishes (e.g. Schmidt, 1991; Teicholz and Orr, 1987).

3) Whereas stand-alone applications have been researched reasonably extensively from an organisational analysis point of view, the integration of CADCAM has not yet gained the same degree of attention despite its greater cost and the fact that it is potentially more radical in terms of its impact (e.g. Winch and Twigg, 1993).

4) The significance of CADCAM, as an integrating technology, lies in its potential ability to force reorganisation not only within the functional boundaries of design and manufacturing but also in terms of the flow of work between them.

5) The scope of an integrated CADCAM will not be limited to design and manufacturing in the future. Other functions will be affected in terms of how individual jobs will be designed (or redesigned) and departmental work organised (or reorganised), both locally and in terms of their respective work relationships with other functional departments.

6) In addition to inward-looking considerations, the breadth of CADCAM implications is such that it is also likely to be viewed in terms that are external to an integrating company. As multiple customer and supplier firms become more involved in integration, because of technical and business reasons, the importance of CADCAM is likely to increase in the future, not only as an internal company-wide issue but also as a cross-organisational concern.

2.3 IT and its Profound Implications

"Diffusion" is a word often used in the literature to describe the spread of an innovation or technology (see Attewell, 1992). The diffusion of CAD and CAM has been assisted largely by the considerable advances in computer technology over the last three decades. The appearance of the "personal computer" (PC), as a direct consequence of changing cost and capability relationships between microcomputers and mainframe computers, was perhaps the most significant milestone aiding this diffusion (Krouse *et al.*, 1990).

The revolution in the microprocessor market since the late 1970s has resulted in a greater information processing power and capacity being available than ever before and at a reasonable cost to many smaller businesses. Computer-based technologies have therefore found a wider scope of application, and the question for management is no longer one of whether or not to adopt the technology, but which system to use (Bessant, 1991) .

According to the *"Dictionary of Computing"* (Illingworth *et al.*, 1983) the term "information technology" was coined in the late 1970s to refer to a combination of modern microelectronics, telecommunication technologies as well as major parts of consumer electronics and broadcasting. It is:

> ".... an all inclusive term that encompasses computers and telecommunications in all their forms, whatever their use. It includes mainframe computers, supercomputers, microcomputers ..... It includes the public telephone network, television and radio broadcasting, credit cards ...., radio paging systems, facsimile machines, and cellular telephones, as well as the software that controls them all." (Hoffman, 1994: 11).

Back in the late 1950s Leavitt and Whisler (1958) predicted in their seminal article *"Management in the 1980s"* that IT would spread rapidly. It has (see, for example, Ang and Pavri, 1994; Attewell, 1992; Coates, 1992; Scott-Morton, 1991; Tapscott and Catson, 1993). Over the last twenty five years innumerable articles and books have been published on tomorrow's work place in the light of the wide-spread applications of microelectronics in industry and offices (Sarfati and Cove, 1986). The potential of computing and related technologies to affect society at large underlies recent more futuristic visions, often given attractive names (e.g. "the information age" [Coates, 1992]). In these technology is introduced progressively as a means of supporting faster and more accurate flows of information by overcoming constraints of time and place (Scott-Morton, 1991; Tapscott and Catson, 1993). IT's impact on society, organisations and individuals, particularly in industrially advanced countries, can be felt nowadays in daily life and in every sector of society (see, for example, Kling, 1980; Sarfati and Cove: 1986). Its effects are "complex and defy any straightforward interpretation" because they are "more complicated and convoluted than has been traditionally assumed, and much more research is needed before a clear picture is likely to emerge" (Ang and Pavri, 1994: 125 and 132).

Indeed, paradoxes of the "information age" are recognised (Coates, 1992). For example, IT is potentially capable of encouraging political democracy by virtue of widely dispersed information but, at the same time, creating economic elitism because access to such information is less widely shared. This situation can be understood, in general, in the broader context of contrasting views on the social and economic advantages and disadvantages of scientific and technological development. In general, three basic reactions can be identified in society vis-a-vis the spread of IT: the pessimists, the optimists and the relativists or pluralists (see Hirschheim, 1985; Sarfati and Cove, 1986).

The optimists assert that IT increases productivity, creates as many jobs as it destroys, improves organisational efficiency, enhances communication, improves the quality of working life, and allows for more varied leisure and medical facilities. The pessimists associate IT with mass unemployment, deskilled jobs, reduced job satisfaction, centralisation of power, and lessening of personal privacy and freedom. The pluralist view is non-deterministic; it lies somewhere in the middle by stressing that the results of IT assimilation depend on the way the technology is put to use. As Frost and Egri (1991: 274) put it: "adopting a philosophy of technological determinism denies the critical human role of social choice in innovation". This view reflects an established theoretical current in the literature, which argues against technological determinism (see, for example, Durand, 1990; Sorge *et al.*, 1983; Buchanan, 1984).

Researchers such as Ang and Pavri (1994: 133) realise the implications of such diversity of perspectives for the present and future research agenda. They rightly argue that:

> ".... the important thing is to know that while each perspective has its merits, it also has its restrictions. Researchers have to be aware of the restrictions of the various perspectives so that conclusions drawn are less likely to be challenged on grounds of validity." (Ang and Pavri, 1994: 133).

The universal applicability of IT has encouraged its use for so many different purposes. In this respect, IT differs from most technologies which offer benefit within a narrower range of possibilities. This, in turn, supports the view held by many that IT is:

> ".... much more than a single technology: like steam power or electricity before, it is a generic technology. And it is this property that - the potential to offer a wide range of competitiveness-enhancing benefits right across the industrial spectrum - which really explains the claims for its revolutionary status." (Bessant, 1991: 49).

2.4 The Role of Computers in Manufacturing: An Overview

In general, computers play a significant role in manufacturing in, for example, assisting process monitoring and control, CAPP, numerical control data, line balancing, and inventory control (Boubekri *et al.*, 1955). The potential advantages include allowing better use of skilled time, speed of computation, mass data storage and fast retrieval, rare production of errors and systematic detection of problems through the formal organisation of information.

As Browne and his colleagues (1988) point out, the computer is used in "direct" and "indirect" manners. Direct applications serve the purposes of monitoring and controlling manufacturing operations at a "plant level" (e.g. flexible manufacturing systems [FMS] and computer-aided warehousing [CAW]) and at an "operational level" (e.g. computer numerical control [CNC] and computer-aided testing [CAT]). Indirect applications include, for example, CAD and production management systems at a plant level; they also include applications such as CAPP and computer-aided NC (Numerical Control) programming at an operational level.

The next section discusses product design and manufacture as the main activities conducted in the context of a manufacturing organisation's operations.

2.5 Concurrency in Product Design and Manufacture

A design process involves a range of activities that are essential for the creation of a new or improved product. Product ideas, customer specifications, safety and regulatory standards, and materials are acquired and converted into drawings containing detailed information about a product (Bessant, 1991).

Various engineering skills are often incorporated into design processes in manufacturing engineering industries where products can be extremely intricate in technical terms. Engineering design involves its own version of engineering synthesis, analysis, optimisation, evaluation and presentation (Groover and Zimmers, 1984). In the particular case of the electronics engineering manufacturing industry[1], which is the subject of investigation in this study, the activities typically carried out by designers include printed circuit board (PCB) layout, integrated circuit design, drawing and blueprints for mechanical parts, engineering calculations, structural analyses as well as responding to customer-specific requests (Bessant, 1991).

[1]Large and varied amounts of data are processed in this industry where the final deliverable product typically incorporates complex assemblies of tens or hundreds of components and probably thousands of subcomponents, including resistors, capacitors, inductors, transformers, transistors, connectors and integrated circuits.

The significance of design activities in any enterprise is that they determine, to a large extent, the quality and cost of manufacturing a proposed product since they establish the initial data base for production (Teicholz and Orr, 1987). Information produced by design provides vital input to other functions such as production planning and control, and shop floor production as well as to engineers responsible for developing new processes or improving existing ones.

This helps one explain the unique importance of CAD as "a core technology" in the development of flexible automation (McLoughlin, 1990). As indicated in reports such as those by *NEDC* (1984) and *ACARD* (1983), AMTs, in general, are considered of crucial strategic importance to the competitiveness of the UK manufacturing industry (see also Bessant and Buckingham, 1993). CAD, in particular, is deemed essential for the "design-led" regeneration of British industry (ACARD, 1983). The competitive importance of design has grown further recently in line with increased demand for product innovation, greater response to customers and rapid new product development cycles (Bessant, 1991).

Whereas design results in the presentation of a synthesised conceptual image of a product, manufacturing results in the physical realisation of this image. Manufacturing is essentially a productive activity which involves "the collection of physical and intellectual activities associated with designing and making tangible, movable items of value, either by hand or through the use of machinery" (Bedworth, *et al.*, 1991: 600). A manufacturing process is carried out jointly through the collaborative efforts of many individuals organised for the purpose. The above definition is particularly useful because, by deduction, it identifies product "designing" and "making" as the core functions of a manufacturing organisation. These are associated directly with CAD and CAM. They involve the application of computers in, respectively, designing and making a given product.

Product design and manufacture could be done in parallel (i.e. simultaneously or concurrently) or series (i.e. design followed by manufacture). However, a DEM process would benefit greatly from concurrency. The role of computers in a manufacturing enterprise environment could, potentially, be maximised through "incorporating various life cycle values into the early stages of design. These values include not only the product's primary functions but also its aesthetics, maufacturability, assembly, serviceability, and even disposability" (Ishii, 1990: 217). This is the crux of what is widely known both in industry and in the technical literature as "concurrent engineering" (CE) or "simultaneous engineering" (SE).

Current roles of the computer in CE include: (1) CAD environment, (2) simulation programs of the production process, (3) design assessment programs, (4) on-line advisory programs, and (5) Concurrent design programs for products and processes. Potential computer-aids in the CE area include: (1) software to help in design for value (DFV), (2) design for injection moulding and die casting, (3) design for serviceability and reliability, and (4) integration of simulation programs with CAD (Ishii, 1990: 223).

2.6 Evolution of CAD / CAM Technologies

Historically, the roots of CAD technology could be traced to the invention of interactive computer graphics which were used as early as 1959 to generate pictorial representations. CADD systems were then developed to generate two-dimensional representations of parts and basic manufacturing information (Bedworth *et al.*, 1991; Bessant, 1991). Experimentation in mainframe-based graphics CAD technology began with a view to commercial application in the mid-1960s by giant US manufacturers. Major technological breakthroughs in the computer industry during the 1970s resulted in the development of "turnkey systems" which became widely available on a commercial basis. The US military played a crucial role in developing CAD (Senker, 1985). British industry's interest in CAD began in the 1960s. A major factor which stimulated the proliferation of CAD technology was the commercial availability of turnkey interactive graphics systems since 1977 (see Senker and Arnold, 1980; 1982). By the end of the 1960s, *Elliott Automation*, *Ferranti*, *ICL* and *Marconi* were offering mainframe-based CAD systems and services (Senker, 1985).

The emergence of PC-standard computers in the early 1980s was a turning point in the history of CAD (Krouse *et al.*, 1990). The CAD market originated in some of the most resourceful companies in the defence, aerospace, and aeronautical industries with the collaboration of major mainframe computer manufacturers (Kaplinsky, 1983). The scope of CAD application is expected to grow even further (see, for example, Mac Conaill, 1993; Newton, 1989).

New, smaller firms spun-off from larger, older firms and entered into the CAD supply market, penetrating a wider user base by selling limited capability dedicated CAD systems. Consequently, prices dropped considerably (Kaplinsky, 1983). This made possible the availability of some features which were previously only confined to larger and more complex systems, such as 3-dimensional and simple CAD/CAM. More user-friendly PC-based CAD systems also reduced installation and training costs. Therefore, it was not surprising that CAD technology was destined to attract many more users with less money to spend. Such developments help explain the rapid growth in the CAD market through the 1980s and the proliferation of CAD suppliers (see Bessant, 1991; Hoffman, 1994; Kaplinsky, 1983):

> ".... the personal computer revolution is a direct consequence of changing cost and capability relationships between microcomputers and main frame computers ..... the PC has generated profound business and organisational changes, as well as major changes in the way many people do their work." (Hoffman, 1994:11-12).

The diffusion of CAD technology has taken place mainly in industries with major design requirements (e.g. aerospace, electronics, automobile, and construction). It is in these fields that the majority of users work, either as designers employed by companies or by independent design houses. Coding and classification systems are, therefore, essential for managing part and assembly manufacture more efficiently. Hence, CAD gives designers more opportunities to experiment with alternative designs and offers a potentially vast improvement over, for example, manual PCB design for both managers and engineers (Salzman, 1989). This is why it is viewed by some as a labour saving technology (Newton, 1989).

CAD can potentially help the standardisation of product parts, thereby minimising the variety of fittings and reducing design time (Salzman, 1989), manufacturing complexity (Adler, 1989) and increasing productivity (Newton, 1989). However, it should be stressed that, as researchers such as Liker and Fleischer (1989) and Adler (1989) note, this is conditional on user companies taking greater advantage of more advanced CAD features and changing their design and manufacturing organisations in order to realise the full potential of computers in the design process. Significantly, the importance of the organisational adjustments required to accommodate CAD is seldom recognised.

The evolution of CAM could be understood in the context of the history of automation in manufacturing. The roots for automation of discrete-part production, which is the focus of attention of the study (i.e. as opposed to continuous or process type of manufacture), could be traced to the mass production concepts developed by Henry Ford early in the twentieth century. Since then the evolution of CAM systems has come from progressive developments in manufacturing technology concepts such as NC, CNC, CM (Cellular Manufacturing) and FMS since the 1950s through to the present day (Bedworth *et al., 1991*).

2.7 Technical Rationality, the Diffusion of CAD / CAM and Issues of Concern

The value of CAD in is widely seen in terms of how useful it is as a tool for supporting a traditional manual design process. Long lead-times, errors, lack of connection to manufacturing, lack of simultaneous working, and storage and retrieval problems are typical characteristics of a traditional manual design process (Bessant, 1991). The use of CAD is often justified on the basis of resolving one or more of such problems.

From a technical rationality perspective, the growing utilisation of CAD technology is presented as a progressive trend towards further rationalisation of design (see Forrester *et al.*, 1995). For example, the potential advantages of using CAD over a manual design system include decreased lead-time and reduced errors. In this respect, CAD advocates tend to look at its implementation as an essentially technical issue involving selecting a suitable system to improve efficiency, quality and reduce cost or increase flexibility and competitiveness (Lowstdt, 1988). The emphasis is on justifying CAD in terms of desired technical advantages. The critics of CAD, nonetheless, disagree fundamentally with this view, as will be discussed below.

Much of what can be said of CAD in this respect can be said of CAM too, although the latter is in many ways more associated with the "shop floor", the base of "blue-collar", "direct" workers than the former which is more associated with "indirect", "white-collar" office employees. From the same technical rationality perspective, the attraction of CAM technology can be largely explained in terms of how widely it is believed to increase accuracy, reliability, and efficiency of production processes and improve ancillary tasks such as materials handling (Adler, 1989). In PCB assembly, for example, researchers such as Edosomwan (1987) have demonstrated that it increases total and labour productivities[2]. CAM also offers greater efficiency and quality (Adler, 1989).

Technical rationality is characteristic of the engineering literature on CAD/CAM and CIM (and, to a certain extent, of some consultancy literature on the management of technical change), whose discourse is dominated by a "technocentric" logic (Brodner, 1990). This logic tends to emphasise a problem-solving orientation and typically concludes with practical recommendations for practising mangers and/or engineers. However, there are some doubts about the practicality of this rationality. For example, it tends not to pay too much attention to important aspects of change such as organisational politics (e.g. Frost and Egri, 1991; Pettigrew, 1973), symbolism (e.g. Pfeffer, 1981; Brown, 1995) and legitimacy (e.g. Brown, 1995, Meyer and Rowan, 1977). Insufficient attention is given to "anthropocentric" considerations of technology design in frames of reference dominated by technical rationality (e.g. Brodner, 1990;

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[2]Nonetheless, CAM is responsible for decreasing the productivities related to capital, energy, computer operating expenses and administrative expenses and have no significant impact on material productivity, according to a controlled experimental study carried out by Edosomwan (1987) to investigate the impacts of CAM on a range of productivities of concern to practising manufacturing managers in the US PCB industry.

Uden, 1995). An organisation is, implicitly at least, assumed to be essentially a "technical system" rather than also a "political system" within which "political behaviour is defined by individuals or, in collective terms, sub-units ..... which make claim against the resource sharing system of the organisation" since "power resources ... must not only be possessed by an actor, they must also be controlled by him" (Pettigrew, 1975: 192 and 195).

Technical rationality discourses do not concern themselves with assumptions embedded in the nature of organisations as seen from the sociological perspective; they tend to be rather didactic in a manner uncharacteristic of the social sciences literatures. They assume authority on the basis of specialist technical know-how in problem-solving. Some sociologists would call this a technocratic attitude. Technocracy, like other competing ideologies of organisational control, often alleges objectivity, meritocracy and an apolitical perspective (Dillard and Burris, 1993). As Clegg (1991: 3) puts it:

> "The 'engineering' argument would say that technology equalled progress; it is natural, neutral and inevitable and needs only to be managed in its introduction to minimise irrational problems of social adaptation to it. Technological development is inherently good and to be welcomed; any opposition is illegitimate."

In this respect, the current resurgence of the *Tavistock Human Relations Institute* socio-technical system perspective in researching technology issues in organisations is justifiable (see, for example, Newton, 1989; Plonski, 1989; Susman and Chase, 1986; Winfield, 1991). The pioneers of the open socio-technical system approach (see Emery and Trist, 1960; Rice, 1963), who, following the famous Durham mines' study (Trist and Bamforth, 1951) which soon extended beyond the UK, succeeded in developing a balanced discourse that incorporated a technical rationality element. They were able to do this without detriment to the human and social relations elements as had been the case with earlier highly influential "scientific management" approaches, such as the work of Frederick W. Taylor (1911). The latter's "model of man" implied that people were inherently "lazy". As Clegg and Dunkerley (1980: 91 and 96) proposed: "Taylorism offered management a path to the dehumanisation of work under capitalism" and added: "In just the same way that management task is to maximise output from capital equipment, under the principles of scientific management it is also part of the managerial task to maximise the output of the human component". "Labour process" theorists after Henry Braverman (1974), such as Littler (1983), Storey (1983) and Thompson (1983) launched a passionate Marxian attack against management as an institution (or, more accurately perhaps, as an enterprise) whose entire culture, they insisted, was being legitimised by capitalist forces in society and used as a means for an "explicit verbalisation of the capitalist mode of production" (Braverman, 1974: 86).

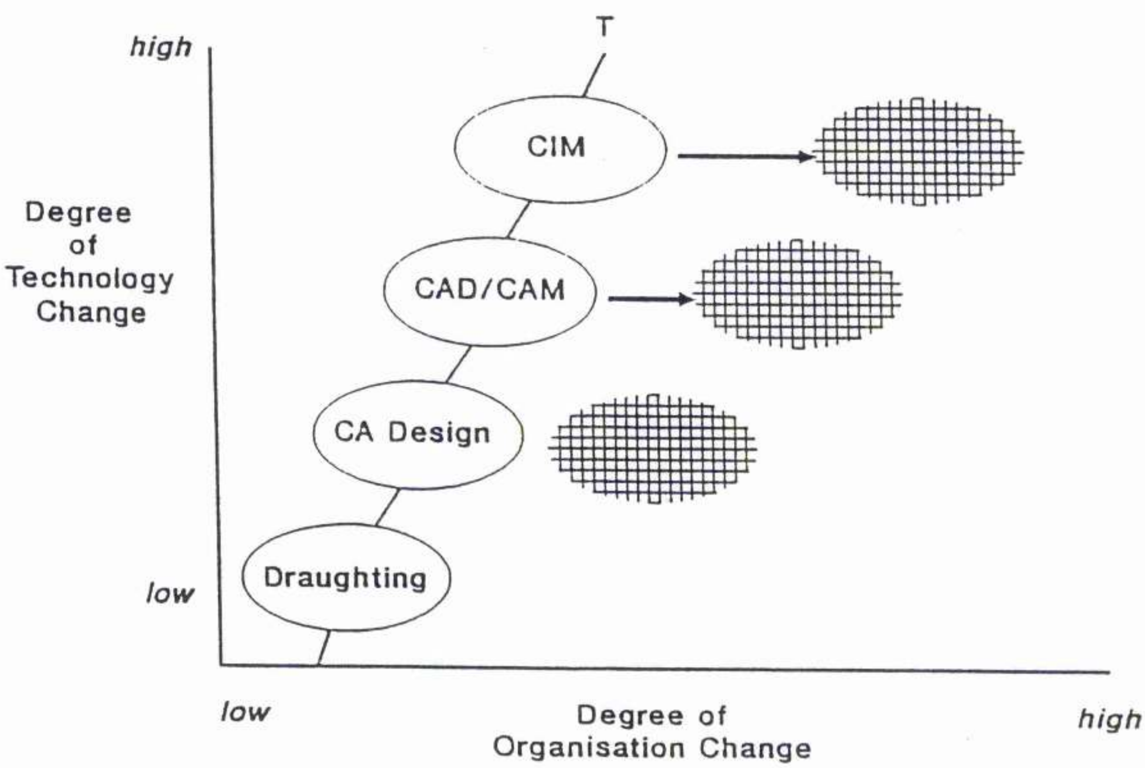
Whatever the historic background to the technical rationality discourses underlying the managerial ideologies which have been so influential during the current century, it remains clear that CAD is capable, upon sound implementation, of enabling management to standardise product parts and thus minimise the variety of fittings required and reduce design time (Adler, 1989; Salzman, 1989), reduce manufacturing complexity (Adler, 1989), and increase design productivity (Newton, 1989). It also gives designers more opportunities to experiment with various designs (Salzman, 1989) and simplify sophisticated design analyses (Adler, 1989). However, one has to stress an important point in this respect, namely that, contrary to prevailing beliefs of many executives and professionals, investment in CAD does not guarantee a successful innovation (Plonski, 1989). Introducing a new technology does not necessarily involve the "initiation, adoption and implementation of new ideas in an organisation" (Howell and Higgins, 1990: 40). Often, the technology fails to deliver its full potential for reasons that are more explicitly organisational and social than they are technical and neutral.

Issues of concern regarding CAD are worthy of consideration because of their contribution to the wider debate on the present and future impacts of technological development, whose practical and theoretical significance should not be in question. CAD critics take a rather pessimistic view of it as a technology-based work method that threatens to reduce professional skills, increase worker alienation and decrease staffing levels (Lowstdt, 1989). Historically, such concerns are not uncommon in societies which have had a "Tayloristic" managerial heritage, such as the USA and the UK (see, for example, Browne *et al.*, 1988; Huczynski and Buchanan, 1991). The human cost of technology has often been expressed in terms of downsized work force as less people were required to perform a certain job after computerisation, increased job dissatisfaction, decreased job autonomy, and increased employee alienation.

2.8 Organisational Implications of CAD / CAM Implementation

Implementation of a technology involves a change of some kind; it brings with it a new element into the status quo of the accommodating organisation, affecting people's jobs, relationships and ability to carry out their jobs. Different degrees of organisational change could reasonably be expected in relation to different technology applications. For example, as Voss's model (1992) suggests, the magnitude of organisational change brought about by the implementation of CIM will be invariably much higher than that associated with CAD, CAM or CADCAM (see Exhibit 2.1).

Exhibit 2.1
Aligning technology and organisation change



Source: Voss (1992: 39)

It can be said that people differ considerably in assessing the impact of a given change, some of which might have been predicted by certain people but not by others. Indeed, some consequences of a change might not be predictable at all. Therefore, it is not surprising to find both advocates and critics of CAD/CAM and CIM.

As the diffusion of CAD/CAM technology grew and some user companies not only failed to make optimum use but also experienced negative results, serious and legitimate questions began to emerge regarding the promised competitive advantages of CAD/CAM. How achievable are they upon implementation, and how guaranteed are they just by using the technology without changing work organisation practices? (e.g. McLoughlin, 1988; Plonski, 1989; Senker, 1985). Many companies complained that the promised CAD/CAM gains remained modest (Beatty and Gordon, 1988).

Bessant (1991) discusses a few studies focusing on problematic implementation, one of which will hopefully help solidify the point. In 1989 the UK was reported to be investing in CIM at a rate of nearly £2 billion per year (i.e. approximately 20% of all capital expenditure in manufacturing). Up to a third of that money, however, was potentially being wasted because integration occurred only at a technical level, not at an overall business level. Therefore, "benefits on the whole have been disappointing ..... CIM has not resolved the problems of quality and performance to schedules as anticipated" (Kearny, 1989)[3].

Signals sent by studies such as this suggest clearly that the implementation of such technologies *per se* is by no means guaranteed to deliver their potential advantages (see Forrester *et al.*, 1995). It often fails to live up to expectations (Gunson and Boddy, 1989). As mentioned in the previous chapter, the question of the gap between the "promise" and "reality" of such technologies is unavoidable, given the reported problems companies experienced in implementation.

Many managers have to face the consequences of lack of planning for, or even recognition of, the organisational changes required to accommodate the introduction of CAD and CADCAM systems. Thus the full potential of such technologies could hardly be achieved, nor could they, upon introduction, be used as a catalyst for larger organisational developments. It can be argued that this is one of their less recognisable

[3]Bessant (1991) also reports a study on AMT users conducted on behalf of the UK *National Economic Development Office*, which concludes that:

> ".... of the 21 systems observed, 12 were operating satisfactorily but the other 9 were performing considerably below expectations. Indeed, the performance of one system was so bad that the company eventually scrapped it altogether ... even in the 12 instances where satisfactory performance was achieved, in four cases there were major problems and long delays had to be experienced in bringing the systems to expectations." (Burns [1988] quoted in Bessant [1991]).

but important "intangible" characteristics (see Brooks and Wells, 1989; McLoughlin, 1990).

If CAD/CAM tools are to be used to assist the achievement of a business mission, then management's responsibility for turning potential advantages of these technologies into measurable technical and financial gains comes into question. Where exactly the responsibility for CAD/CAM lies within a given management set-up depends highly on the specific nature of individual organisations and cannot be generalised. Nevertheless, there are several questions of high practical significance, whose clear and accurate answering could help managers address issues of technology-organisation alignment. Who is to blame when the potential of a CAD/CAM system could not be achieved in a certain organisation? What should be done if organisational changes were not planned or even recognised prior to, or during, implementation? What opportunities can the introduction of CAD/CAM create for facilitating changes in work organisation and procedures in ways which may in their turn be as effective for further rationalisation? Are such opportunity used effectively? And what new horizons of planning may result from the introduction of CAD/CAM to facilitate the integration of technical and social objectives for the benefit of business goals?

In short, it is insufficient for management to rely totally on technical problem-solving logic in introducing CAD/CAM without a careful consideration of the organisational context in question and its psycho-social specifities. The implementation of CAD/CAM is highly likely to present management with challenges of reorganisation of work and rearrangement of supervisory and managerial work, particularly against a background of dynamic change, both in the broader business environment and inside organisations (e.g. Fjermestad and Chakrabarti, 1993; Voss, 1989). Hence, in the face of an increased emphasis on competitiveness as a distinguishing feature of the current age, managers in charge are advised to be conscious of the implications of moving from "a condition of relative stability to one of continual change" for the task they are entrusted with (Hoffman, 1994: 3). According to this perspective, senior managers in particular are required to think critically about existing practices and work closely with middle and lower-level managers to develop creative ways for reorganising work in line with the new environment. To do so, those managers who could be described as change leaders would need to assume new roles not only in designing systems but also in getting more involved in the business process and how to organise work in order to support it best.

2.9 CADCAM Integration, CIM and CIE

This section will introduce the concept of integration in the context of the technology applications that are utilised in manufacture. It begins with a discussion of the general background to the concept of integration. It then discusses the rationale for it, the definitional problems surrounding it, and concludes by indicating the significance of managerial and organisational challenges encountered in its implementation.

2.9.1 General Background

Integration of stand-alone computerised systems, and CIM in particular, can be viewed as a most advanced stage of technical progress in manufacturing industry's pursuit of automation in an evolutionary process comprising four stages: mechanisation, point automation, integrated islands of automation and CIM (see, for example, Browne *et al.*, 1988; Fjermestad and Chakrabarti, 1993; Forrester *et al.*, 1995). Mechanisation in the 1770s and beyond (e.g. in the metal-working engineering industry) was concerned with the replacement of human labour with machines (e.g. lathe power); point automation in the 1960s and 70s with the replacement of human control of machines by automatic control (e.g. CNC and material requirements planning [MRP]); integrated islands of automation in the 1970, 80s and 90s with the integration of points of automation within their local environments (e.g. CADCAM, MRP II and FMS); and the more futuristic CIM stage is concerned with the application of computer-based automation and decision support systems to manage the total operation of a manufacturing system (see Browne *et al.*, 1988).

This subject of this thesis is concerned with the latter two stages, particularly the third (i.e. CADCAM integration) which, arguably, represents the current phase of development not only in terms of the companies that were studied during the course of this research but also in the majority of manufacturing enterprises the world over. For example, Patricia Mac Conaill (1993) of the *Commission of the European Community*, Brussels, provides an insider's explanation of the state of integration in member countries: less than 10% of systems used in European production industries are integrated, a further 20% capable of integration, and 70% considered to be extremely difficult to integrate due to technical, financial or organisational reasons. According to her, Europe suffers a trade deficit in the CIM market; whilst accounting for 27% of world markets, it supplies only 21% of these markets.

The main challenge of CIM is to implement the appropriate level of technological sophistication to achieve competitive advantage without over-investment of capital and time (Fjermestad and Chakrabarti, 1992). CIM will probably attract an increased governmental support within and across national economies, particularly in industrially-advanced countries, to support a more competitive manufacturing performance. For example, Mac Conaill (1993: 9) outlines the strategic significance of CIM to the European Community by declaring that the:

> "..... overall strategic goal of the European Community R&D programme ESPRIT is to provide the European IT industry with the technology base it needs to become and stay competitive. CIM is an important part of this programme and has an additional objective to accelerate the modernisation process in a wide range of manufacturing and engineering industries."

2.9.2 Rationale and Justification

Bessant (1991: 52) discusses the rationale for integration in manufacture in a broad sense. His description is particularly relevant because it is supported by a historic background and it also summarises the whole philosophy of CADCAM integration. He states:

> "Although IT has undoubtedly been a powerful force for change, it would be wrong to see this as the only factor which has influenced the emergence of advanced manufacturing technology in the form available to us today. Perhaps the most significant trend - which IT has accelerated, but which it predated by many years - is that towards *integration*. ..... Innovation in manufacturing has been taking place since the Stone Age, as new and better things have been discovered and developed. But there is a qualitative difference between innovations which are primarily associated with 'doing what we have always done, but a little better' and those which fundamentally change the nature of the process to which they are applied. ..... The distinction is one of *integration*. Through a synthesis of different elements the whole becomes greater than the sum of the its parts. As we move from substitution towards more integrated forms, so we bring together more of the previously separate functions in the manufacturing process. At the same time, the benefits which the technology offers increase with higher levels of integratio. ..... In terms of systems theory, more integrated systems have 'emergent properties', appearing only at the higher levels of integration of subsystems."

Mac Conaill (1993: 53-54) expresses the importance of the principle of integration in her own words so as to highlight its potential advantages from a narrower, task-centred point of view:

> ".... even allowing for the very powerful contribution of computer-aided design to the draughting and design process, its real significance emerges as IT facilitates integration with the manufacturing process itself. Since CAD systems make use of information coded in electronic form, it follows that other systems - ..... which also use such information - can be linked via some form of network. This is the basis of CAD/CAM ..... in which not only can the product be designed on a computer screen but, when the design is finally refined, the necessary instructions can be generated and sent to the machine tools and other devices which will actually manufacture it. ..... The advantages of this kind of integration are enormous, and extend beyond the generation of designs and the relevant information necessary for controlling the manufacturing process to those for other activities such as the planning of material requirements and capacity planning, and quality control. Benefits arising from this include significantly reduced lead times, imp-roved quality, better machine utilisation and much improved customer service."

In system terms, justification of integration finds expression in optimised flows of information between systems and subsystems which possess different data base formats, by means of a communication link and the physical interfacing of stand-alone hardware elements through some form of a network. Data translation is often needed since different computer languages are typically used to describe the same algorithm or graphical object throughout computerised systems in an enterprise.

An integrated CADCAM system can help management simplify a complex administrative and control system for cost estimation, lot release, shop orders, materials, and performance tracking (Adler, 1989). In PCB production CADCAM integration facilitates the designers' task of assessing manufacturing cost, quality considerations and avoiding expensive engineering changes. More accurate artwork, profiling, and drilling programs as well as connectivity test programs can be produced with less effort using CADCAM. Assembly can benefit from a CIM database in generating automatic component insertion programs and functional tests. Cost and quality objectives can be considerably assisted by improving the criteria for manufacturability in a CIM system (Venkatachalama, 1990). Less recognisable benefits of a CIM system would include its potential ability to facilitate and decentralise a decision-making mechanism through the use of an enterprise-wide distributed AI architecture in which simulation techniques would play a major role (Lucas-Smith, 1990).

2.9.3 Problems of Definition and Managerial and Organisational Challenges

Although manufacturing industry is increasingly being asked to move towards integration, little has been given to defining integration or to the management challenges involved in making it happen (Bessant and Buckingham, 1993; Bessant *et al.*, 1985; Voss, 1989).

As could be deduced from what has been discussed in this chapter so far, defining CIM is more difficult than defining CAD or CAM because:

1) the words "integration" and "manufacturing" mean different things to different people (Bedworth *et al.*, 1991: 600); and

2) it is much more complex and radical (Fossum, 1986). Consequently, interpretations regarding the nature, scope, and implications of CIM are bound to vary considerably between individuals, different departments' perspectives within an organisation, and across organisations as well as between researchers from various backgrounds (Forrester *et al.*, 1995).

Numerous definitions can be found in the literature but none of them is universally accepted, although a consensus could be found on CIM as a networked information system which encompasses various computerised subsystems of a manufacturing concern. Typically, constituent component technologies of CIM will include, among other subsystems, CAD, CAE, CAPP, CAM. They also include other "islands of technology" that have, historically, met the needs of specific business areas but also resulted in the fragmentation of systems applications and the organisational functions responsible for them. This was because their limited and specialised purposes "had nothing to do with the overall business objectives and strategies of the corporation" (Tapscott and Catson, 1993: 61).

It can be said, nonetheless, that an integrated CADCAM system forms the core of the technical (or "product definition") component of a total CIM arrangement (See Teicholz and Orr, 1987: 58). Until the early 1980s defining CIM in the USA and Japan was narrowly restricted to product development and manufacturing through CADCAM. Later definitions, however, broadened to include, for example, MRP systems as a major part of the production planning and control component (Scheer, 1991).

Scheer (1991: 2) defines CIM as "the integrated information processing requirements for the technical and operational tasks of an industrial enterprise. Bessant (1991: 54) defines it as "the integration of computer based monitoring and control of all aspects of the manufacturing process, drawing on a common database and communicating via some form of computer network". However, Bedworth *et al.*'s (1991: 600) definition better serves the purpose of this study because it emphasises the central role of design and manufacturing activities, and hence CAD and CAM, in the operations of a manufacturing enterprise. According to them, CIM is "a management philosophy in which the functions of design and manufacturing are rationalised and co-ordinated using computer, communications and information technologies".

Interest in CIM as an enterprise-wide technical issue can be found in the work of researchers such as Patankar and Adiga (1995) and Kovacs *et al.* (1994) who attempt to model CIM and CIE using computer simulation techniques. Their aim is one of developing conceptual tools to observe and create an abstraction of an enterprise with a view to supporting decision-making across functional boundaries. Integration at an enterprise level is conceptualised at three levels: the physical systems level, the applications level, and the functional level (it is at this third level where enterprise-integrated modelling (EIM)[4] features as a means of high-level functional modelling and integration, giving rise to the broader notion of CIE [see Hunt, 1991; Patankar and Adiga, 1995]). A fourth level, business, may be added[5] (Mac Conaill, 1993). CIM, by contrast, is generally restricted to integration at the two previous levels.

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[4]Enterprise Integration Modelling can be defined as: "an activity that produces models which address enterprise-wide integration issues" (Patankar and Adiga, 1995)

[5]Based, for example, on the *European Community*'s *CIM-OSA* project launched with a view to defining a framework within which all CIM components in an enterprise could be integrated at the

More encompassing forms of integration which go beyond a DEM domain within a manufacturing company are possible. These are conceptualised as a more advanced, more futuristic stage of integration and termed "CIM" in a "factory of the future" context at the technical level, and "CIB" (Computer-Aided Business) at the business level. According to Browne *et al.*, (1988: 29-30), the likely characteristics of the "factory of the future" include: "round the clock operation, very small lot sizes, greatly reduced lead-times, little or no human labour at the point of production". CIB incorporates a high level of integration among the different functions of an enterprise, including administration and financial systems, engineering support systems (e.g. CAD and CAPP), production management, and manufacturing monitoring and control functions; "CIB is concerned with reducing the cost and time taken to transfer information between the factory and the external systems with which it must interface" (Browne *et al.*, 1988: 35). A higher level of integration is still achievable beyond CIB as a "four walls activity", (Browne *et al.*, 1988: 37). Outward-looking integration via the inclusion of suppliers and customers or other external parties concerned into an integration process can be highly rewarding in business terms since the integration of supply and demand is itself an issue of strategic concern (MacDonald, 1995).

A broader notion of integration, which encompasses but goes beyond purely technical definitions arising from system concepts, is needed for the purpose of the present study. Researchers more tuned to the organisational issues of integration (e.g. Bessant, 1991, Voss, 1989; Winch and Twigg, 1993) are concerned with conceptualising CIM from a perspective which is more directly comparable to the one adopted in this study. For example, Voss (1989) identifies five dimensions of integration, whose own integration into a single vision through an appropriate formula remains an outstanding managerial challenge. The dimensions are:
1) strategy integration whereby decisions in manufacturing are integrated with marketing strategy (see also Porter, 1983);
2) material flow integration whereby efficient flow through the supply chain is achieved for maximum flexibility;
3) technical integration whereby strategy integration is linked to the technical choices made by ensuring that production process choices are consistent with the strategy and all technical choices made are consistent with each other;
4) information integration whereby different functional information sub-systems are integrated with market requirement information sub-systems; and

physical, application, and business levels, using *MAP* (*Manufacturing Automation Protocol*) and *TOP* (*Technical Office Protocol*) and other standards (see Mac Conaill, 1993).

5) organisation integration whereby new forms of organisation and job design are developed in line with the other four dimensions across the organisation in concern.

One important point to stress in this chapter is that integration involves a long-term, necessarily problematic process of change, because it goes deep into the core of a manufacturing organisation.

> "Moving towards total integrated manufacturing is not simply a matter of a short-term investment in one or two discrete items of equipment, but rather a long-term philosophy involving technological and organisational components which need to be carefully linked to provide support for the overall business." (Bessant, 1991: 333).

Throughout this thesis, however, the emphasis will be on CAD and CAM primarily but other application areas, such as CAE, CASE (Computer-Aided Software Engineering) and CAPP, will also be discussed as appropriate. At a product DEM level, therefore, it is assumed that an integration process proceeds in a direction whereby CAD and CAM systems are interfaced physically and integrated technically and organisationally, based on a careful redesign of what is technically known as the "design-manufacturing interface" (Badham, 1991).

2.10 Selected Studies on CADCAM Integration

This section discusses eight selected studies on CADCAM integration, which, from the extensive literature, can function as research exemplars. The studies have been selected on the grounds of their relevance to the subject matter of this research. They include outstanding research efforts by Adler (1989); Lee (1989; 1991); Winch and Twigg (1990; 1993); Winch, Voss and Twigg (1991); Dean and Snell (1991); and Beatty and Gordon (1988; 1991). Such studies have contributed considerably to knowledge in the chosen topic. Thus they warrant a critical consideration. In what follows each of the mentioned studies will be considered individually in terms of summarised accounts of its aims and methodology, findings and conclusions, and strengths and weaknesses.

* ***Adler Study (1989)***

* ***Summary of Aims and Methodology***

Paul Adler studied 13 US firms: nine in electronics and four in aircraft industries with a view to investigating the managerial challenges involved in CADCAM integration. This was an exploratory study which focused on specific areas of production in these industries: PCB (engineering, design, fabrication, and test) and hydraulic tubing (design and fabrication), respectively. The study did not target a statistically representative sample; exploration of issues and development of propositions and hypotheses for further research was the guiding objective.

Using an inductive method, Adler aimed to synthesise elements of "best practice" in leading organisations; he devised a conceptual framework of possible challenges at five key levels of "organisational learning": skills, procedures, structure, strategy and culture.

A total of 120 managers and engineers were interviewed over a period of four months. Data was gathered during site visits by two researchers using semi-structured interviews and company tours.

* ***Summary of Findings and Conclusions***

1) Whilst PCB manufacture using CAM required less manual dexterity on the part of operators, AIMs demanded a greater formal training to operate effectively, as well as a broader knowledge of the variety of components being inserted.

2) Although CAD/CAM reduced labour requirements per unit output, it created an upgrading trend in the overall skill requirements of personnel both in individual occupational categories and in the balance between occupations. CAD and CAD/CAM increased the sophistication of design analysis in PCB manufacture.

3) The use of CAE drove the skill profile upwards and CAM increased workers' skill requirements in PCB manufacture.

4) Deskilling was not feasible for drafting technicians due to the limitations of these systems and the emergence of other higher level drafting tasks.

5) A company's specific product and the intensity of "environmental pressures" influenced the choice of strategic pathways that companies had followed on CAD/CAM.

6) Different companies used CAD/CAM in different ways. Three kinds of CAD/CAM strategies were adopted: (a) energetic anarchy, (whereby departments were encouraged to develop their own islands of automation independently, ending up with many different incompatible systems); (b) minimal government (whereby senior management intervened only to a limited degree in system management); and (c) integrated planning (by senior management for the entire organisation).

7) Technological change encouraged organisations to develop more differentiated and specialised subunits which needed structural co-ordination mechanisms to ensure the consistency of their efforts.

8) The companies were under pressure to find mechanisms for co-ordinating CAD and CAM development efforts as well as design and manufacturing activities. The question

was: who would fund the development of the parts data base which related directly to the activities of design but paid off in manufacturing efficiency? Five various kinds of integrating mechanisms were found: a) forming liaison roles and task forces, b) setting up cross-functional CAD/CAM committees, c) creating a product definition data base, d) nominating a CAD/CAM manager, and e) creating a central CAD/CAM organisation.

9) The technical potential for integration was found to be insufficiently exploited in the most advanced segments of US industry.

10) The overall benefits of integration could only be achieved when organisational changes in procedures, structure, strategy, culture, and skill training were made together with the technical changes involved.

11) Three cultural challenges arose because of integration: first, manager-worker co-operation as they were asked to play a more active problem-solving role; second, co-operation between lower and higher level management in participative strategy processes; and third, co-operation between design and manufacturing personnel. Finding a proper linkage mechanism to accommodate a shared functioning of these groups arose as a major challenge.

12) The lack of technical expertise and top management commitment to CADCAM for competitive advantage were the two main factors in the lack of further progress towards integration.

** Summary of Strengths and Weaknesses*

Adler's study was relevant to this dissertation because it was conducted mainly in PCB manufacturing environments. Also, it was exploratory in nature, with a view to discover all plausible organisational issues associated with CADCAM integration. It provided a realistic description of the state of CAD/CAM in the late 1980s and surveyed all kinds of organisational obstacles to integration in the US industry. A fact-finding investigation like Adler's facilitates a critical assessment of the theoretical literature concerning CIM on the basis of an empirical account of practice in some of the most advanced US electronic and mechanical engineering firms, which were chosen for research because they were the "leaders of CADCAM integration" (p. 203).

The comprehensiveness of the five organisational domains he developed from "first principles" in a sequential logic running from the simpler, objective, non-reflexive to more complex, subjective and reflexive levels facilitated his broader exploratory objectives. Conceptualising them in terms of organisational learning was a fundamental contribution to theory building in relation to the organisational aspects of CADCAM integration.

Nonetheless, some of the findings were not interpreted in terms of their likely implications for the firms in the study. For example, the results did not reveal whether the closer co-ordination required by CADCAM had, or could have, a positive impact on corporate performance or profitability in the researched companies. The study touched upon the issue from a purely theoretical point of view but did not discuss it in the light of the findings.

Methodologically, a relatively short period of four months was not sufficient longitudinality for an inductive research in this area of change where things develop continuously over long time frames. Also, the companies were deliberately chosen from a technically advanced class of manufacturers; this unfortunately denied the study an opportunity to learn about non-integrating companies as well and why the issue of integration appeared to be irrelevant to them from a socio-technical, rather than purely technical, point of view.

* ***Lee Study (1989)***

* ***Summary of Aims and Methodology***

Gloria Lee studied how companies in Britain managed change with CAD and CADCAM. The study aimed to analyse key contextual and organisational factors in the implementation of CAD, CAM, and their linking into CADCAM arrangements. Of particular interest to the present research were issues related to the organisation of work around such arrangements.

Seven British engineering companies were chosen from a wider range of research sample, six of which were in manufacturing and one was an engineering services organisation. Four were of small to medium size (under 500 employees) involved in the manufacture of machine tools, pneumatics, industrial valves and engineering services for the automobile industry. The other three were large multi-site organisations: two were in aerospace and the other was a vehicle manufacturer.

Semi-structured interviews were conducted with executives, trade union representatives, and professional engineering institution and training board officers during the course of a two-year long field work.

* ***Summary of Findings and Conclusions***

1) The motive for a company's adoption decision (i.e. market- or technology-driven) affected the episode of change implementation.

2) The "sociopolitical context of change" served to promote a successful change process in companies which enjoyed an atmosphere of "high-trust" relationships whilst hindering it in firms with a history of confrontational management-union relationships.

3) Managerial strategies for implementation and control were found to be one of two types: "Taylorist-oriented" direct control approach or a "responsible autonomy" approach.

4) Direct control strategies resulted in selective training and a traditional work organisation, whereas autonomy resulted in general training leading to flexibility in work organisation.

*** Summary of Strengths and Weaknesses***

A wide range of concerned actor groups were interviewed, which must have facilitated a balanced analysis of responses by virtue of comparing and contrasting the different accounts presented. This was an obvious methodological strength of the study. The inclusion of companies of various sizes and lines of business provided another strength to the theoretical representativeness and generalisability of the study.

The duration of the field work makes this virtually a longitudinal study. The number of people who had been interviewed was not stated. Theoretically, the study narrowed down managerial control strategies into a polarity of either Taylorist or non-Taylorist approaches; another alternative would have been to present them in terms of a continuum showing degrees of control instead of reducing them to a dichotomy. The advantage of the dichotomy used, however, was that it was one with considerable previous application in the field of industrial sociology.

* *Lee Study (1991)*

*** Summary of Aims and Methodology***

Gloria Lee expanded her previous study of British firms (1989) to include North American companies, with more focused attention on CADCAM integration. The overall objective was to identify the factors that influenced the readiness of management to associate organisational with technical change within various contextual specifities.

Semistructured interview schedules were used to collect data from senior and middle technical and other managers in six British and six Canadian companies. The British companies included two aerospace, one automotive, one machine tool, and two component manufacturers. Three of these were large (over 1,000 employees), one medium (500-999), and two small (less than 500). The Canadian companies included the following manufacturers: one aerospace, one automotive, two electrical, one domestic appliance, and one component. Of these four were large, one medium and one small.

*** *Summary of Findings and Conclusions***

1) Societal and organisational cultural contexts had played a significant role in the change process and its outcome.

2) Market pressures and a determination to keep at the forefront of technological innovation were major factors for innovation, despite the many uncertainties that were associated with new technologies.

3) Differences in culture and traditions were found to be significantly influential factors in change "even in countries like these [i.e. Britain and Canada] with strong historical links" (p. 109) due to significant contrasts in the positions of engineers in the two countries and the way they were trained and educated.

> "..... there are other aspects relating to the wider cultural context and traditions, which it has been argued impact in different ways upon approaches to technological change." (p. 109)

4) The engineering profession developed along two different lines historically in terms of its professionalisation process, education and training. Unlike in Britain, Canadian engineers were not concerned about their professional identity, status and prestige; "the position of Canadian professional engineers is institutionally distinct from that of other technical occupations" (p. 109). This was reflected in the social organisation of technical work in design: there was more vertical segregation between professional engineers carrying out design work and technicians who undertook doing the draughting.

5) Canadian managers deliberately left design and draughting as separately organised activities, whereas British managers saw the introduction of CADCAM as an opportunity for higher integration of activities within design as well as between design and manufacture.

6) Unionisation and the notion of collective action amongst Canadian engineers was very rare and did not exist in the companies studied, but it was the norm amongst British engineers.

7) The professional status of Canadian engineers supported their authority in senior positions with strategic decision-making powers. This made them

> "..... more confident than British engineers, in their ability to further their case for investment within management hierarchies and they were less inhibited by the implications of accounting rules than their British counterparts ..... " (p. 110)

8) Professionalisation in Canada produced a social organisation distinguishing between engineers and technicians, which was a factor impeding functional flexibility in implementation. It caused a slowing down in progress toward organisational change, in terms of the integrative potential of CAD/CAM, particularly in larger companies.

9) Canadian engineers had a very strong sense of their personal worth and value to their respective companies; "they expected their performance to be individually evaluated" (p. 110). They did not perceive management as causing any serious threat to them as a group. This situation resulted in both engineers and managers being "reluctant to move ahead quickly with any form of radical restructuring" (p. 110). Neither of them were ready to break down traditional barriers to achieve horizontal integration within design or between design and manufacture.

** Summary of Strengths and Weaknesses*

The international dimension of the study strengthened its theoretical premises considerably. The role of national cultures in affecting the shaping, functioning and psycho-social characteristics of organisations across countries and continents was investigated. Also, a wide range of concerned actor groups were interviewed and companies of various sizes and lines of business were included, providing another strength to the study's findings in terms of their theoretical robustness.

However, the duration of the field work was shorter than in the 1989 study. One should not be surprised - to gain synchronic width in research usually involves a trade-off in terms of diachronic depth, for simple reasons of economy of effort. Only large research teams can attempt to do both simultaneously, through specialisation of the research roles within the team. Despite providing a valid platform for a cross-national analysis, the scope for theoretical generalisation from the study remained limited due to the number of industrial sectors in the study, their uneven representation, and the differences in the distribution of company sizes between the British and the Canadian samples. It should be said, however, that it was not intended to be a strictly matched hypothetico-deductive study, but a more grounded and exploratory piece of work. In this respect, it stands as a model for the modest endeavours of this thesis.

** Winch and Twigg (1990 ; 1993) Study*

** Summary of Aims and Methodology*

Graham Winch and David Twigg aimed to construct a model of the process of technological change, which would be particularly suitable to CADCAM integration. They studied 16 British metalworking firms. Structured interview schedules were used to collect information from senior managers and engineers from the two functions concerned. Interviews were written up in a case study format and returned to the participants for validation.

** Summary of Findings and Conclusions*

1) All the companies studied had compared systems and prepared justifications before choosing a system. Some companies had been through this process more than once before embarking on a final choice.

2) None of the firms they studied had an integrated link for the whole of their production information flow.

3) Some companies had unpleasant experiences of system incompatibilities; they had CAD systems that worked satisfactorily in the drawing office but their output was not suitable for part programming or they did not have a suitable and compatible part programming software. Thus operational and information flow problems in manufacture were encountered.

4) Product quality assurance efforts were negatively affected because of the lack of cross-functional flows of information.

** Summary of Strengths and Weaknesses*

The theoretical strength of the study manifested itself in its systematic, literature-supported modelling effort which preceded the empirical investigation. The proposed model was reappraised after it was applied to data collection because it failed to show incremental processes within the stages of change, and, hence, achieved greater validity as a result of this refining. The methodological significance of this study lay in its longitudinal research design. It took account of the passing of time as an essential element in modelling CADCAM as a change process.

Nonetheless, the research utilised a rather "rigid" structured interview schedule. Its margin for flexibility in data collection and analysis must have been unduly constrained prior to data gathering. Unlike Adler's (1989) exploratory study, for example, this research narrowed its scope unnecessarily. For example, it interviewed only senior managers and engineers and while it focused on work organisation issues in a broader sense, it excluded job design issues. It was impossible, therefore, to discover or develop a link between the two important and complementary areas of theoretical concern.

* *Winch, Voss and Twigg Study (1991)*

** Summary of Aims and Methodology*

Graham Winch, Christopher Voss and David Twigg assumed that the implementation of an integrating technology, such as CADCAM, would lead to organisational integration. Their study aimed to identify the organisational design issues specifically relevant to the integration of design and manufacturing functions. The main question of the study was: what different integrating mechanisms would be found in different organisations?

The study was financed by both *SERC* (The *Science and Engineering Research Council*) and *ESRC* (The *Economic and Social Research Council*) in Britain. It involved 15 firms from the metalworking industry, which produced various building, hydraulic, vehicle and aerospace components.

*** Summary of Findings and Conclusions**

1) Integration became an issue only under the conditions of differentiation between the engineering and manufacturing functions which dominated the British metalworking industry.

2) Merger between engineering and manufacturing functions was not viable because of various sources of differentiation. These included differences in: (a) capital intensity, (b) organisation design and structuring, (c) levels of task uncertainty, and (e) the nature of processed functional input and output.

3) Mechanisms used for integrating Design and Manufacturing varied from one company to another and included:

a) Direct Contact (the simplest and easiest form of engineering manufacturing liaison found).

b) Liaison Roles (i.e. two-way communications whereby a manufacturing person had an identified opposite number in engineering or a certain group within one function reported also to another function).

c) Secondment (the most common mechanism in the volume manufacturing companies, whereby a representative from manufacturing engineering would be transferred for one or two years to the product development team in engineering).

d) Task Forces (widely used techniques for solving specific finite problems, whereby a task force was distinguished from a committee in that its role was one of policy implementation rather than formation).

e) Project Teams (different from task forces since these had a full-time long-term status).

f) Cells (i.e. multi-disciplined groups working as teams in an open plan office to facilitate maximum feedback among the individuals, bring together all the functions involved in the early stage of design and thus achieve paperless design).

g) Integrator Functions (i.e. specialist integrating departments set up to bring together the various issues and tasks in engineering for the development of CADCAM in liaison with manufacturing.

h) Matrix Organisations (these were increasingly popular; they involved functional managers being responsible for recruiting, retaining and developing engineering skills which project managers deployed in product-oriented project teams).

4) Emerging CIM technology provided a potential for greater organisational integration, but was inadequate for facilitating shorter lead-times, lower costs and improved quality due to current market pressures.

5) Fully Integrated CIM was not a real possibility in the foreseeable future because the CAD and CAM systems that were found in use still required interpersonal co-ordination among users.

*** Summary of Strengths and Weaknesses**

The strength of the study lay in the theoretical richness of its detailed explanation of : (1) why design and manufacturing functions were found to be differentiated in the context of the companies studied and (2) the various forms of inter-functional integrating mechanisms found. This suggested that variation amongst organisations in a single industry was sufficiently worthy of investigation due to the unique specifities of such organisations.

The study, however, did not sufficiently explain the data-gathering methods and procedures that were used. Knowledge of these would have helped a more informed assessment of the study.

* ***Dean and Snell Study (1991)***

*** Summary of Aims and Methodology**

James Dean and Scott Snell studied, quantitatively, the relationship between an integrated manufacturing model and job characteristics in the US metalworking sector. They focused on the implications of integrated manufacturing (IM) for job design, particularly in terms of the possible demands of integration on task uncertainty and interdependence.

The concept of IM was used by the researchers to refer to a newly emerging, complex paradigm of AMT (including CAD, CAE, CAM, and CAPP), just-in-time (JIT) inventory control, and total quality management (TQM). The primary objective of the research was to construct a conceptual framework to characterise the emergence of the paradigm and to develop theory about its impact on jobs.

Dean and Snell hypothesised that performance, size and external control would moderate the relationship between IM and organisational redesign. The study formulated and tested three hypotheses:

1) "The relationship between integrated manufacturing and job characteristics will be stronger in organisations with low performance than in those with high performance" (p.786);

2) "The relationship between integrated manufacturing and job characteristics will be stronger in small organisations than in large ones" (p.786); and

3) "The relationship between integrated manufacturing and job characteristics will be stronger in independent organisations than in dependent ones" (p.787).

A total of 123 firms in Pennsylvania participated in the study. The range of products manufactured by these firms included primary and fabricated metal products, industrial machinery, transportation equipment and precision instruments. Structured questionnaires were used to gather data from 123 plant managers, functional managers: 101 in operations, 109 in quality assurance and 97 in production control. Non-managerial employees in these functions also participated: 74, 79 and 77, respectively.

Hierarchical regression analysis was used to test the hypotheses. The three IM variables were first entered into the equation simultaneously. Secondly, each moderator was entered. Thirdly, the cross-products of the variables were entered with the moderator variables (e.g. AMT by performance) to develop a complete statistical explanation.

** Summary of Findings and Conclusions*

1) Generally, the results showed no major effects of IM on job design among employees in the functional areas which were studied; the relationships were found to be contingent on organisational context (i.e. the conditions under which a technology was introduced).

2) Contrary to their initial expectations, it was found that high performance could either accelerate or impede changes in jobs as a response to IM.

3) The moderating effect of size on the focal relationship was found to be confined to production control.

4) Only partial support was provided for the third hypothesis. This, consequently, gave way to a greater emphasis on the contingency element in their interpretation of the results.

** Summary of Strengths and Weaknesses*

The study was relevant to this thesis because it addressed AMT as one of the three most essential factors which contributed to shaping, changing and developing the kind of work organisation required to facilitate efficient and effective operations. Comprehensiveness of approach was an obvious theoretical strength of the study. It combined AMT with JIT and TQM in its theoretical framework. Conventional manufacturing was compared with IM, in terms of job features, under a new condition where the effects of each of these were considered. Methodologically, the richness of quantitative analysis of the study succeeded in showing as high a level of rigour as one could look for in any classic research based on "science" as its normative ideal. The greatest emphasis was on devising a "water-tight" quantitative research design whose credibility lay in the statistical validity of the data and its analysis.

However, the true value of such accuracy should be assessed in terms of how embedded the data was in the socio-technical contexts that were researched. This would appear to be particularly important in a study whose basic unit of analysis was the individual employee, which would probably suggest the need for supporting such methodology with a qualitative analysis of individuals' experiences as suggested by their own respective cognitive processes and perceptions. The researchers' own interpretation of the statistical results was in the end subjected to a contextual frame of reference since the quantitative results appeared not to be meaningful enough to deduce any conclusions worthy of generalisation. The relationships, which were investigated quantitatively, were found to be contingent on organisational context.

This study showed that a quantitative approach, with all the rigor it could depict, might still be limited in its ability to provide results to explain variations between different organisations' behaviour vis-a-vis CADCAM integration. Therefore, "organisational inertia", whereby specific sources of variation (both internal and external to an organisation) not assumed in generic theoretical hypotheses would be likely to override the variables that were set up for testing. As the researchers confirmed in their conclusion: "..... our findings indicate that organisational contexts can simultaneously facilitate and inhibit alignment ..... the role of organisational context as a provider of resources should be examined" (p. 799). Another theoretical shortcoming of the study was that it analysed IM job requirements at the level of the individual (using a "microscopic view") without linking that, if only by way of a recognised theoretical relationship, with the wider context of work organisation (using a "macroscopic view") where individuals' jobs' were assumed to be affected by the overall organisational arrangements of division of labour, control and co-ordination of work tasks and power relationships. The study's conclusive emphasis on the significance of organisational inertia could perhaps be interpreted as indicative of this missing link. The total absence of this link from the study's theoretical framework left a gap which, eventually, found expression in the rather vague concept of organisational inertia. It appeared clearly that a "part" could not be studied by isolating it completely from the "whole" without theoretical assumptions linking both of them in order to comprehend the former in the context of the latter. In the same way the latter could not have been isolated from its environment completely for investigation purposes without taking into account, theoretically at least, the organic relations of interaction between the two.

* ***Beatty and Gordon Study (1988)***

* ***Summary of Aims and Methodology***

Carol Beatty and John Gordon studied the implementation of CAD/CAM systems. In the course of their research, they interviewed and surveyed Canadian managers and employees with a view to identifying barriers to successful adoption. The study resulted in sorting the identified barriers into three groups, offered an explanation of their underlying causes, and proposed remedies to help managers overcome them.

* ***Summary of Findings and conclusions***

The barriers the study identified were classified into three categories: structural, human and technical.

The problems included in each category, their causes and proposed remedies are summarised as follows:

* Structural barriers:

a) An excessive focus on direct labour and ratios, caused by the use of obsolete decision criteria; a careful analysis of the real costs incurred and benefits gained was proposed.

b) A failure to perceive true benefits, caused by the lack of measures of intangible benefits in use; an analysis of total productivity and "intangibles" was proposed.

c) A high risk for managers, caused by reward systems that discouraged risk taking; development of different reward systems for managers was proposed.

d) A lack of co-ordination and co-operation within companies, caused by profound organisational fragmentation; devices to integrate and co-ordinate efforts at a company level were proposed.

e) High hopes and hidden costs, caused by an overselling of CAD/CAM; a careful planning and presentation of the technology's strategic objectives was proposed.

* Human barriers:

a) Uncertainty avoidance, caused by fear of uncertainty associated with change; a higher degree of involvement and communication was proposed.

b) Resistance to change, caused by fear of loss of power and status; careful implementation and a capable and highly skilled champion were required.

c) Hasty decisions and chronic "fire fighting", caused by a short-term, action-oriented management work style characterised by impatience with planning and waiting; a greater emphasis on objective setting and pre-implementation planning was needed.

* Technical barrier:
Incompatibility of systems, caused by purchase of a variety of hardware and software without considering long-term integration requirements; purchasing integrated systems and writing own software and neutral files were proposed.

**** Summary of Strengths and Weaknesses***
Beatty and Gordon's study's main achievement was in devising a conceptually useful framework for classifying obstacles to the implementation of CAD/CAM systems. The framework would contribute to the development of clearer future conceptualisations in this field of research. Another theoretical strength of the research was the ability it demonstrated to diagnose the problems that prevented successful implementation and trace these to their, at least perceived, root causes. Further, the study provided a complete diagnosis and a treatment plan by recommending a remedy to each of the root causes and moulding these effectively into a well-presented study report which would be of practical benefit to concerned managers.

Nevertheless, the study did not clearly orient itself towards integration theory; it only presented "CAD/CAM" *per se* and seldom made mention of "integration". It appears that the issue was of a relatively marginal significance to the study. This was particularly so given the fact the acronym "CAD/CAM" is often used in the literature to imply no more than a CAD system that is slightly more sophisticated than "simple" drafting CAD without "CAE" and/or "CAPP" capacities for engineering analysis and/or process or production planning and control purposes. The authors did not use the more comprehensive "CAD/CAM", or even more accurately, "CADCAM"[6] acronym which encompasses such implications but goes much further to integrate shop floor manufacturing technology with CAD.

However, the study was vague about the methodology that it used. As to whether such vagueness corresponded, proportionally, to any weakness in methodology could not be judged with certainty because of the lack of information provided. The study said nothing more about methodology than a single sentence: "In the course of our research into the implementation, we have interviewed or surveyed more than two hundred

[6]Throughout this thesis the acronym "CADCAM" will be used to refer to integrated CAD and CAM systems. "CAD/CAM" is used to imply either of the two; it will also appear as such in quotations from other authors who use the acronym to imply either integrated CADCAM or either a CAD or CAM system.

managers and operating-level employees" (p. 25). This raised more questions about the methodology followed in the research than it answered. For example, what was the duration of the research? What kind of organisations were researched? What were the positions and functional backgrounds of the interviewees in their respective organisations? What precisely was meant by "operating-level employees"? How many of them were interviewed and how many surveyed? And what surveying instruments, if any, were used? It could be said, therefore, that the absence of answers to such significant questions put in doubt the methodological credibility of the entire study, and hence the reliability of its findings. Nonetheless, it was selected here because of: (1) its direct relevance to the subject matter of the present research and (2) the profound issues that it raised, particularly with regard to the barriers to CADCAM integration.

* ***Beatty and Gordon Study (1991)***

* ***Summary of Aims and Methodology***

Another study by Carol Beatty and John Gordon was published three years after their 1988 study. Ten Canadian companies were researched over a 3-year period whilst in the process of implementing CADCAM. The companies were selected with the help of CAD/CAM vendors on the grounds that they had recently purchased either new CAD or new CAM equipment and planned to integrate CAD with CAM.

The researchers aimed to study the process of implementation itself using a structured interview method with managers at various levels in various departments. A cross section of operators were also interviewed at each site. Case histories of the projects concerned were, finally, written and their content analysed.

* ***Summary of Findings and Conclusions***

1) Full integration was the target of all the companies studied but only two achieved it by the end of the three-year research period. In four others integration was only partially or largely forged but needed more time for completion.

2) Many of the problems resulted from insufficient attention paid to implementation.

3) Implementation resembled more a kind of religious conversion than a rational one.

4) Firms did not take seriously the crucial role of an enthusiastic mid-level champion in the implementation process.

5) The role of an "evangelist" was crucial to the continuity of new technology projects since a "patriarch" would typically pass on the responsibility to the former.

6) Patriarchs, who were persons or corporate bodies representing senior management, often left the firm or had a diminished interest in the project after an adoption decision had been made.

7) An evangelist might not necessarily drive a project in the right direction.

8) Certain personal traits were found to be crucial for leading integration projects. Successful evangelists were found to fulfil three crucial roles: pathfinding, problem-solving and implementing. They were rare individuals who combined skills in transformational leadership, interpersonal sophistication, and technical knowledge. They used their

> "vision, determination, technical expertise, and interpersonal and political skills ..... to build power and influence at multiple levels of the organisation, crossing departmental boundaries to build alliances, to preach the gospel of AMT and to win enough converts so that new technology was espoused by a critical mass of believers." (p. 93).

* ***Summary of Strengths and Weaknesses***

The study provided a rich description of the processual dynamics of the change process. Its most significant theoretical contribution was that it stressed the effective role of interpersonal relations as a politically sensitive issue in the division of labour in the change process and, thus refuted the notions of rationality and linearity often associated with innovation. The differentiation between the respective contributions of senior and middle managers to the process was another theoretical insight in that it stressed the differences between decision-making processes on adoption and implementation. Three years was a reasonably sufficient period to capture several "snapshots" of the process and thus provide "a moving picture of it" (p. 80). The credibility of such a strong methodological feature of the study was further supported by the wide range of actors who were interviewed at various levels of the ten companies. The structured interview schedules used for data collection would have facilitated a comparative analysis of the various rationalities that could be found within an organisation, which could be attributed to differences in position, status, specialisation and decision making capacity.

Nonetheless, the study classified the cases into four grades according to the degree of success, or lack of it, with integration but did not explain the criteria utilised for such classification. Furthermore, it failed to define what "full integration" meant in terms of the progress achieved at the organisational adaptation level.

2.11 Summary

This chapter presented the chosen technology applications in the context of a manufacturing company organisation. The emphasis is more on the implementation of

CADCAM integration and the organisational change process that goes with it than on the introduction of stand alone CAD or CAM systems as specific IT application areas.

The chapter began by justifying the importance of CADCAM and discussed its wide diffusion and integration potential. It pointed to the practical value of integrated manufacturing via CADCAM from a technical rationality perspective. It also discussed the theoretical issues relating to the organisational processes involved in achieving integrated CADCAM.

Some of the most relevant studies were critically reviewed and their theoretical and methodological strengths and weaknesses assessed. This chapter has demonstrated some important points regarding the state of current knowledge about CADCAM, namely that:

1) Both CAD and CAM technology applications have implications for job design and work organisation.

2) Different companies use these technologies in different ways to meet different requirements.

3) The technical potential for integration is being insufficiently exploited in the most advanced segments of today's manufacturing industry.

4) CADCAM integration is problematic because of a variety of structural, human, and technical barriers.

5) Integrated CADCAM will have implications for procedures, structure, strategy, culture, and training , and should not be treated as a purely a technical issue.

6) Differences of national culture and traditions have an impact on change and its outcomes.

7) Historically, the development of the engineering profession in a country (in terms of the professionalisation process, education and training) and the consequences of such development for professional engineers' sense of identity, status and prestige affect their behaviour as a distinguished group (e.g. in terms of their leadership assumptions, working relations with management, and unionisation) and thus influence the role they play in CADCAM integration.

It can be said that CADCAM is arguably a subject of increasing importance, given its future importance for the manufacturing industry due to the anticipated growth in the diffusion of CADCAM. Therefore, further research into it is justifiable on such basis, as can be deduced from some of the reviewed studies (e.g. Adler's, 1989, and Winch and Twigg's, 1993). A grounded analysis of the phenomenon will arguably contribute to a better understanding of it; an analysis that focuses on implementation, since, as Beatty and Gordon (1991) point out, many of the problems in CADCAM seem to be caused by an insufficient attention being paid to the processual dynamics of implementation. Hence, the present study aims to contribute to a developing research process in this area of knowledge.

In conclusion, six points can be made in summarising the limitations of current knowledge in this area, which will be addressed in the present study:

1) The significant role of environmental and market factors in CADCAM integration as a seemingly in-company change process is addressed only in three of the above studies (Adler's, 1989; Lee's, 1989; 1991; and - to a certain extent - Dean and Snell's, 1991). The present research will take such factors into account with a view to understanding how they influence integration in the chosen companies.

2) A number of crucial groups of factors affecting CADCAM integration are identified in the literature (e.g. sociopolitical context, managerial strategies, [Lee, 1989] national culture and professional status [Lee, 1991], size, performance and external control [Dean and Snell, 1991], structural, human and technical barriers [Beatty and Gordon, 1988]). By adopting an exploratory approach, this research will seek to establish how these and other factors interact and influence CADCAM by accounting for them in a single conceptual model.

3) Apart from Beatty and Gordon's (1991), very few studies are concerned with the role of change agents in the process of change towards CADCAM. The present study will investigate the leadership role of change agents by assessing the effect of departmentalised functional structures (i.e. engineering vs. manufacturing) on key individual change leaders' attitudes, assumptions, views and actions regarding integration.

4) With the exception of Adler's (1989) study, no explicit attempt is made to explore a plausible link between integration and learning. This research aims to establish to what extent integration, as an organisational change process can offer organisations, and, among others, key individual change agents in them, opportunities to learn from past experiences of success and failure in implementing an integrating technology.

5) The notion of CADCAM integration as an advanced stage of a longitudinal process of technological (and also organisational) change is not addressed sufficiently in much of the literature. The idea that integrated CADCAM can be conceptualised in terms of a process of change whose historic roots in any integrating company go back to the times when its basic constituent sub-system components (e.g. CAD, CAE, CAM) were initially introduced is almost missing. This study aims to address this point. For example, it will concentrate on how a specific company's approach to integration is contingent upon its past experiences relating to why and how sub-systems were

introduced in the first place, how these were used or customised, how they were maintained and developed, what their technical and financial rewards were, and what types of effect they had on work and organisation in general (e.g. employment and training implications, user and manager job design, industrial relations, and organisation of work within and across functional boundaries).

6) Current knowledge addresses issues relating to CADCAM integration in as far as its application in integrating firms is concerned. This research aims to address the question of why integration seems to be inapplicable to non-integrating firms.

CHAPTER THREE

Theoretical and Methodological Concerns

3.1 Introduction

The design of any study begins with the selection of a topic and a research methodology. Chapter 1 introduced the topic of this research. Having identified an interesting phenomenon to investigate, a researcher's next major task is to observe, discover, or in some way stumble across empirical examples of it with a view to exploring, describing, explaining, and interpreting the topic through a suitable methodology (Marshall and Rossman, 1989). For every research project a focus emerges gradually and guides the process of study design towards fulfilling the purposes intended by the researcher; this is what is termed methodology (Creswell, 1994).

Although it is generally accepted that theoretically oriented research deals with either theory building, theory testing or a combination of both (Brewer and Hunter, 1989), the place of theory in research can still be controversial. Theory is used at one extreme to imply a faithful commitment to an established school of thought, such as Marxism, or, at the other extreme, it is assumed to serve a strictly descriptive, exploratory purpose pertaining to a specific social problem (Silverman, 1985). This study seeks to avoid both extremes and to devise a middle approach guided by:

1) The tentative research questions presented in Chapter 1.

2) The basic theoretical insights that resulted from an extensive review of the literature (summarised in Chapter 2, section 2.11) and informed the development of the research instruments for field work.

3) The use of a research methodology that allows a considerable scope for flexibility, reflexivity, and incrementality in order to assist the researcher in exploring human interaction and political processes associated with technological change.

4) The theoretical issues that emerged from the data itself during the process of data collection and analysis.

As will become clearer from this chapter onwards, the theoretical and methodological approaches adopted in this study are in some ways unconventional. It can be said that his chapter discusses what Pettigrew (1990) terms the "theory of methodology". A detailed explanation of the field work methods utilised in the present study will be given in the following chapter. Having outlined, in broad terms, the study's overall approach, this chapter begins by defining certain key terms that are going to be used frequently throughout the thesis. An important part of this chapter then follows; it discusses the relationship between theory and methodology in a way that is appropriate to the nature of this research. The discussion will serve as a basis for formulating a research strategy accordingly. The ontological, epistemological and methodological assumptions of the study will be explained and a choice of a qualitative paradigm justified. The chapter goes on to discuss grounded theory, case study approaches and their relevance to the present study. Finally, it concludes by showing the measures devised in defence for the reliability, validity and credibility of the methodological and theoretical choices made in the study.

3.2 Clarification of terms

Addressing methodological issues means, essentially, clarifying, explaining, and justifying ways of studying topics of interest to a researcher. In so doing, several terms are likely to be used to refer to specific meanings. Although achieving terminological precision in the area of methodology is rather challenging, yet it is important to try to clarify the researcher's position vis-a-vis key methodological terms that are widely used to imply different things in the methodology literature. This is particularly important as they may have different meanings depending on how they are used.

The following four points will help clarify the terms that will come up frequently during the course of this chapter in terms of how they are going to be used and their intended meanings in the context of this thesis:

1) To begin with, some basic terms will be used interchangeably. These include "research design", "research approach", "research strategy" and "research methodology". The term "research methods" is not considered synonymous with these, as will be shown below.

2) The terms "case study" and "qualitative research" are often used interchangeably in the methodology literature. This, however, should not be so since a case study need not always be qualitative; it could also be quantitative (Bryman, 1989). Nevertheless, this distinction should not be problematic for this study since it utilises a case study approach in a qualitative research design context, as will become clearer in this chapter.

3) A "research design" is regarded as the overall structure and orientation of a given academic inquiry. It is, therefore, to be distinguished from "research methods" which refer to mechanisms or instruments for data collection and analysis within a design framework. Hence, the distinction between a "method" and "methodology" is important.

4) "Methodology" is considered to be a more encompassing concept that subsumes one or more "methods" within it. It follows from the previous point that, within the methodology adopted for this research, various methods for gathering and analysing data were utilised to guide data collection in line with the project objectives.

5) Central to the adopted methodological stance are: (a) the use of integrated methods and (b) the deployment of less formal and conventional methods than those of survey research in order to help the researcher achieve a faster and stronger rapport with participants in the field (see, for example, Whyte, 1984; Glaser and Strauss, 1967). Hence, the project uses a general qualitative, composite-method research methodology (see Brewer and Hunter, 1989). As used in this study, the combination of multiple methods, empirical materials, and perspectives in a multi-method research implies the use of various techniques within a qualitative paradigm.

3.3 Theory - Methodology: What Kind of a Relationship?

The link between theory and methodology has always been an important issue in social sciences. As Greer (1969:160) puts it:

> "The link between observation and formulation is one of the most difficult and crucial of the scientific enterprises. It is the process of interpreting out theory or, as some say, of 'operationalising our concepts'. Our creations in the world of possibility must be fitted in the world of probability; in Kant's epigram, 'Concepts without percepts are empty'. It is also the process of relating our observations to theory; to finish the epigram, 'Percepts without concepts are blind'."

It could be said that theory, in general, has two basic functions in research: (1) solving research problems by accounting for unexplained phenomena and superseding imperfect existing theories and (2) guiding researchers in shaping research problems for further investigation (Brewer and Hunter, 1989). Therefore, emerging new theories can be regarded as ".... nets to catch what we call 'the world': to rationalise, to explain and to master it. We endeavour to make the mesh ever finer and finer" (Popper, 1959: 59). Yet, of course, there is far more than a single stitch for making tighter nets; similarly, there is far more than one best way of conducting research. Research strategies should be designed on a contingency basis: by making the methods adequate and appropriate to the types of data best available, in the context of a range of other contingencies. Amongst these will be factors such as: the time and resources available to conduct the research; the structure of any possible population from which one might sample; the relative degree of ease and difficulty in gaining research access; the nature and design of other programs of research which one knows about at the design stage of one's own work. Additional contingencies may suggest themselves in the context of particular projects.

Competing theories of society, contesting philosophies of science, and varying assumptions about the very nature of sociology are among a number of different interfering factors that affect how the relationship between theory and methodology is perceived in the minds of those concerned about it. As will be discussed later on in this chapter, different ontological, epistemological and methodological positions taken by different analysts create differences in how this relationship is defined (see, for example, Burrell and Morgan, 1979). As Markus and Robey (1988: 595) put it, "social theories embody researchers' conceptions of causality". This is true for the degrees of difference in the claims for generalisability of theory, for example, which broadly quantitative and broadly qualitative paradigms assume.

Although this chapter is about methodology, it is essential that it also addresses theory. In a way, designating a relationship between theory and methodology is the starting point of this thesis. Theory concerning the organisational aspects of integrating technologies needs to be developed further in line with the fast and far-reaching technological changes being experienced in industry today. This is particularly important when viewed against the background of confused, and thus confusing, theory concerning the relationship between IT and organisational change in general (see Markus and Robey, 1988; Robey and Azevedo, 1995). As Steinfield and Fulk (1990) argue, the huge body of empirical data that has accumulated over the past two decades on the impacts of new technology - IT in particular - on organisation has not significantly increased knowledge in this area of research. This field of knowledge remains "data rich but theory poor", because it still lacks a "theoretical infrastructure - a tree to which individual findings can be grafted to generate the synthesis and integration needed to support knowledge claims" (Steinfield and Fulk, 1990: 13).

A theoretical infrastructure for organisation theory needs to be promoted and continuously developed to cope with changing organisational contexts and, thus, support theory development, rather than testing, in this area. The aim of this is to enable organisation theory to be better equipped to provide meaningful interpretations by virtue of theory development and integration. That is, the need for serious attempts in the late 1990s and beyond to contribute to the development of theoretical structures, the synthesis and integration of which will hopefully provide a basis for a sound theoretical infrastructure with integrative characteristics. These will hopefully provide researchers in this area with directions as to what patterns to look for in the data, point them towards such patterns, help them explain them, assist them to interpret and resolve inconsistencies across studies, support them in accounting for anomalous findings, and provide them with guidance as to when to direct and how to incorporate future studies (see Steinfield and Fulk, 1990).

In general, the future of the theory-methodology debate is as significant for the 1990s and beyond as it has always been, if not more so (see Markus and Robey, 1988; Robey and Azevedo, 1995). The emergence of new theoretical currents in sociological theory, such as "post-structuralism", "post-positivism" and "post-modernism" (see, for example, Clegg, 1990; Denzin and Lincoln, 1994; Gergen, 1992; Guba and Lincoln, 1994; Quantz, 1992), promises to reactivate old debates and add new dimensions. Just as the radical humanist school did before, some newer theories seek to give explanatory weight to human intention and the political and power interaction processes that people initiate in social settings, which the radical structuralist school tended to deny (see Burrell and Morgan, 1979). Introducing such dimensions into the theory-methodology debate may appear to challenge the very foundations of well established research traditions. It is, nonetheless, necessary for the development of theory that it recognises people's positive interaction with, rather than mere submission to, social structures. Human action within an established structure, its interaction within it, and interaction among different actors may cause established structures to change. A stress on the role of human agency necessarily entails stressing the symbolic and constructionist role of culture - even when discussing seemingly "material" aspects of the social world such as technology.

The role of culture in analysing modern technology's consequences for organisations, by investigating the former's "instrumental and symbolic roles", has emerged as yet another significant axis for research enterprises tending to move towards less deterministic explanations (e.g. Robey and Azevedo, 1995: 25). According to Meek (1988), the concept of culture was imported from the field of anthropology, where it forms part of a well established research tradition, to be used alongside or in place of the more conventional concepts used in the study of organisations (e.g. structure, leadership behaviour and group norms) whenever these seemed inadequate for explaining the qualitative differences that even casual observations revealed across organisations (Schein, 1990).

It can be said that rapid technological change in increasingly uncertain environments is likely to be a stimulating factor in encouraging theorisation about organisational change in the future (Scott-Morton, 1995). Another factor is, as supported by the growing acceptance among social scientists of, a shift in the dominant techno-economic, "Fordist" paradigm towards an emerging "post-Fordist" (or "neo-Fordist" from a neo-Marxian perspective [Clegg, 1990: 211]) paradigm, despite the vagueness surrounding its definition. The main features of the emerging paradigm include a greater emphasis on: non-price factors, flexibility in technology, flexibility in organisational structure, and the changing relationships within and among organisations in the context of changing national and global political economies (Bessant, 1991).

It is important for a researcher in an exploratory or explanatory research, particularly in an emergent area of interest, not to impose a particular theoretical scheme on reality, because this would reduce the chances for achieving intended objectives of exploration or interpretation of the investigated reality.

The endeavour to devise a link between theory and methodology, which serves the purpose of this study, is supported by three factors concerning: first, the impact of a quantitative or qualitative research design on a theory process; second, the dual theoretical and methodological role of a tentative conceptual framework in research design; and third, the question of whether theory should be tested or generated in a research. Each of these aspects will be discussed in what follows.

First, the perceived nature of the theory-methodology link can vary greatly depending on whether a quantitative or a qualitative research research design is chosen. In a quantitative study a "theory base", "theoretical rationale", or "theoretical perspective" is often placed toward the beginning of the plan of study. The objective is to verify a logically-deduced theory in the form of hypotheses or propositions. In a qualitative study, on the other hand, a "pattern", "generalisation", or "holistic picture" are alternative terms used to describe theory depending on the chosen research design. Inductive reasoning in qualitative design allows a researcher to collect, code, and analyse data while capturing the emergence of theory. Therefore, theory here is often placed towards the end of the research process (Creswell, 1994). Most qualitative researchers avoid generalising, to any considerable extent, the theoretical implications that they see resulting from their work (Glaser and Strauss, 1967). This contrasts fundamentally with the quantitative-positivist view of theory (or "theoretical law"), particularly what may be regarded by some as "scientific" theory consisting of "sets of highly general universal statements, whose truth or falsity can be assessed by means of systematic observation and experiment" (Keat and Urry, 1982: 13-14).

Second, a methodological assumption informed by Miles and Huberman's (1984) proposition is considered, namely that the evolving nature of a theory requires a "tentative conceptual framework" to begin with for data collection, coding, and analysis before theory generation can reach its maturity. The purpose of such a framework is to show:

> ".... simply the current version of the researcher's map of the territory being investigated. Without such a map the research is slipshod. ..... As the explorer's knowledge of the terrain improves the map becomes correspondingly more differentiated and integrated." (Miles and Huberman, 1984: 33).

The tentative conceptual framework used in this study, which will be used to organise the analysis of the data emergent from the field, will be explained in Chapter 7.

Third, a radical endeavour by Glaser and Strauss (1967) in addressing the gap between theory and research in the social sciences. They challenged the overwhelming emphasis revolving around the verification of theory as the "chief mandate for excellent research" (p. 2) and argued for "grounding theory in social research itself - for generating it from the data" (p. viii). Glaser and Strauss's (1967) methodological approach is appropriate for this study because it offers two propositions that are directly relevant to serving its purpose. These are: (1) theory at different levels of generality is vital for deeper knowledge of social phenomena, and (2) researchers should be fully aware of themselves as instruments for developing theory closely with the sets of data they gather and analyse.

In short, this section concludes by proposing that a contribution to the development of a more solid theoretical infrastructure on the phenomenon of technology-induced organisational change is far more relevant to the central objective of this research than a verification of a set of theoretical hypotheses.

3.4 Choice of Methodology: Influential Factors

Choice of methodology for the present study is based on the link identified above between theory and methodology. The research strategy should be guided by its central objective. In this regard, about half a century ago Homans (1949: 330) speculated about the importance of strategy for industrial sociology in general. He wrote:

> "People who write about methodology often forget that it is a matter of strategy, not of morals. There are neither good nor bad methods but only methods that are more or less effective under particular circumstances in reaching objectives on the way to a distant goal."

One does not have to accept Homans's suggestion in its entirety in order to agree with him on a single aspect of his reasoning, namely that the choice of methodology for any research is influenced, necessarily, by a number of factors (e.g. Creswell, 1994; Glaser and Strauss, 1967; Marshall and Rossman, 1989; Nelson *et al., 1992*: Whyte, 1984; Yin, 1987). The nature and purpose of the research problem, the state of development of the relevant body of knowledge and budget and time constraints are particularly important in methodological choices (e.g. Marshall and Rossman, 1989; Pettigrew, 1990). Also, the suitability of a given strategy should be determined by the extent of control a researcher has over behavioural events, and the degree of focus on contemporary as opposed to historical events (Yin, 1987). It is also influenced by the audience before whom a study is conducted (Creswell, 1994).

The philosophical, ontological and epistemological assumptions that ground a study should be recognised and made clear. These influence the researcher as part of the research process, particularly in a social sciences or humanities context, and the individual attributes that the researcher carries can have serious implications for the entire process. In this connection, a distinction can be made between "researcher-related" and "research-related" sets of factors (Creswell, 1994) where the former include one's: (1) world view, (2) training and experience, and (3) psychological attributes. Therefore, the primacy of emphasis in a specific research situation depends on the circumstances of the research, the interests and training of the researcher, and the materials required for one to build one's theory (Glaser and Strauss, 1967).

One of the very basic decisions a researcher has to make in formulating a research strategy is whether to follow a quantitative or qualitative mode of investigation. This helps a researcher crystallise the direction of his/her study in the light of such influential factors. This issue will be discussed in the following section.

3.5 Justifying a Qualitative Research Strategy

The present research requires a methodology that helps the researcher focus on CADCAM integration as a process of change, the context in which it unfolds and its outcomes. To achieve this, the methodology chosen should enable the researcher to:

1) Begin the investigation with as much of an open agenda as possible. The reason for this is simple: it is in order to be flexible enough to design the research in the light of the issues of concern to those who play a key role in real integration processes and, thus, be informant-biased, rather than researcher-biased, in setting out a framework for the study.

2) Embed the investigation in day-to-day reality wherein behaviour patterns manifest themselves, more so than in formal interviews.

3) Extract as much data about the organisations under investigation as possible and for as long as possible with a view to establishing a comprehensive picture of integration experiences.

4) Study organisations in their entirety as much as possible in terms of their formal and informal structures, social relations, cultures, power politics as well as their information systems, work patterns, engineering and manufacturing production cycles.

Creation of theory is needed to support our understanding of CADCAM-induced integration as an organisational process worthy of analysis due to the practical and theoretical considerations outlined in Chapter 1 (section 1.7) and Chapter 2 (section 2.2). Since the aim of this study is to develop a thorough understanding of a process as it unfolds over a considerable period of time, it thus requires what Glaser and Strauss

(1967: 9) describe as a "work-in-process" approach or "discovering *theory as a process*", and explanation in terms of "theory as an ever-developing entity, not as a perfected product" (p. 32). Therefore, a qualitative research approach is justified on the grounds that it will better meet the overall objective of this research than a quantitative one[1].

This choice is justifiable on the grounds that this study's purpose is to understand how specific companies and key figures in them account for their attitudes towards, and actions on, CADCAM integration and its wider organisational implications - rather than to measure the degree to which integration exists as a phenomenon across a wide domain of industrial firms or sectors. Qualitative research on organisational functioning, change, and interactional relationships (between groups and individuals) is, essentially, about producing findings that are difficult to achieve statistically through a quantitative research design[2]. Therefore, an underlying interpretative or constructivist mode of thinking is more appropriate; in order to understand the world of meaning one must interpret it (Schwandt, 1994)[3].

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[1]Creswell (1994: 7) summarises the essential difference between a quantitative methodology and a qualitative one as follows:

> "One approaches a quantitative methodology by using a deductive form of logic wherein theories and hypotheses are tested in a cause-and-effect order. Concepts, variables, and hypotheses are chosen before the study begins and remain fixed throughout the study (in a static design). One does not venture beyond these predetermined hypotheses (the research is context free). The intent of the study is to develop generalisations that contribute to the theory and that enables one to better predict, explain and understand some phenomenon. ..... Alternatively, in a qualitative methodology inductive logic prevails. Categories emerge from informants, rather than are identified *a priori* by the researcher. This emergence provides rich 'context-bound' information leading to patterns or theories that help explain a phenomenon."

[2]Advocates of qualitative research stress its ability to provide researchers with advantages unachievable quantitatively. That is, it is best in terms of revealing the crucial elements of sociological theory via data on structural conditions, consequences, norms, processes, pattern deviances, and systems (Glaser and Strauss, 1967), because it concentrates on "situational and structural contexts" (Strauss, 1987: 2). This could not be achieved easily with quantitative strategies since they implicitly predefine and preconstitute social reality, and thus tend to be "weak on context" (Strauss, 1987: 2).

A published version of a "scientific" research would reflect a reconstructed logic, necessarily with relevant methodological and conceptual problems, subject to human limitations (Silverman, 1985).

Organisations are more abstract in nature and more difficult to comprehend with certainty (Winfield, 1991). Studying them, therefore, can be problematic because they are not naturally a tangible object that could be examined "scientifically" under laboratory-controlled conditions, although it is possible to create an approximation to these conditions. But much of what is "natural" to them can be lost in making them suitable objects for scientifically conceived work, reproducing their rich symbolic life to numeric scores. Sometimes it may be more appropriate to develop these research strategies, where a field is very precise in its focus and mature in its definition of the subject matter. Other times, where the field is emergent because the phenomenon under study is still emergent, a more qualitative and grounded approach will be appropriate - as was for this research.

[3]Recent attempts by researchers such as Robey and Azevedo (1995) to introduce culture as a centre line for analysing technology-induced organisational change are justifiable; "knowledge of technology's social meaning may help to explain its social consequences" through "social interpretations of cultural artefacts, such as information technology" (Robey and Azevedo, 1995: 25). The distinguishing feature of cultural analyses, which are arguably more naturally and effectively linked with the qualitative paradigm, is that they are reluctant to attribute organisational changes to any single cause since =

The justification of a qualitative strategy is based on an informed understanding of the essential differences between the two approaches and the historical contexts in which each of them have thrived. To summarise, this study fits into a qualitative methodology, because of four reasons:

1) Organisational integration induced by an integrating technology is such a complex and multi-faceted issue. As used in the context of this study, it involves integration at the levels of machinery hardware interfacing, inter-software communication, work procedures, and organisational structure and culture. It is thus prone to confusion due to the wide variety of overlapping considerations involved. A qualitative approach is much more likely than a quantitative one to come into direct contact with the social world and thus embed its findings in it through intimate familiarity with field conditions and the social processes it witnesses directly. It is essential that the theory generated in this research springs from the field of investigation. This is in order to reflect, realistically, the circumstances as found in the field since the overall aim of the study is one of building a better understanding of change as a process unfolding in the field of investigation. Hence, qualitative data are required for exploring, describing and analysing CADCAM integration as a specific area of organisational change.

2) Integration is an evolving phenomenon in terms of its emergence in present-day manufacturing industry. It is also relatively new in terms of how it is reported and analysed as an organisational issue in the literature. Its beginnings were as late as the late 1980s and early 1990s. Its relative novelty, therefore, has contributed further to the lack of theoretical vision and relevant variables being identified that can help us understand and explain this phenomenon, particularly in terms of the far-reaching organisational implications involved. Therefore, a qualitative approach is preferred because the concept is relatively immature due to a conspicuous lack of theory.

3) The lack of empirically-informed academic literature on the subject in relative terms, particularly on the theory of integration from an organisational perspective. Stand alone

= changes are assumed to emerge slowly out of a web of interdependent elements (Kling, 1987). In this respect, it could be argued that the crux of the qualitative approach is a commitment to "naturalistic" and "interpretative" or "constructivist" (Schwandt, 1994) modes of analysis as well as an organised critique of the principles of positivism (Denzin and Lincoln, 1994; Guba and Lincoln, 1994). These principles can be identified in terms of: (1) "phenominalism" - i.e. the notion that there is no real difference between "essence" and "phenomenon" and (2) "nominalism" - i.e. the rejection of value judgement under an assumption of the unity of scientific method (see Kolakowski, 1993):

> "Positivism stands for a certain philosophical attitude to human knowledge. .... it is a collection of rules and evaluative criteria referring to human knowledge: it tells us what kind of contents in our statements about the world deserves the name of knowledge and supplies us with norms that make it possible to distinguish between that which may not reasonably be asked. Thus positivism is a normative attitude, regulating how we are to use such terms as 'knowledge', 'science', 'cognition', and 'information'." (Kolakowski, 1993: 2)

computer applications in industry (e.g. CAD) gained considerable academic attention throughout the 1980s, particularly from researchers in the engineering, operations management, industrial relations, and sociology fields of interest. Integration of such applications, however, has not gained a fraction of that attention yet. Rich qualitative data are, therefore, needed because the relevant variables are largely unknown with any considerable degree of certainty.

4) Most of the information available on the practical applications of CADCAM integration in industry in the Anglo-American literature is largely based on reports published in manufacturing periodicals or articles written by consultants or practising managers. A considerable descriptive literature exists, often with conflicting definitions and measures of IT (Bakopoulos, 1985), blurring of distinctions between levels of analysis (Ang and Pavri, 1994), and contradicting conclusions. Little theoretical back-up also contributed to the lack of a solid theoretical base for the notion of technology-induced integration. A qualitative approach is, therefore, justifiable in the case of this study because the little relevant theory that is available is liable to be inaccurate or methodologically biased.

Furthermore, the relevance of a qualitative mode of analysis is much greater for the present research. This is because it:
1) could not be done experimentally;
2) seeks to capture individuals' points of view, of both those who take part in change and those affected by it;
3) aims to look for informal and unstructured linkages and processes in organisations;
4) strives to understand real, as opposed to stated, organisational goals and realities and explain why organisations behave the way they do; and
5) avoids the use of positivism and perceived certainties, which would have been implied by statistical techniques, in interpreting various meanings of reality as they are found.

Qualitative data are more suited because they are a source of well-grounded explanations of processes occurring in their local contexts and, thus they will hopefully help preserve chronological flows, evaluate local causality, develop new explanations in order to deduct qualitatively-informed theoretical integrations (see Miles and Huberman, 1984). Qualitative strategies are by far more capable of exhibiting action and reaction in sociological studies and, thus could be considered better for showing the dynamic nature of any substantive organisational change that becomes the subject matter for an investigation.

The challenge of devising a clearly defined methodological vision based on the above criteria is such that it involves defining minute details of the organisations to be studied, making decisions on what constitutes their environments, and making decisions on priorities which are by no means universally accepted. As Scott (1995: 55) puts it, "given the complexity of social phenomena, any particular set of distinctions will be somewhat arbitrary".

In short, in the light of the above considerations, it is obvious that the present study warrants a qualitative mode of investigation, one that must be flexible enough to help it meet its identified purpose. A positivist-quantitative paradigm would have been inadequate for explaining the phenomena under investigation. However, the question of what constitutes knowledge outside a conventional positivist framework becomes perhaps more important when a constuctivist-qualitative strategy is adopted. The following section addresses this point in the context of this study.

3.6 Defining Sociological Knowledge for the Purpose of the Research Methodology?

Since research is, essentially, a knowledge-bearing exercise, a researcher should clearly define what knowledge is before deciding on the type of methodology to be used to that end. The researcher's "ontological" and "epistemological" positions play a decisive role in his/her choice of methodology because he/she expresses their definition of knowledge therein (Guba and Lincoln, 1994); "axiological" positions are also significant as a prerequisite for deciding what methodology to choose (Creswell, 1994). Such assumptions are subject to the type of research approach adopted in any given study. It is crucial to clarify a researcher's assumptions that, in their totality, give a specific, context-dependent meaning to sociological knowledge. Therefore, the researcher's knowledge-defining assumptions in this study will be discussed in the following three subsections before the methodology chosen is addressed in detail.

3.6.1 Ontological Assumptions

An ontological position is an expression of the question: "what is the form and nature of reality, and therefore what is there that can be known about it?" (Guba and Lincoln, 1994; 108). Two contrasting perspectives are identified in this connection: the objectivist and the subjectivist approaches. The objectivist approach assumes "realism" whereas the subjectivist assumes "nominalism"(Burrell and Morgan, 1979; Kolakowski, 1993).

Framing the distinction between quantitative and qualitative research in terms of two ontological approaches is an important indicator of the competing claims concerning what constitutes warrantable knowledge. In a quantitative research reality is viewed as "objective", "out there" independent of the researcher who can measure it using a research instrument (Creswell, 1994). The qualitative paradigm, on the other hand, recognises the existence of more than a single reality: that constructed by the researcher, that constructed by those being investigated and the readers' own reality. This is based on the assumption that participants' perceptions and experiences play an influential role in shaping the way they make sense of their lives (Merriam, 1988). The researcher, therefore, has to admit such realities and use his/her interpretative or constructivist capacity in this context. In doing so, the researcher should attempt to understand not a single but multiple realities (see Lincoln and Guba, 1985).

This study is based on qualitative ontological assumptions; the researcher believes the existence of various realities. The researcher's admission of this assumption will be reflected in presenting some of the case findings (see Chapter 5) as "observed facts", starting with an objectivist presentation of the actors' reality and then moving towards the main part of data analysis assuming a constructivist interpretative researcher role (see Chapters 6 and 7).

3.6.2 Epistemological Assumptions

An epistemological position is a response to the question: "what is the nature of the relationship between the knower or would-be knower and what can be known?" (Guba and Lincoln, 1994: 108) or " how one might begin to understand the world and communicate this as knowledge to fellow human beings" (Burrell and Morgan, 1979:1). In addressing this question, objectivist social scientists would assume positivist criteria whereas the subjectivists would adopt anti- or non- positivist criteria.
In a quantitative study the researcher usually attempts to maintain distance and independence from what is being researched through surveys or experiments. On the other hand, in a qualitative study the researcher interacts with those being studied over a period of time by means of participation, observation, or collaboration (Creswell, 1994). According to Hamilton (1994), the qualitative paradigm's historic epistemological roots in the collection of data on the human condition could help us understand such interaction between the researcher and the researched, which is characteristic of qualitative studies.

Actors' viewpoints must be grasped, analysed and comprehended in the present research which aims to understand interaction, process and social change as these relate to the implementation and integration of CAD/CAM. Therefore, qualitative epistemological assumptions are adopted for this study.

3.6.3 Axiological Assumptions

The axiological question involves "the role of values" (Creswell, 1994: 5). The quantitative paradigm aspires to produce value-free research. The qualitative paradigm, on the other hand, recognises a researcher's own value-biased judgements as long as they are acknowledged.

The position of the present study is one that is more inclined to qualitative axiological assumptions. However, the present research design should be such that it allows the researcher to develop reasoning gradually from a starting point of attempted "absolute" objectivity to the more subjective, reflexive, and value-laden stage of data analysis. As could be deduced from the researcher's ontological and epistemological assumptions, value judgements are recognised and should be acknowledged in this study.

3.6.4 Methodological Assumptions

Ontological, epistemological and axiological assumptions have important consequences for the methodological nature of a given research enterprise, because of their implications for addressing the question of methodology, namely "how can the inquirer (would-be knower) go about finding out whatever he or she believes can be known?" (Guba and Lincoln, 1994; 108).

Whatever world view a researcher takes, he/she should attain a sufficient degree of consistency that justifies and gives credibility to the particular quantitative or qualitative paradigm he/she chooses. A researcher's ontological assumptions help him/her decide on certain criteria for judging consistency. Similarly, analysis and interpretation should be guided by criteria derived from his/her epistemological position. Therefore, the question of meaning attribution should be presented in such a relative context that admits the conditionality of his/her work. Also, the selection of data collection and analysis methods for any research is dependent on whether the methodology adopted is quantitative, qualitative or both[4].

In short, as explained above (in section 3.5), a qualitative methodology is chosen for the present research for the reasons which have been given. Details of the present study design in the light of the adopted qualitative methodology will be explained in the following section.

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[4] Whilst this chapter's main purpose is to address methodological issues in a broad sense, the following chapter will discuss the finite details of the methods chosen for data collection and analysis procedures in this study.

3.7 Research Design

The present research design is in some ways unconventional in terms of its theoretical and methodological approaches. As shown in Exhibit 3.1, the main components of the present research's design are threefold:

1) It draws largely on the methodological underpinnings of the GT approach (see Glaser and Strauss, 1967).

2) It utilises a multiple-case study approach as a means of initial data presentation and analysis.

3) It stresses time as an important factor in the research process and adopts a longitudinal, time-series type of study.

Before discussing each of the above components in more detail, three important methodological clarifications are necessary for defining the relationships among them. First, GT was not used in a restrictive sense (i.e. excluding other useful qualitative procedures of data collection, indexing and analysis) because of an underlying assumption that qualitative research is inherently multi-method in focus (Brewer and Hunter, 1989). This assumption is consistent with Strauss and Corbin's (1994) contention that all the sources of data normally utilised in other qualitative methodologies could be utilised in a GT research. Flexibility in approach is crucial for providing the study with the distinctive benefits of GT, case studying and longitudinality. As Layder (1992) points out, GT must be viewed flexibly as a methodology open to the influence of other approaches, particularly to the advantages that could be gained from combining important features of both "humanism" and "scientific realism" in social analysis. Therefore, in designing this research a multiple-case study approach was incorporated within a GT context without neglecting the wealth of other useful qualitative approaches.

Second, a comparison between GT and case study approaches would reveal at least three basic differences which can potentially cause a conflict when both approaches are used simultaneously. These were observed carefully during the course of data gathering and analysis:

1) Data collection in GT would be as unstructured as possible whereas in a case study approach it would better be reported in a detailed protocol so that the procedure of a qualitative case study could be replicated in other settings (see Yin, 1989).

2) Data analysis procedures in GT would involve the use of specific coding techniques without a predefined commitment to a specific theory. In a case study research, however, data analysis would be likely to involve searching for emerging "patterns" and comparing them with others predicted from theory using causal links to establish plausible or rival explanations (see Yin, 1989). The mode of causal analysis in a

naturalistic GT research would assume that the researcher would observe directly the causal process which would produce the phenomenon under investigation in particular instances (Brewer and Hunter, 1989). As Glaser and Strauss (1967: 40) put it, ".... general relations are often discovered in vivo; that is, the field worker literally sees them occur".

3) The narrative in GT would proceed from "open coding" and use more advanced coding techniques to develop a story that would relate the open and "axial" coding to one category through "selective coding" or, alternatively, to draw a visual exhibit to explain propositions or hypotheses (see Strauss and Corbin, 1990). In a conventional case study approach, however, only a single case (for a single unit of analysis), multi-case, or illustrative structures such as linear-analytic, comparative, or chronological structures would be considered sufficient (see Yin, 1989).

In this thesis, the case study component of the overall research design was not used as an independent qualitative methodology in its own right as, arguably, could be done in a qualitative study, but rather as a method subsumed in a GT framework. Whenever a conflict seemed to appear, GT's canons were given priority over those of case study.

Third, it is essential to stress an important assumption underlying the present research design, namely that the individual's own personality and background should not be ignored when one is acting the role of a researcher. Research would constitute "an interactive process shaped by his or her personal history, biography, gender, social class, race, and ethnicity, and those of the people in the setting" (Denzin and Lincoln:3). This, in turn, is consistent with the ontological, epistemological and axiological assumptions underlying the present study (explained above in sub-sections 3.6.1 - 3.6.4). The question of the researcher's background's implications for the research design will be addressed further later on in this chapter (see sub-sections 3.7.1.1 and 3.7.1.2 as well as section 3.9 for the implications of the researcher's assumptions for the study's validity, reliability, and credibility measures).

The following three subsections will deal with each of the constituent components individually.

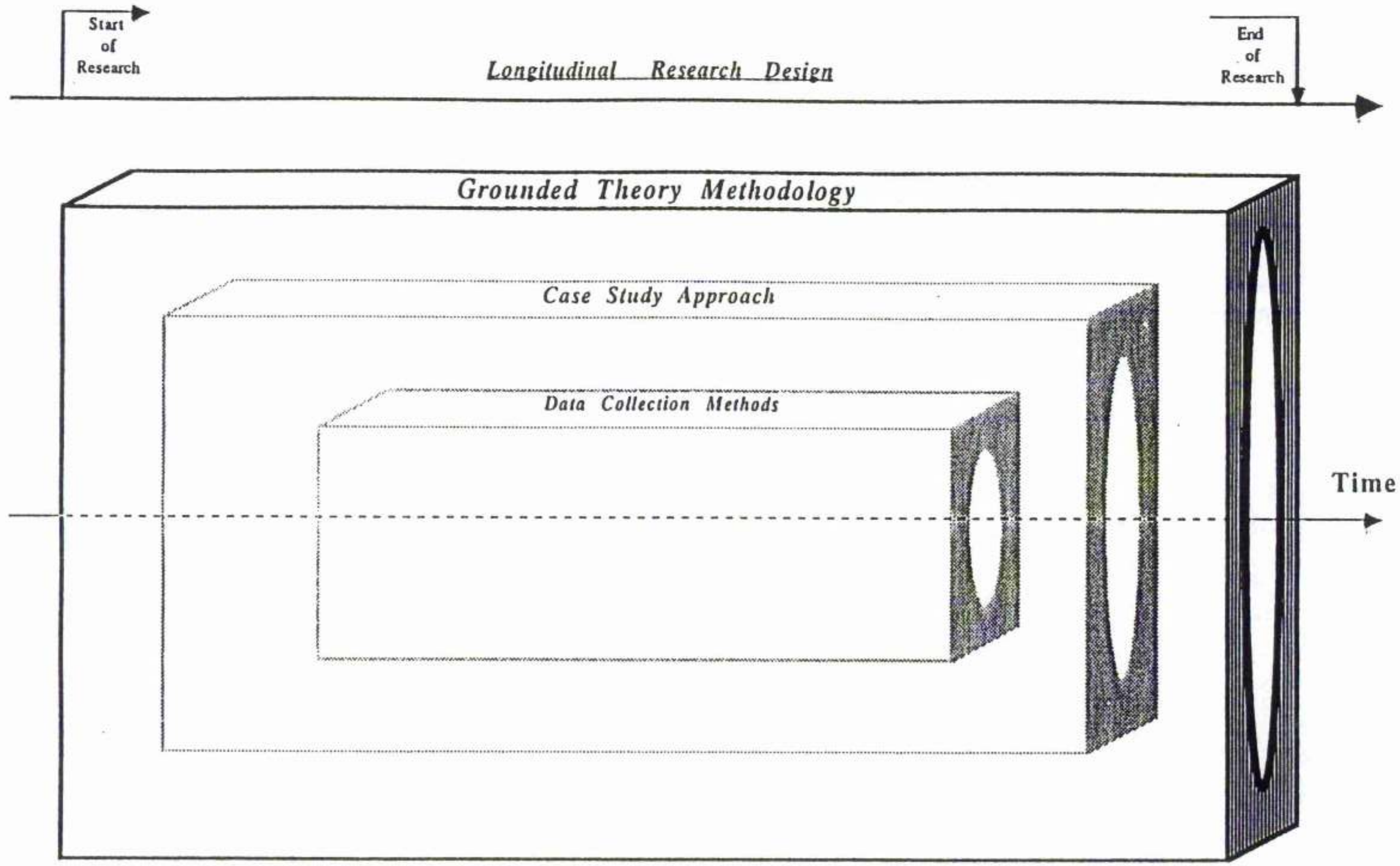

Exhibit 3.1
Overall research design: a GT methodological skeleton subsuming data collection methods within a case study framework - all concurrently longitudinal

3.7.1 Grounded Theory

This subsection will deal with GT. It begins by presenting a brief account of its origins, historical development, and critique. It then discusses theoretical sampling and sensitivity as two of its main characteristics. It also introduces the notion of the constant analysis method in a GT context. Finally, it explains the levels of theory as applicable to the construction of theory in a GT context.

3.7.1.1 Background, Developments and Critique: A Summary

GT was developed by two American sociologists, Barney Glaser and Anselm Strauss in the early 1960s during an observational field study of hospital staff's handling of dying patients (Glaser and Strauss, 1965; 1965a). The GT approach called for strengthening the mandate for gathering theory, defending against doctrinaire approaches to verification. The two pioneers of GT were adamant that GT would be more successful than theory logically deducted from *apriori* assumptions, because they viewed the latter as a framework for static and artificial variables inappropriate for sociological sciences. They also questioned the validity of such theory on the grounds that it would not fit the real world.

GT has been used in studies of diverse phenomena because of its high adaptability (Strauss and Corbin, 1994). It could be argued that its theoretical base has been strengthened and refined because of what has been published exclusively on the methodology and its procedures (see, for example, Strauss, 1987; Strauss and Corbin, 1990; 1994). Its application has varied with the specifities of the particular area being studied, the aims and focus of a given research, the contingencies encountered during the study, and the gifts and temperament or weaknesses of the researcher concerned (Strauss and Corbin, 1994).

In this respect it is relevant to note Strauss's divergence, in his recent writings, from the original line of thought he had taken with Glaser, namely that a researcher should approach the field without any pre-developed theoretical assumptions, that the actors should set the agenda for research, and that the researcher should merely present their, rather than his/her own, interpretation of reality. Strauss argues that broad questions should already be present in the researcher's mind on approaching the field, that the researcher should be the one who sets the agenda, although it should be flexible, and that the researcher should not give up his/her interpretative role or surrender it to the actors. Unlike Strauss in his co-authorship with Juliet Corbin (1990; 1994), Glaser (1992) has recently insisted that the crux of GT lies in allowing theory to emerge without any "forcing" whatsoever by virtue of prestructured orienting framework on the part of the researcher. This stance has taken him away from the position adopted by his former colleague and co-founder of the GT methodology[5]. For reasons which will be explained further on in this chapter, Strauss's perspective will form a more appropriate framework for the present study than Glaser's.

The researcher's coincidental inclination towards Strauss's line in this study is based on the following grounds:

1) The researcher happened to have a reasonably defined set of theoretical issues before embarking on this study, as mentioned in Chapter 1 (section 1.4).

2) The researcher had to design the invitation questionnaire, the first basic interview schedule for the exploratory first round of data collection, and the more detailed schedule as a way of instrumentalising the data collection and analysis process. There was no rigid research design to start with and the research process became gradually shaped by the emerging data.

3) The researcher had to choose a more structured style because of the time and resource constraints that surrounded this study.

According to its advocates, GT is more than a research strategy; it is "a way of thinking about and conceptualising data" (Strauss and Corbin, 1994: 275). Generation of formal theory from substantive material by means of comparative analysis will ensure that the concepts and categories so produced will be appropriate and relevant since such analysis is grounded in empirical reality. This gives a theory developed through a grounded analysis a distinguished place among other types of theory, which, according to Glaser and Strauss, are generated from speculations and assumptions about what "should be" the case rather than what, really, "is" the case in factual terms.

Nevertheless, GT has been criticised on the basis that theoretical reflection cannot be put off until so late in the research process (Bulmer, 1979). That is, the researcher should not approach the field with a "blank mind" because research cannot keep its consistency without an existing theory. However, it can be argued that the essence of GT is not to "freeze up" theoretical reflection completely until after data collection, but rather to free the researcher from being "imprisoned" in a "theoretical cage" prededucted without any experience whatsoever of the field work or environment chosen for investigation. Theoretical reflection would remain flexible initially and then get formulated by the interactive process of joint data collection, coding, analysis and

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[5]It should be stressed, nonetheless, that the two leading GT theorists' differences remain to be a matter of degree since they still agree that the core of GT is the generation of relevant theory from research, that the researcher should be inductive in generating theory from data, and that both the actors' and the researcher's own interpretations are invaluable in any study. They are both of the opinion that an emerging theory should provide categories and hypotheses that could be utilised in future research.

interpretation in a cyclic fashion, rather than sequentially as Bulmer's (1979) criticism would implicitly suggest.

GT has been also criticised as a methodology that advocates a form of "inductivist positivism" (Stanley and Wise, 1983: 152). Glaser and Strauss (1967: 3) would disagree; they stated clearly that " the researcher does not approach reality as a *tabula rasa*". Emergent theoretical accounts could be regarded as the product of a continuous interaction between data and conceptualisation or the research experience and the researcher's ideas. Therefore, no claim for positivism should follow an inductivist research which involves such an interaction in the light of qualitative, anti-positivist ontological and epistemological assumptions. This position would be supported by GT assumptions regarding the obscurity of the relationship between data and theory initially, the declared need for tolerance and innovativeness in exploring the less obvious aspects of this relationship, and the need for being sensitive to insights that would arise during the research process.

According to Layder (1992: 69-70), GT assumptions have a tendency towards undervaluing the importance of "macro structural" features and emphasising theories which are limited, rather than guided, by empirical data analyses. Therefore, field researchers are advised to search carefully for the influence of structural features on the apparent behaviour of the individuals being observed. It could be said that this criticism is worthwhile in the sense that GT could be used, or abused perhaps, in a short-sighted manner which focuses only on micro structures, isolated events and local interaction contexts without analysing these in their macro-structural environments. This is because GT grants a researcher such a degree of flexibility and a wide margin for manoeuvring in directing his/her research process, collecting data and interpreting it. Any theory resulting from a grounded analysis, however, should be assessed on its own merits. Gross generalisations can be misguiding. In this study sufficient account is taken of the influence of macro-structural characteristics on the behaviour of individuals and groups alike. Indeed, the conceptual model developed in the study (Chapter 7) acknowledges the role of such characteristics not only at functional department and whole company levels but also at industrial sector market, state and national culture levels.

3.7.1.2 Theoretical Sampling and Theoretical Sensitivity

Theoretical sampling is an important feature of GT. It has important implications for the present research. It is defined as:

> "…. the process of data collection for generating theory whereby the analyst jointly collects, codes, and analyses his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges." (Glaser and Strauss, 1967: 45).

Theoretical sampling differs profoundly from statistical sampling. The former involves selecting units of investigation on the basis of how widely and diversely they could saturate the categories of the theory a researcher would wish to develop. The latter, on the other hand, involves the development of adequate samples using techniques of random or representative sampling in reference with the social structure of the groups sampled. The logic of comparative analysis concentrates on accurate evidence for the purposes of description and verification. In such cases, the rules of comparability may hinder the formulation of theory due to the possible non-comparability of groups on some occasions. Another difference is that in theoretical sampling the researcher must learn when to stop by reaching "theoretical saturation". By contrast, statistical sampling requires continuous data collection regardless of how much saturation has been achieved.

A theory that emerges from a GT type of research points the researcher to the next step in a developing research process. As Marshall and Rossman (1989: 112) put it, "qualitative data analysis is a search for general statements about relationships among categories of data; it builds grounded theory". Essential and evolving questions before a researcher concern the selection of multiple comparison groups. Therefore, the central question is: "what groups or sub-groups does one turn to in data collection? And for what theoretical purpose?" (Glaser and Strauss, 1967: 47). The ongoing inclusion of groups must be determined principally by the researcher's basic goal guiding the research towards comparison groups on the basis of their theoretical relevance. How many groups could be considered sufficient? And to what extent should a researcher gather data on a single group? Answering such questions will be guided by the emerging research process. It depends on when the point of theoretical saturation is reached.

Formulating a theory from a set of data requires a great deal of theoretical sensitivity on the part of the researcher, which he/she derives from the literature, his/her professional and personal experiences, and the increased interaction he/she will have with the data (Strauss and Corbin, 1990). Any process of data collection, coding, analysis and further guided collection demands a certain degree of awareness about how to formulate theory by conceptualising data through categories and their constituent properties. Therefore, theoretical sensitivity is an essentially accumulative phenomenon; it is part of the research process in so far as it represents a learning opportunity for the researcher in terms of his/her field, topic and personal development (Glaser and Strauss, 1967; Strauss and Corbin, 1990; Whyte, 1984). The argument is that theoretical sensitivity is best promoted by the amount of freedom it gives a researcher to approach and investigate his/her field without committing him/herself exclusively to one preconceived theory. In essence, it could be viewed as a call for liberating research from those forms of prior indoctrination that cause a researcher to become insensitive to "other" theory and defensive towards challenging questions and proposals or, in Glaser and Strauss's (1967: 46) words "preoccupied with testing, modifying and seeing everything from this one angle".

3.7.1.3 The Constant Comparative Analysis Method

When comparative analysis is used in a GT context it should not be restricted to comparisons between formal social units but it should be used in comparing smaller social units as well (e.g. individuals and their roles). The comparative method helps a researcher develop his/her discussional and prepositional theory during the research process. In the present research it is used, for theory generation purposes, at various levels corresponding to different units of analysis, including companies, integration processes, integration project leaders.

The constant comparative analysis method is important for data analysis (Chapters 5, 6 and 7). The procedure followed comprises four stages: (1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) refining the theory, and (4) writing the theory.

3.7.1.4 Orienting, Substantive and Formal Levels of Theory

In a GT research two types or levels of theory are recognised: "substantive" and "formal". These are derived from data at different levels of generalisation. A substantive theory is "developed for a substantive, or empirical, area of sociological inquiry" whereas a formal theory is "developed for a formal, or conceptual, area of sociological inquiry, such as ... formal organisations .... authority and power" (Glaser and Strauss, 1967: 32). Generation of formal theory from substantive theory grounded in the data involves a progressive transition from concrete to abstract thinking.

As Whyte (1984) points out, however, a researcher is likely to approach his/her study with some kind of theory, albeit in the form of a guiding frame of reference, a rough theoretical framework or a horizon of expectations. Before reaching substantive and formal levels of theory, a researcher should begin theorising at a more basic level. An "orienting theory" is thus proposed initially. It precedes more advanced theorisation and helps a researcher organise his/her data gathering and analysis effort[6]. Miles and Huberman (1984: 28) also argue the need for a "tentative conceptual framework" that

[6]Orienting theory would guide a researcher indexing in two areas: (1) actors and their relationships and (2) events and references to problems of importance to or mentioned by informants (Whyte, 1984; 118).

"explains, either graphically or in narrative form, the main dimensions to be studied - the key factors, or variables - and the presumed relationships among them". As will be shown in Chapter 7, this research develops a conceptual framework for modelling CADCAM as a change process and, in this sense, makes use of an orienting theory based on the answers to the tentative research questions to be discussed in Chapter 6.

A generated theory consists of "conceptual categories" which, in turn, consist of "conceptual properties". During the course of a research "lower level categories" emerge rather early whereas "higher level, overriding and integrating conceptualisations" emerge later as joint data collection, coding and analysis reaches maturity. Theoretical proposals or hypotheses will develop as this process progresses. As Glaser and Strauss (1967: 40) comment:

> "In the beginning, one's hypotheses may seem unrelated, but as categories and properties emerge, develop in abstraction, and become related, their accumulating interrelations form an integrated central theoretical framework - *the core of the emerging theory*. The core becomes a theoretical guide to the further collection and analysis of data." (Glaser and Strauss, 1967: 40).

Joint data collection, coding and analysis is the core activity in GT. During the research process "integration" of the emergent theory, gradually, becomes more important than the emerging categories and properties themselves. This is crucial for developing a consistently cohesive theoretical framework capable of encompassing the fullest diversity of conceptual elements indicated by data. Integration of theory is important for correcting inaccuracies of hypothetical inferences and data.

Having discussed GT as the first component of the research design, this chapter now turns to address the second component.

3.7.2 Case Study

This subsection will introduce the case study approach, discuss it critically in terms of its advantages and limitations, and justify its addition to a GT methodology. It also explains design issues and analysis units associated with the adopted approach.

3.7.2.1 Background

A case study approach gives the researcher an opportunity for an intensive observation of one or more individual units, rather than a total population or a sample of it, with a view to answering one or more research questions. This approach is particularly preferred in examining contemporary events (Yin, 1987). Hence, it is relevant to this study because it aims to investigate processes of CADCAM integration as they occur in their natural organisational settings. In this study the case study approach is chosen in order to allow the researcher a considerable degree of flexibility, scope and freedom regarding the quantity of data to be collected, the collection procedure, and the sources of information to be used. An intensive case approach is suited to exploratory research, since it is capable of stimulating insights in studying unformulated areas, revealing more information for understanding relationships between real life variables, and suggesting hypotheses for further research (Yin, 1987).

It is hoped that detailed case descriptions (Chapter 5) and analyses (Chapters 6 and 7) help counteract a simplistic and discipline-biased analysis. Like any other method of research, however, this approach has its own advantages and disadvantages. These will be discussed in the following subsection before proceeding further to talk about the need for it in the present research design.

3.7.2.2 Strengths and Weaknesses

A researcher must be sufficiently aware of both the strengths and weaknesses of the research methods he/she utilises.

In short, the strengths of this approach can be summarised in the following points:

1) Case studies enable the researcher to observe events of the study in its natural setting[7].

2) In a case study situation a researcher can utilise various methods for data collection, as is the case in this research. For example, interview data can be combined with the researcher's observations for improved reliability.

3) The case study technique permits interdependent reactions and mutual perceptions to be obtained from different individuals whose behaviours are interrelated in a single social organisation. Discrepancies in information given by different informants will warrant additional exploration, which is possible in case study, to establish whether such discrepancies resulted from differences in perceptions and personal experiences or a reflection of group membership and role dissimilarities.

4) Case studies tend, particularly in a longitudinal research context as is the case in this research, to continue over a period of time, allowing the researcher to maintain continuous observation. A longer involvement allows interconnections and events to be traced over time, so that processes can be inferred. Also, data and emerging findings can be continuously cross-checked and refined to increase reliability.

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[7]The case study approach allows a researcher to establish a direct contact with the studied reality and, arguably, provide more reliable knowledge in answering difficult questions than he/she can by statistical generalisations due to a more grounded basis for personal understanding. It could also be contended that it would provide a more solid ground for considering action in applied research situations. The case study approach is strong in realism, significance, theory orientation, and heuristic quality (Kerlinger, 1973). Therefore, the value of case study lies in the adequacy of the theoretical inferences that are generated (Yin, 1987).

Weaknesses of the case study approach should be carefully taken into account. These can be summarised in the following points:

1) Biased views and dubiousness of evidence would influence the degree of rigour applicable in a case study situation. This could negatively affect the credibility of findings and conclusions.

2) Data collection procedures are not routinised. Therefore, they require extra skills on the part of the researcher than in experimental and survey approaches.

3) Some respondents might not be prepared to co-operate sufficiently such that all data requirements could be met. They might avoid an explicit rejection with excuses of being busy with their work.

4) Findings and conclusions from a single case study cannot be generalised for a population. However, the use of multiple case studies, as has been done in this study, is a conscious attempt to increase the level of generalisation[8].

3.7.2.3 Case Study As Well: Why?

The need for case study besides GT in the context of the present research design is clearly defined. It is used in the earlier stages of the research process as a means for the following:

1) Creating conceptual "boxes" for the collection of data with respect to each of the companies researched in order to keep filling them with data as the field work progresses.

2) Organising the accumulative data with a view to building more structured data collections which are organised in such a way as to show classified information about the companies, individual actors and their relationships, events and references to problems of importance affecting or mentioned by informants.

3) Analysing data categories and properties common to all cases as these emerge from cross-company comparisons.

4) Helping the researcher answer the tentative research questions in terms of the cases in the study (Chapter 6), each of which with its unique history and operating as a complex organisational entity within its environment.

The case study approach is theoretically important for the study in three ways:

1) Unless a technological change process is explained through a case study approach, with a view to tracing the decisions and actions involved in it through to their

[8]Also, by choosing to study the "typical", the "common" and the "ordinary" a researcher can maximise generalisability from the outset when a multi-site research design is adopted deliberately on the grounds that the chosen sites are typical representatives of the social institutions or phenomena under investigation (see Schofield, 1993).

outcomes, the experience of the process itself and its consequent outcomes will remain to be the best route to knowledge about it. Case histories can show what actions in what circumstances will lead to what outcomes. Theoretical relationships can be synthesised with a view to explaining what exactly happens in organisations .

2) The experience of conducting a systematic and rigorous case study brings home the complexities of the technological change process. In conducting a detailed study of selected cases the complex social and political web in which technological change is undertaken becomes salient with positive implications for theory generation.

3) A process of technological change and its successful or failed outcomes cannot be understood thoroughly with superficial data-gathering methods that yield face value information. The case study approach will hopefully unveil what is problematic in the chosen field of investigation; it helps generate ideas about cause-effect chains and stimulates the researcher's thinking about practical solutions in constrained organisational contexts. This is because case study is an effective approach for answering "how", "why", and "what" research questions when asked in an exploratory context (see Yin, 1987: 17).

3.7.2.4 The Case Study Design

Different researchers have different purposes for studying cases. Designing a case study should be guided by the purpose one sets out to achieve. Depending on a single case study can be unreliable in a study founded on a non-statistical logic. A multiple of cases will provide confidence in claiming a higher degree of representativeness. Therefore, this study utilises a case study style involving a multiple of cases with a view to developing theory on the chosen subject matter.

Case study is a useful way for inducing and directing further research, because it helps a researcher develop an informed account about the case(s) being studied and enables him/her to pursue missing or unclear points that may emerge with a view to further theoretical development.

A replication, as opposed to a sampling, logic is suggested for studies involving more than a single case. Each case resembles a single experiment. Analysis follows a cross-experiment, rather than a within experiment, design logic. Replication is relevant to the case study design adopted because of the multiplicity of cases studied (see Yin, 1987). Case history details forms an important part of the case study design in this research. Through a case history the researcher aims to establish a historical account of the companies involved and their experiences with stand alone DEM systems such as CAD and CAM (see Chapter 5). This is needed to study the issue of integration against a realistic background knowledge of each of the companies, not only as they are researched in their present form, but also in terms of how their respective technical, commercial and organisational developments have shaped them historically. Assessing the experiences of key individuals involved in such developments will be important in order to establish historical accounts of how stand alone computer applications have evolved. The aim is to develop as comprehensive an account as possible of the cases through a longitudinal case study design[9].

Three considerations are important in the design of the present case study element of the research strategy. In other words, for a case study approach to be useful for this study it has to fulfil the following three conditions:

1) encompass enough of the facts about the company in question, the engineering work flow process that essentially characterised its DEM activities, the stand alone technology systems in applications, their formal technical and financial objectives and outcomes, the implementation process, the organisational implications of implementation, and the status quo of the issue of integration in the light of such particular specifities. Hence, the length of case write-ups should be decided on the basis of a calculated estimation of the minimum sufficient details required to give an in-depth appreciation of all the factors involved in the studied processes.

2) Be conducted consistently and rigorously. A well researched case study should not risk being biased by giving an account based on a single source of information. Data of all types and from all the sources available to the researcher will be used.

3) Establish what is common and what is particular about each case to unveil the degree of uniqueness available, by defining: (a) the nature of the case, (b) its historical background, (c) the physical setting, (d) other relevant contexts and (e) those informants through whom the case can be recognised. Case specifities such as these are discussed in detail in Chapter 5 to justify the claim that the uniqueness of cases is likely to be pervasive through such particulars.

Deciding on the unit(s) of analysis is an important step to be taken in any research design since it helps define the research's boundaries. In this sense it can be viewed as part of a case study research design. The units of analysis used in the study will, therefore, be discussed in the following subsection.

[9]As Layder (1992) points out, incorporating a historical dimension into a study should be taken seriously because it offers an enriched analysis. Whyte (1984) also argues that any study of an organisation should be built on a firm historical base whereby historical data should be integrated into any analysis of present structural and social process data.

3.7.2.5 Units of Analysis

The present study is more interested in understanding the ebb and flow of the processes of CADCAM integration in the cases studied than in isolating static factors affecting these processes and their organisational outcomes. Therefore, its unit of analysis must be the project incorporating the whole CADCAM (or CIM) process from initiation to termination and the implications of this process for integration at a manufacturing organisation level, particularly in so far as the DEM interfaces are concerned. Therefore, the design, engineering, and manufacturing functional departments of the cases studied will represent the core of the cross-site comparative analysis. The companies will be investigated firstly in their entireties as organisational settings (see Chapter 5). Consequently, as the research process progresses the emphasis will shift towards the mentioned functions specifically as the more immediate functional environments involved in change.

In short, the central unit of analysis in this research is a manufacturing company's project for implementing CADCAM integration and the leadership of the integration process. To begin with, however, five tentative units of analysis will be utilised in the initial stages of case data analysis. These are the: (1) organisational setting, (2) engineering and manufacturing activities within such settings, (3) elements of integrating technologies in application, (4) historical background to technological change in the CAD and CAM areas, and (5) background to the organisational contexts for integration (see Chapter 5).

The next section will discuss the third component of the research design: longitudinality.

3.7.3 Longitudinality

The present research is exploratory and explanatory in that it aims to explore CADCAM integration as a process of technological (and organisational) change and, thus develop a deeper understanding of it, rather than one that seeks accurate measurement of an instantaneous kind. Therefore, the decision to adopt a longitudinal, rather than cross-sectional, research design is a dimension of strategic importance to this research process.

A crucial advantage of a longitudinal research design, in the light of the methodological assumptions adopted in this study, is that it will allow the researcher an opportunity to analyse the dynamic background against which technology-induced organisational change has to be managed in the light of continuous and accumulative action[10].

Also, longitudinality will facilitate the cause of a realistic analysis of the true nature of innovation as a political, rather than a totally rational and unproblematic, process. That is, since innovation involves organised human beings of various subjectivities, then it is not unreasonable to suggest that it must have a subjective dimension involving values. Therefore, differences amongst different actors due to value, perspective and self-interest differences should be taken into account when studying their behaviours concerning the ways they acquire and control resources. The idea is that such differences, among other factors, are likely to cause disputes, contests and power struggles - instead of collaboration - as the different actors (both individuals and groups) set about conducting their organisational work.

Perhaps it may often be the case that a technological innovation begins as a purely rational initiative, but it is likely to become a politically sensitive issue, particularly at the stage of implementation where partial or complete failure becomes public knowledge. Therefore, a longitudinal research design offers the researcher an opportunity to monitor change as it develops and assess to what extent it involves elements of objective rationality and to what extent it is a problematic political process driven by competing self-interests, contests and power struggles. Without this "extra time" advantage that a longitudinal approach gives, the researcher's task of establishing an independent assessment based upon evidence that survives the test of time would be much more difficult. The strength of such evidence lies in the fact that it has its roots embedded in the historical contexts of the realities in concern, in which the present CADCAM processes being investigated are unfolding with actors' contributions - both positive and negative, legitimate and illegitimate, formal and informal, or/and invited and voluntary as far as a given technical rationality logic is concerned.

Additionally, such research evidence, it can be argued, is more reliable for predicting future trends of development concerning integration than other "ungrounded" evidence which is obtained at a single point in time and used, by virtue of cross-sectional quantification, to draw somewhat "static" and "instantaneous" conclusions concerning something which is dynamic by definition. The chances are that a researcher is likely to end up with a theoretically sound model of change based on a linear rationality logic, but one that fails to explain some of the "irrational" aspects of actors' behaviour, those

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[10]As Pettigrew (1990: 271) contends, "for the practitioner of longitudinal research, issues of time are crucial and pervasive" because of the fundamental assumption about time as a prerequisite for constructing an accumulative account of "reality" of what is being researched, and thus the expression that "truth is the daughter of time"(p. 271).

aspects which could easily be missed if a questionnaire is used or a single interview conducted as a "one-off" data collection effort. Indeed, the problem is more complicated than that since the actors themselves may tend to justify many of those seemingly "irrational" aspects in a different rationality's frame of reference, or - as may be often the case - present them as aspects that are motivated and justified in the name of pragmatism and self-interest alone without necessarily a coherent rational logic underlying them. This is particularly so in a logico-deductive research strategy where the researcher predefines the "reality" being investigated in his/her mind prior to data collection and then goes on to gather only the data which fits into his/her theoretical model or, alternatively, imposes the model on other data which cannot be incorporated and probably interprets the emerging data surplus or deficit in error terms. Unfortunately, when left to manifest itself freely, in a longitudinal research design, such "other data" may suggest important clues to important issues not taken into account by the model.

Many researchers will agree with the position adopted in this study, namely that a distorted picture of innovation is often presented in much of the relevant literature where exaggerated assumptions of rationality and linearity often deform the reality of messy change processes in organisations (see, for example, Frost and Egri, 1991; Pettigrew, 1985; Robey and Azevedo, 1995; Winch and Twigg, 1993). Conflicts over economic, political, and ideological inequities in social arrangements are bound to challenge the idealism inherent in simple notions of shared organisational goals and effectiveness of organisational change (Robey and Azevedo, 1995). This supports the line of thinking adopted in this study, namely that a longitudinal research is more likely to yield a valid and realistic picture than a cross-sectional research or one with simplistic assumptions about innovation as a purely objective process.

The relevance of a longitudinal research design to CADCAM integration is perhaps obvious since integration involves a long-term change process. The period of time during which a manufacturing company experiences the implementation of stand alone computer applications is conceptualised in terms of an accumulative organisational learning process that terminates at integration (see Bessant *et al.*, 1996; Jones and Hendry, 1994; Kim, 1993). This is particularly so when integration is a set and pursued objective.

Different kinds of data are important for this type of research because they will give the researcher different vantage points from which to understand a theoretical category and to develop its properties. This justifies the utilisation of different devices for gathering data and presenting the research findings, which, when taken together in an integrated manner, will hopefully enable the researcher to place individuals in a group context and gain a realistic picture of the dynamics of individual and group behaviours in the context of a longitudinal research design. Such devices will include quotations from interviews and informal conversations, segments of the researcher's "on the spot" field notes and case writings to help the researcher organise and summarise information about events, actions, and actors and the roles they play in their respective organisations.

To summarise, a longitudinal, process-oriented research is believed to be crucial for theory generation on technology-induced organisational integration. This argument is based on the grounds that:

1) Integration theory is currently at a phase of infancy in an expectedly extended life cycle towards maturation due to profound anticipated technological and organisational changes yet to occur in the future. Further diffusion of integrating technologies, such as CADCAM and MRP II is likely to increase the demand for further theorisation in this area of interest.

2) A theory generated on CADCAM integration will benefit from a realistic assessment of the problematic nature of the kinds of organisational change often associated with integration. For the reasons discussed above, such a realistic assessment may be, justifiably, sought through a longitudinal research design since it is more likely to serve this purpose than other research designs which do not study the subject for the same length of time.

3) Leading technologists and managers learn from their past experiences of implementing stand alone technology applications; they learn important lessons that they will find useful in future when managing more complex technology projects with greater organisational challenges such as CADCAM integration. A manufacturing company will encompass a skill base enriched by practical experience over the years. Such a base comprises the total sum of the skills and experiences of its leading technologists, professionals and managers and, hence will play a vital role in how CADCAM integration is approached. The experiences of such key individuals in implementing, managing, developing and maintaining stand alone project applications will be an important learning asset for future investment in integration. This is based on the assumption that learning represents the "capacity or processes within an organisation to maintain or improve performance based on experiences" (Nevis *et al.*, 1995: 73). Thus, the significance of a longitudinal study design can be defended; a relatively long time is needed to establish to what extent companies make use of their learning experiences in ways that serve the interests of CADCAM integration.

Finally, it should be noted that a sense of measure of the time involved in a longitudinal study is important in addressing longitudinality with a view to defining it. For example, researchers such as Van de Ven and Astley (1981) argue for the need to combine micro and macro perspectives on organisational change. At one extreme, the former focuses on part of a changing organisation over a short period of time (e.g. 6-12 months). At the other extreme, the latter focuses on the whole organisation within the context of its environment over a considerably longer time (e.g. over 80 years). The present study avoids both extremes, as will be explained in Chapter 4.

The tentative research questions initially used in the research process will be discussed in the following section in the context of the subject matter of the present chapter.

3.8 Linking Tentative Research Questions and Underlying Assumptions with Data Collection

This study takes a rather unconventional approach to defining the role and capacity of research questions. It does not approve of formulating clearly defined and fixed research questions before approaching the field of investigation. However, the researcher found that his thoughts needed to be arranged somehow prior to field investigation. Therefore, tentative research questions were used temporarily during the first stages of the research process (as mentioned in Chapter 1), but not with a view to deriving testable logico-deductive theoretical propositions nor with the aim of answering such tentative questions as the main "formal" objective of the investigation, as would have been suggested by more conventional research methodologies (see, for example, Creswell, 1994; Silverman; 1985; Yin, 1987). Rather, these questions were used (see Chapter 6) only in order to: (1) synthesise a case history for each company, (2) appreciate the types of production systems, technical tasks, products and industry sector environments relevant to the companies; and (3) orient the process of identifying the issues that were regarded to be of vital concern to the people involved in each of the studied organisations.

The study's main data collection instrument (see Appendix D) was designed so as to facilitate answering these questions in a case study format. It was designed on the basis of a series of assumptions as part of the research's tentative conceptual framework. These assumptions took the form of sets of "raw" questions and were deliberately left without further development along logico-deductive lines in order to address them in a GT methodological framework. These sets of questions or vague queries could be summarised as follows:

* What are the motives for integration? What circumstances precede and probably trigger off a process of change? How does a company become exposed to the

technology concerned? What possible processes of initiation, adoption, implementation and adaptation are involved in each case?

* Who is/are responsible for the process of change in terms of authorisation, championship, evaluation, implementation, management and maintenance? What are the positions, professional expertise, and levels of authority of such people in their respective organisations?

* Which categories of employees are affected by the change, how significantly, and in what ways? What are the different possible meanings attributed to integration held by different agents and interests? Which of them becomes dominant? How does it do so?

* How do companies come to adopt stand alone systems? How do they go about implementing them? To what extent and how is the adoption also a process of adaptation (design and use) of these technologies to fit their respective organisational settings?

* To what extent does the implemented technology meet its predefined technical and financial objectives and why? To what extent does it serve and support business objectives and how? What are its implications for work organisation and job design?

* Where applicable, how do those companies seeking to implement CADCAM or CIM systems go about realising integration? How does a company's past experience of stand alone systems affect the way it goes about defining and implementing integration?

These queries eventually were expressed in the form of the research's seven tentative questions stated in Chapter 1 (section 1.4). It is worthwhile to present them again here so as to explain them further in terms of the underlying assumptions that gave rise to their formulation:

1) Why do manufacturing companies acquire CAD and CAM systems?
2) How do manufacturing companies design/use CAD and CAM systems?
3) How do manufacturing companies introduce, maintain and develop CAD and CAM systems?
4) What are the outcomes of the implementation of CAD and CAM systems in terms of pre-identified objectives ?
5) What are the impacts of the implementation of CAD and CAM systems on manufacturing organisations?
6) Why does a manufacturing company seek (or decline) to integrate CAD and CAM systems?
7) Where applicable, how does a manufacturing company manage the integration of CAD and CAM systems in the context of its accumulative experiences in this area of technical change?

The assumptions underlying, and reflected in the questions, are summarised as follows:

A) A manufacturing company would initially begin its experience of advanced technology systems in the engineering and manufacturing functions by introducing a stand alone computer system, typically but not necessarily CAD, motivated by its potential technical and business benefits. This assumption is reflected in question (1).

B) Work organisation and job design issues that would arise due to integration would be far more serious than those raised by stand alone systems. The potential impacts of integration in this area would be much greater. This assumption is reflected in questions (4) and (5).

C) Integration would be much more difficult to manage than stand alone applications. It would necessarily place new challenges on managers at various levels. Managers would face difficulties as they attempt to implement integration. These would, however, present them with learning opportunities. Individual managers' roles, inter-managerial relations, and, consequently, the nature of the management function as a collectivity would therefore be affected. This assumption is reflected in question (7).

D) A manufacturing company would encompass a skill base comprising the total sum of the skills and experiences of its technologists and managers. This would play a vital role in how it approached integration. The experiences of leading technologists and managers with stand alone project applications could be an important learning asset for success in integration. This assumption is reflected in questions (2), (3) and (7).

E) Integration would be an organisational, rather than, technical problem in essence. It would have implications for machinery, material flow, information systems, strategy, formal and informal organisation, and culture. It would have political implications at the individual, group, departmental, corporate and cross-organisational levels, because integration projects would tend to be cross-functional, organisation-wide, or/and cross-organisational. This assumption is reflected in questions (6) and (7).

F) Different manufacturing companies would approach integration differently due to a complicated interplay of interfering, overlapping sets of factors that this research would aim to investigate longitudinally by embedding its findings in companies' natural organisational settings. Obstacles to integration should also be researched in their natural settings. This assumption is reflected in questions (4), (5) and (7).

G) Integration would be a long-term, costly project involving a gradual, piecemeal addition and upgrading of stand alone applications. Hence, it would require to be studied as a process of change. Therefore, it would be crucial to study it in an historical context in order to trace a host company's experiences in this area and its learning process. Also it would require a careful consideration of the implications of such a project for strategy in order to avoid decoupling the study of technological innovation from that of competitive strategy as is too often the case. This assumption is reflected in questions (1) to (7).

H) The attribution of various meanings to integration by different agencies and interests would be likely. Different individuals, groups, and departments would react to integration in different ways due to perceived gains and losses arising from change and, hence resistance would be likely. This assumption is reflected in questions (1), (2), (3) and (7).

I) Technical, business and organisational development processes should be managed simultaneously. Integration would support profitability when it would be likely to meet a manufacturing system's technical requirements in the light of long-term business objectives on the condition that the company would deliberately develop its organisation so as to accommodate integration. This assumption is reflected in questions (2), (4), (6) and (7).

J) Two major conditions would be necessary, but not sufficient, for the success of an integration project. If and when the design and specification of constituent systems, databases, and linking mechanisms were carried out to facilitate: (i) business strategic objectives through a strategy-technology alignment process and (ii) organisational change and development so that technical integration would be accompanied by organisational integration. This assumption is reflected in questions (6) and (7).

The theoretical links between the above ten assumptions, the seven tentative research questions and the questions used in the data-gathering instruments (see Appendices B, C and D) are of a profound methodological importance. They will be explained in detail in the next chapter in the context of a three-phase research strategy devised for the field work.

Consistent with the ontological assumption stated in subsection 3.6.1 and the epistemological assumptions stated in subsection 3.6.2, it is assumed that behaviour patterns will manifest themselves more in day-to-day reality than in formal interviews or through survey methods. Therefore, the need for a field study type of research design, rather than a survey, is established. The view taken in this study is that the researcher is the primary instrument in data collection, rather than other insentient mechanisms. Data-gathering in this research targets as much data, of as many types, by as many means as the researcher can afford within the constraints surrounding the study[11].

Choosing data collection methods for the present study is considered to be an "operational" or "tactical" decision made within the framework of its research strategy and, therefore, will be discussed in more detail in Chapter 4. In the meantime, the theoretical and methodological choices adopted in the concluding part of this chapter will be upheld in reliability, validity and credibility terms.

3.9 Validity, Reliability, and Credibility

It is justifiable to argue that truthfulness and objectivity are critical to any research, but it is not justifiable to claim that the criteria for judging them will be universally acceptable; these will be subject to disagreements among various methodological ideologies and schools of thought. Ontological and epistemological assumptions are important determinants of the criteria for judging credibility, reliability, and validity of any research. Subject matter choice, research design, data presentation and interpretation and practical implications will be amongst a range of factors contributing to such disagreements. Whatever these may be, however, a researcher should pursue believability on the basis of coherence, insight and instrumental utility (Eisner, 1991). In a study such as the present he/she should aim for "trustworthiness" (see Lincoln and Guba, 1985) through a process of verification rather than through validity and reliability limits applied in a conventional positivist paradigm[12].

Four criteria against which the truthfulness of the study can be assessed are proposed[13]. These match, and are alternatives to those criteria to those applied in the

[11]As Marshall and Rossman (1989) notes, most qualitative studies utilise several data collection methods over the course of the research. This depends on the researcher's assessment of the strengths and weaknesses of each technique and how these relate to the research questions. It also highlights a widely held belief that data collection methods are both imperfect and not mutually exclusive (Brewer and Hunter, 1989).

[12]In general, it can be said that validity and reliability verification is more problematic in qualitative than in quantitative research, because of the lack of "consensus" on addressing such issues (Creswell, 1994). Quantifiable measures in a quantitative study are likely to make these a less controversial issue. On the other hand, the likelihood of multiplicity of meanings and interpretations in a qualitative research is a question that deserves to be addressed from different perspectives because of the recognition that these are negotiated with human data sources since it is the subjects' reality or realities that the researcher attempts to reconstruct (see Lincoln and Guba, 1985; Merriam, 1988).

[13]Corresponding to four questions to be addressed in establishing "trustworthiness" (See Lincoln and Guba, 1985: 290):
1) How truthful are the particular findings of the study? By what criteria can we judge them?
2) How applicable are these findings to another setting or group of people?
3) How can we be reasonably sure that the findings would be replicated if the study were conducted with the same participants in the same context?
4) How can we be sure that the findings are reflective of the subjects and the inquiry itself rather than the product of the researcher's biases or prejudices?

quantitative paradigm, and pertain to a research's: (1) "truth value" instead of "internal validity", (2) "applicability" instead of "external validity", (3) "consistency" instead of "reliability", and (4) "neutrality" instead of "objectivity".

It must be admitted that the question of objectivity imposes a greater degree of awareness on a researcher in a study premised on the assumption that totally objective reality may well be attempted by a researcher but is very difficult to achieve in absolute terms. However, maximising the right conditions for siding with objectivity should be attempted through the rigour, breadth and depth of the investigation as well as the study's reliability measures.

Interpretation forms an important part of the study. Its credibility, therefore, has to be maximised via appropriate controls for bias. This is based on a fundamental concern that a respectable place in interpretation should be guaranteed for both the researcher's own version and those of the actors.

This chapter is meant to support the present research's credibility by explaining its theoretical and methodological approaches. Chapters 5, 6 and 7 will build upon this basis and proceed further to describe the data of the social reality under investigation. Various techniques will be used for presenting and analysing the findings and developing the theoretical propositions of the study (see Chapters 6, 7 and 8). Such measures, when taken together in an integrated manner, are meant to strengthen the credibility of the theory to be developed. In addition, the use of codified procedures for analysing data, as will be explained in the following chapter, will help clarify how theory is developed from the data.

In short, to ensure maximum possible reliability, validity and credibility of the present research, a number of measures were deployed. Twelve measures were deployed to maximise the reliability and validity of the study in general. In addition, five extra measures were also taken in order to maximise the researcher's interpretation credibility. Firstly, the reliability and validity measures could be summarised in the following points:

1) Data was collected using various methods. Combining multiple sources of data to bear on a single point was sought in order to strengthen the reliability of data collection. This was used not merely as a tool for, but an alternative to, validation[14]. Its aim was to minimise misinterpretation of meanings inferred from the collected data.

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[14]See Denzin (1989); Flick (1992)

2) Continuous data collection, assessment and analysis throughout the course of the research was meant to provide an on-going evaluation mechanism. A continuous dialogue with informants regarding the researcher's interpretations of the their realities and meanings was sought to ensure the true value of the data.

3) Four specific controls to increase the reliability of the case study component of the research design were incorporated into it in the form of a protocol[15] which included: (a) an overview of the project, including a statement of the research issues; (b) field and data collection procedures, including the specification of sources of information; (c) case study questions; and (d) a guide for the case study report, including its outline and format.

4) Representativeness would raise an important question for any case study research. The present research did not adopt a statistical logic and, thus did not propose a reliability assessment against quantitative criteria. However, it was important for it not to rely on a single case study. A multiple-case study approach was pursued to provide more confidence in claiming a degree of representativeness proportional to the quantity of cases studied but without claiming universality of the research's overall conclusions.

5) Regular and repeated on-site observations of similar phenomena occurred over a long period of time and were compared across the cases studied.

6) Negative instances of the findings were shown and accounted for.

7) Theoretical significance and generalisability were made explicit wherever applicable.

8) Data collection strategies and methods were explained explicitly in this chapter and the following one.

9) Three academic members of staff (excluding the research supervisors) and three doctoral students were requested to play the roles of an interviewee and peer examiner and provide a critical feedback.

10) The researcher's biases and assumptions were articulated in writing in this chapter.

11) Participants' truthfulness was assessed. The aim was to try to explore and detect any implausibility that might have been present in a given participant's account. This involved a special attention paid by the researcher - accumulatively over a period of time - to learn about and take into consideration individual informants' (a) values, attitudes, sentiments and patterns of behaviour and (b) current emotional state whilst providing

[15]See Yin (1987: 21-22; 1989).

information and reactions to the subject under discussion. Learned knowledge in this area was used in: (i) cross-checking an informant's account with what other participants told the researcher about the same events[16], (ii) looking for consistency in an informant's earlier and later statements.

12) Tape-recorded data was reserved.

Secondly, the interpretation credibility measures[17]could be summarised as follows:

1) A person was asked to play the role of a "devil's advocate" in critically questioning the researcher's analysis on a continuous basis.

2) Data was checked and rival hypotheses assessed continuously.

3) Reports of analysis of findings were sent to the companies in the study and feedback on the researcher's interpretation sought[18].

4) The guidance of experienced researchers to control the quality of the data was followed.

5) An audit of the data collection and analysis strategies was conducted.

3.10 Summary

This chapter discussed theoretical and methodological issues of concern to the present study. It identified a relationship between theory and methodology with a view to meeting the objectives of the research in the light of the researcher's ontological, epistemological and axiological assumptions. A qualitative research methodology was chosen. The methodology was based on the following assumptions:

1) Since social reality is interpreted by various human beings through their cognitive capacities, therefore various perceptions will be available to the researcher. These should be investigated so that a reasonably realistic picture of an organisational setting can be developed, one that will reflect the wealth of variation likely to be found at a perceptional level.

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[16]This resembles weighing and balancing the testimony of different witnesses, appraising their motives, comparing their reliability and considering circumstantial evidence in a courtroom setting.

[17]Based largely on measures derived from the methodology literature (e.g. Glaser and Strauss, 1967; Lincoln and Guba, 1985; Marshall and Rossman, 1989).

[18]Based on the assumption that feedback prior to publication would strengthen the credibility basis for any research. It was necessary to have a continuous feedback during the course of the field work to check the researcher's understanding of the field against those involved in it.

2) Different accounts of reality, which are likely to emerge from data, will be indicative of such variation.

3) The researcher must cross-check such accounts through the research methods utilised to establish his/her own independent account.

4) During the course of the field work, the researcher should distinguish, by means of cross-checking, between planned tactical or strategic action and unplanned or accidental action or that imposed upon an organisation by its environment. Also, it will be important to distinguish between innovation and imitation behaviours an individual and organisational levels.

5) The researcher should utilise multi-factor analyses because of the inherent complexity of social reality. These will be likely to guide the criteria to be developed for theory development.

6) An organisation can be conceptualised as an homogeneous entity in terms of its technological infrastructure but not so in terms of the individuals and groups that constitute its social system.

The chosen methodology blended GT and case study approaches with a longitudinal research design outlook. This combination was designed such that the overall objective of the study could best be met. Data collection, analysis, and theory are meant to stand in a complementary relationship with each other by virtue of such research design.

The methodological outlines described in this chapter will facilitate theory development by means of induction through the utilisation of raw data to construct thematic categories of investigational concern. The aim is to outline the guidelines needed by the researcher to make sense of a situation in which several actors play their respective roles in CADCAM integration. This approach gives flexibility in the way further data will be collected as earlier analysis can be used to modify the tentative research questions, assess and test competing working hypotheses and continuously develop theory in a dynamic manner.

Finally, this chapter has, hopefully, succeeded in demonstrating that the researcher is aware of the advantages and limitations of the present research design, his role in the research process vis-a-vis the data sources in concern, the devised measures for supporting the reliability and validity of the study in general and the credibility of his interpretation in particular. This chapter has discussed the measures specifically taken for these purposes.

Details of the research process, methods, and the case study conduct and analysis will be described in the following chapter. In this sense Chapter 4 is an extension of this chapter. The substantive and formal theoretical propositions and hypotheses resulting from the grounded research described in this thesis will be presented in Chapter 8.

CHAPTER FOUR

The Field Work

4.1 Introduction

Chapter 3 established that a field work type of study was the most appropriate methodology for this study because of the kind of data and theory it set out to collect and derive. This chapter spells out the details of the filed work followed in this research.

It begins by describing the decisions taken on organisation sample size, the type of organisational settings suited, and how the sites in the study were chosen. It then distinguishes between the chosen companies on the basis of how integrated their DEM processes are in CADCAM terms. Details of the ten researched companies will be given. This will be followed by a description of the progress of the research process. The chapter will then proceed to describe the details of the methods and procedures followed in data collection, coding, analysis and interpretation. The lessons learned from the field research will also be outlined in the final sections of this chapter.

4.2 Deciding on the Sample Size?

How many companies should be studied in this research? This was an important question which had to be addressed right from the outset. Two guiding concerns were used in this connection, namely that:

1) A quantitatively large sample would not be applicable since generalisability through hypothesis-testing was not targeted.

2) A single company would provide too narrow a "window" through which to view the real world of technology-led change in manufacturing industry, with all the diversity it contains.

The latter consideration aimed to avoid partial, biased, and unbalanced inferences from a single case; it sought to go as far as possible towards selecting a representative sample, though not in a strict statistical frame of reference.

The following considerations guided the decision on the size of the sample of companies to be studied:

1) It was assumed that the larger the sample, the greater the chances would be of finding the contexts underlying the study's tentative questions and addressing the

questions on the basis of a greater diversity in conditions, which would, thus, be made available.

2) Although multiple cases would not make the study a quantitative one, it would facilitate a comparative framework and, thus, give the study a limited quantitative dimension in cross-case comparisons.

3) Multiple evidence would allow a more robust generalisation which would be likely to assist the formulation of the theoretical proposals.

As will be explained later on in this chapter, a total of ten companies were chosen and researched. Another equally important question had to be addressed together with the above one. This was: what kind of organisations should be selected in order to provide the right socio-technical contexts for the fieldwork? The following section addresses this issue.

4.3 What Kind of Organisational Settings?

The ten organisations were chosen according to the following four criteria:

1) Sector:
All organisations had to be chosen from the manufacturing sector of the economy where CADCAM technologies could be found in application.

2) Category of Industry:
All organisations had to be involved in (electrical, electronics or/and mechanical) manufacturing engineering-related operations.

3) Computer Technology in Design, Engineering, and Manufacturing:
All organisations had to be CAD or/and CAM users and to have used such technologies for at least five years in order to utilise their extended respective experiences in enriching the data for the present longitudinal research design.

4) Integration of Computer Technologies :
All organisations had to have DEM systems that were capable of being integrated, even if they were not yet integrated in practice, or had embarked on some kind of integrated CADCAM configuration.

4.4 Choice of Sites

The first step in the field work involved a search for companies meeting the above criteria. An important question arose in the beginning with regard to what organisational level of analysis should be adopted. Researching complete, multiple-site companies was thought to be advantageous in that it would facilitate a comprehensive assessment of production processes in their entirety as well as the work organisation arrangements set up around them. Nonetheless, business units which were part of larger business entities, were identified as sufficiently appropriate for the purpose of this study. Subsidiaries or plants, rather than whole businesses, were also considered. In fact, the vast majority of the researched companies were linked to larger organisations in one way or another[1]. Such a decision was justified on the grounds that the emphasis in this study had to be on business units as places of work. Plants, even those in the same company, might have different levels of IM, so aggregating data to the company level would have been problematic, mainly because of the scattered geographical layout of the companies whose local sites were sampled initially. As will be explained further in the foregoing section, out of a total of 47 companies that responded to an invitation questionnaire to indicate whether they would agree to take part in the research, 30 (i.e. 63.83%) were subsidiaries of larger companies that had other sites in Britain or/and elsewhere in the world, 14 (i.e. 29.79%) were parent companies, and 3 (i.e. 6.38%) did not reveal their legal status.

The decision was also justified on the basis that the emphasis of this study was on the plant as a socio-technical system[2]. Scotland's entire discrete part manufacturing engineering industry was surveyed initially, if ambitiously, to identify appropriate companies for the study. Later, however, the search was narrowed down to target companies which were closer to St. Andrews for purely logistical reasons.

The "new" electronics industry in Scotland presented itself as favourite for the field work. The electronics industry is a major nominee for progress towards CIM since CAD/CAM techniques began in it and diffused successfully into chemicals, construction and mechanical engineering industries (see Bessant *et al.*, 1985; Susman and Chase, 1986). Traditional, long-established industries in Scotland (e.g. shipbuilding, heavy engineering and mining industries) had declined to make way for this "replacement" industry. Growth of the service and financial industries is another aspect

[1]Companies 6 and 7 were the exception in that they were independent small family businesses.

[2]Had the study conceptualised the plant as a purely technical production process or economic entity or been concerned, for example, with analysing total assets of a company, supply chains of a homogenous sample of a population or global marketing strategies of multinational firms, it would have required a strict choice of units such that uniformity at a corporate level was met. This would have been applicable as a crucial criterion of selection in order to establish a complete picture of the company or companies under investigation. A similar position to the one taken in this study was adopted by researchers such as Dean and Snell (1991), for example, in their study of CIM job design requirements in US plants. Currie (1988) also took up a resembling stance in studying management perceptions of CAD in British companies.

of such replacement in Scotland's economic life[3]. Both replacement industries in the manufacturing and service sectors are major users of computer technologies in their operations. The electronics manufacturing industry sector, as opposed to the service sector, appealed, as a potential area of field work, one that was readily within the researcher's reach, both physically and in terms of the researcher's training background.

Initially, *Sell's Scottish Directory* (1991/92) was used for sampling[4]. A nationwide list of 274 firms resulted. This was too large a sample for the purpose of this study and had to be reduced. Eventually, it was whittled down to 90. The elimination process was governed by two criteria: applicability (according to the criteria outlined in section 4.3) and location.

Each of the 90 companies was invited to participate in the study. In total, 70 companies (i.e. 78%) declined participation either actively or passively. The response rate was 52%; 47 companies replied by completing and returning a purpose-developed invitation form (see Appendix B) in a prepaid stamped envelope. Out of these 27 companies (i.e. 30% of the total of 90 companies) declined the invitation but a total of 20 companies (i.e. 22%) agreed to take part in the study.

Exhibit 4.1 shows a flow chart illustrating the procedure followed in company selection. Only 10 companies, including eight subsidiaries and two parent firms, out of these 20 (i.e. 11% of the original sample of 90 and 50% of the "accepting" respondents) eventually collaborated in the study[5].

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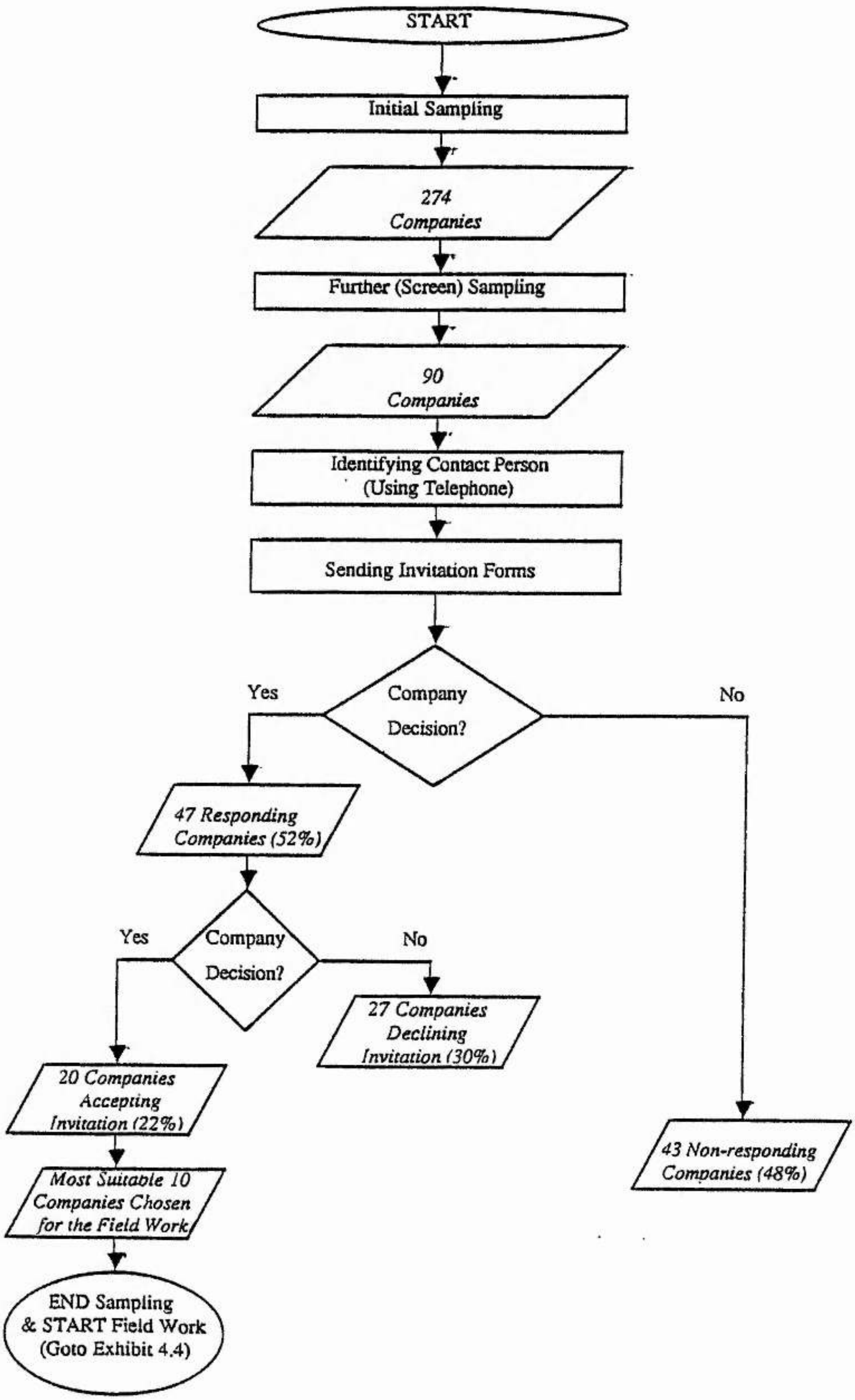
[3]One of the people who were interviewed repetitively during the course of this research lived and worked for over thirty years in Scotland. He described this situation in the following words:

> "..... you only have to look back over 20 years. We've been before - Fife used to be - a heavy engineering and coal mining area ... Heavy engineering died. ..... When coal started to be phased out and oil came in coal mines in the Fife area all started to be closed down .... the district of Kirkcaldy, Methil, Cowdenbeath ... all these kinds of areas. Then these kinds of companies came along and were set up here because there was a wealth of skilled people ..... " (Case 8).

[4]Manufacturers under the following industry headings were listed, studied and then classified: "computers", "microcomputers", "electrodes", "electronic components", "electronic equipment", "electronic instruments", "electronic systems", "electronics", "electronic medical apparatus" and "medical equipment".

[5]Two companies closed down, six were located in the extreme north, west and south of Scotland, one was not suitable for the purpose of the study because it was not a user of the technology in concern, and one company changed their mind after initially agreeing to participate.

Exhibit 4.1
Company selection procedure



Three out of the 90 companies sampled could not withstand the early 1990s economic recession and thus closed down. It was not an easy time either for businesses or their researchers[6].

Fife companies were given priority because of their proximity to St. Andrews since the nature of the data-gathering mechanism deployed in this study required frequent visits and, at times, the continuous presence of the researcher on the researched companies' sites[7]. Fife Regional Council's publication *"The Fife Business Directory"*(1989)[8] was consulted for further information about these companies. Eventually, seven of these turned out to be among the 10 cases in the study.

The next step involved extending the geographical scope of the field and, hence the addition of two Tayside and one Lothian sites to have what was considered to be a reasonably sufficient number of cases for an intensive and exploratory study.

4.5 Primary Vs. Secondary Cases

The ten companies that were selected for investigation could be divided into two broad categories according to the content of CADCAM integration in their respective technological strategies. From this point onwards in the thesis the terms "primary" and "secondary" cases (or companies, interchangeably) will be used to refer to the two equally-represented groups of companies.

The five primary companies met all the criteria outlined in section 4.3 more readily and fully than the secondary companies did. Hence, they were chosen for much closer

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[6]Two "accepting" and one declining respondents closed down. This was a total of three out of 47 businesses (i.e. approximately one out of every 15 businesses collapsed). These statistics were indicative of the kind of environmental pressures companies were subjected to during the time of the research. For example, a Personnel Director of one of the 90 companies sent a reply letter in which he said: "..... I regret to inform you that [naming the company] closed down last year and therefore are unable to assist you with your project. .....". The gravity of these circumstances became even clearer as the field work progressed. Indeed, one of the collaborating companies (Case 8) themselves went out of business in 1993. About two years earlier the company's Senior Production Manager and General Manager, respectively, stated:

> "Our demand's dropped by at least 50% over the last year. Some of that is because the defence industry's suffered a recession and some is due to the fact that nationally we are suffering a recession. ....very, very severe recession ....." (Case 8).

> "It's that crossroads in a sense: we will not get any more money invested until we get more profit but perhaps we won't make more profit till we get more money invested. It's a very difficult time .... it's a vicious circle!" (Case 8).

[7]All the chosen sites were located within a 60-mile radius around St. Andrews. If only questionnaires or single interviews were used this condition would not have been considered significant.

[8]Its section titled "Engineering in Fife", published in 1990, provided an up-to-date population listing with useful information about the region's electronic engineering companies.

attention[9]. These companies were already undergoing transformation. Thus, they had direct relevance to the theme of integration. However, the five secondaries, despite using one or more of DEM computer technologies, had not embarked on integration, had not taken it seriously as an issue of immediate concern, and/or had have no intention to do so in the foreseeable future. It was thought that these seemingly negative cases should not be discarded; their inclusion would be useful for comparing and contrasting purposes (i.e. in addressing the "why nots" of integration, represented by these organisations, alongside the "whys" of it). The assumption was that investigating dissimilar states of affairs would facilitate the emergence of a clearer and fuller picture. Given the objectives of the study, this was a more significant methodological concern than uniformity of the selected sample since all of the ten cases provided a form of socio-technical settings where the application of CADCAM integration would have been technically achievable in an “ideal” world.

The following section displays information about all the companies which participated in the study, as summarised in Exhibits 4.2 (a) and 4.2 (b).

4.6 The Companies in the Study

The names of the companies are not be revealed anywhere in the thesis, nor are the names of those individuals who took part in the study. Instead, each company was given a serial number to identify it and each individual participant's name was coded anonymously for data analysis purposes (i.e. in theoretical sampling, open, axial and selective coding). Confidentiality was promised at the request of the informants due to the commercial sensitivity of the information given, which was coupled with strategic sensitivity in the case of defence companies. Confidentiality was discussed as a main issue during access negotiations and the promise had to be kept[10]. Coding of data, actors, and companies as well as the interrelationships amongst these will discussed in detail in section 4.14.3.

9Researchers such as Winch, Voss and Twigg (1991), for example, adopted a similar position by isolating two of the 15 firms they studied for a more in-depth analysis.

10In the case of Company 9 the gate-keeper requested that the company's product should also be omitted because that would make the company identifiable since it was the only one of its kind in Scotland: " ..... Naming products will be difficult as well ..... the product is also sensitive for us". Therefore, a more generic name was used to refer to it: computer hardware.

Exhibit 4.2 (a)
The primary companies in the study: summary of information

Company	Size (No. of employees)	Location	Nature of Business/ Product(s)
1	95	Glenrothes	Photomasks (supplied to semiconductor industry)
2	210	Kirkcaldy	Stage, studio lighting & control equipment
3	400	Edinburgh	Electronic security products
4	500	Dunfermline	Test systems (for defence avionics industry)
5	1,400	Dundee	Self-service systems & cash machines

Exhibit 4.2 (b)
The secondary companies in the study: summary of information

Company	Size (No. of employees)	Location	Nature of Business/ Product(s)
6	35	Auchtermuchty	Electrochemical sensrors
7	50	Dunfermline	Electronic & other weighing equipment
8	73	Hillend	Printed circuit boards (for defence industry)
9	150	Glenrothes	Computer hardware components
10	370	Dundee	Electronic measurement equipment

Exhibit 4.3 (a)
The primary companies in the study: summary of field work information

Company	Number of Interviewees	Number of Interviews	Total Hours	Tape Hours
1	6	7	10.50	04.97
2	3	3	08.25	03.86
3	3	4	09.10	05.86
4	3	9	13.45	05.40
5	4	4	09.40	04.65
TOTALS:	*19*	*27*	*50.70*	*24.74*
AVERAGES/ COMPANY:	*3.8*	*5.4*	*10.14*	*04.95*

Company	Number of Interviewees	Number of Interviews	Total Hours	Tape Hours
6	5	5	05.20	02.97
7	3	4	03.55	01.07
8	3	5	10.20	05.16
9	2	2	04.05	02.44
10	3	4	10.15	06.47
TOTALS:	*16*	*20*	*33.15*	*18.11*
AVERAGES/ COMPANY:	*3.2*	*4*	*06.63*	*03.62*

Exhibit 4.3 (b)
The primary companies in the study: summary of field work information

The serial number given to each company indicates its size relative to the other companies in its respective group. Size, measured in terms of the total number of employees, was assumed to be an important organisational contingency in selecting the companies. Other measures of size (e.g. financial or technological resource measures) were considered to be less appropriate in the case of this study whose focus lay on the organisational aspects of change. The smallest company comprised of a total of 35 employees whereas the largest of 1,400.

The studied companies represented rather diverse aspects of the Scottish electronics manufacturing industry. They included a service company in the form of an industrial tool supplier (Company 1); component suppliers to other manufacturers (Companies 8, 9 and 10); finished consumer/industrial product manufacturers (Companies 2, 3, 4, 5, 6 and 7). Companies 4 and 8 were defence market suppliers; the rest provided products and services for civilian markets. Such variations were important to provide as wide a basis for comparison as was possible.

Product range diversity varied widely among these companies; they had different product mix structures. Some of the companies chosen were single-product suppliers, though such a product received a wide range of applications and was sold to different customers for different purposes (e.g. Companies 3 and 6); some still supplied a single product but with narrowly specified uses (e.g. Companies 1, 4, 5, 8, and 9); and some were multi-product suppliers with a wider customer base (e.g. Companies 2, 3, 7, and 10).

4.7 Company Individuality Vs. Sample Uniformity

The details of data-gathering were distinctive in each organisation, within the methodological framework developed for the study. On the one hand, in dealing with the companies (as units of analysis) a systematic, structured set of procedures had to be followed, as much as possible, in order to satisfy the uniformity requirements of the comparative aspects of data analysis. However, the practicalities of further access negotiation and frequent data-gathering efforts in each case were "coloured" by a number of factors, including the preparedness, responses and style of a particular company's gate-keeper(s); the size and hierarchical structure of the company; the interpersonal relations among some of the managers concerned, and the management control mechanisms of the company in concern.

As shown in Exhibit 4.3 (a) and (b), a total of 19 and 16 interviewees in primary and secondary companies, respectively, were interviewed. Field work for the entire study entailed a total of 83.85 hours of planned investigation and real-time data-gathering, of which 42.85 hours were tape-recorded[11].

4.8 Preparing for Field Work: Establishing Contact and Arranging Access

The first attempt to establish contact with suitable companies was made by writing to the Scottish Division's Director of the *Institute of Directors* and asking for his assistance in this matter. It turned out to be a complete failure (see Appendix A for copies of the relevant letters of correspondence in this connection). Then, the researcher resorted to published business directories in order to identify suitable companies, find out about their addresses and telephone numbers and, thus, contact them directly.

Identifying people in leadership positions was essential for providing useful contacts and informal sponsorship. As Whyte (1984: 29) noted, "lack of skill in gaining entry may severely limit access to information". Initially, the selected companies were contacted, using the telephone, to identify a suitable contact person in each case, who might act as an "official gate-keeper" and control access. The researcher introduced himself, explained briefly what the study was about, and outlined, briefly, the information requirements to the answering company telephonist/receptionist and asked him/her to nominate an individual whom he/she thought would be most suitable to fulfil the described role.

The next substantial step involved sending each named person a letter requesting their participation in the research, coupled with a simply structured invitation questionnaire and a covering letter from the study's supervisor (see Appendix B)[12]. The detailed field work began properly from that point onwards with those companies which accepted the invitation.

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[11] Total hours differed from tape hours in at least five ways:

a) Data-gathering methods other than interviewing were used (as will be explained in section 4.12).

b) Some data was not tape-recorded but notes were jotted down (e.g. during company tours and demonstrations).

c) Informal discussions (on the subject matter of the research) were not usually tape-recorded.

d) Sensitive comments, typically critical of top or other management groups or individuals, had to be kept "off the record"; they were aired on the condition that they should not be recorded on tape.

e) During interviews some time was not recorded because it involved document examination or visually-aided explanation of company details in general or specific information on an issue of concern.

[12] The invitation questionnaire's objectives were to:

a) Gather basic factual data about a greater number of companies than needed and, thus, identify those amongst them most appropriate for the data requirements of this study.

b) Identify which areas of information technology in manufacturing industry to investigate as an integration topic. Eventually, CADCAM was selected but only after further data collection during the first visits to the researched companies.

c) Invite companies to participate in the study. The most suited companies were eventually researched.

It was essential to note from the outset that an access permission would be subject to the condition that a company's normal business operations should not be disrupted to any considerable extent. Also, in negotiating access it was important to win the trust of the contact persons at an early stage and then build confidence gradually. With regard to this point, Buchanan, Boddy and McCalman (1988: 57) advised researchers to close the distance between their potential respondents and themselves by telling them what they wanted to "learn from your experience", have a "conversation", and "write an account" in place of "research by interview leading to publication", because the latter carried "potentially threatening connotations" implying that "commercial secrets and personal revelations will be revealed in 'The Guardian' within the week".

In one instance, for example, the gate-keeper of Company 1 arranged for the researcher to interview two of the company's managers. The researcher's meeting with them lasted for about two hours and towards the end of the interview one of them asked: "What are you going to do with the information that you got from us today? ..... How many people are participating in this work?" (Case 1). In another instance, a gate-keeper made sure that his concern about confidentiality was well understood. He said:

> "What's the position with regard to the thesis that you write? Will it be available to .... university assessors and possibly external assessors .... you may, you or your colleagues, want to publish a paper or get a paper to a symposium or seminar? One thing that we would prefer obviously from an area of commercial confidentiality is that anything that you take from our discussions wouldn't be specified specifically against the company; you wouldn't say [naming the company] have this ..... We don't want to give our competitors the advantage of telling them what stage of development we are at ..... " (Case 4).

As the field work progressed and the researcher got on well with the informants, formal reservedness decreased and a less formal atmosphere encouraged the researcher to ask questions which could have seemed threatening at first[13]. The progress of the field work gave respondents the opportunity to understand the research and the researcher better and appreciate more the importance of their contribution; "rich information is a product of close relationships of mutual trust and respect" (Buchanan, Boddy and McCalman (1988: 61).

4.9 Progress of the Research

To be successful, a qualitative research should analyse situations, recognise and avoid bias, obtain valid and reliable data, and involve imaginative abstract thinking. Hence, a qualitative researcher requires theoretical and social sensitivity, maintaining an

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[13]The interviewees were invited to visit the *Department of Management, University of St. Andrews.* Three managers from Company 4 accepted the invitation; they spent a day on campus and participated in singular interviews and group discussions on the research. Sustaining the relationships with such key informants was another benefit from the experience.

analytical distance and drawing upon past experience and theoretical knowledge to interpret what he/she sees. In Strauss and Corbin's (1990) words, he/she needs "power of observation", good "interactional skills", and an effective interaction with data to increase, progressively, during the course of the research his/her insight and understanding about the phenomenon under study and the parameters of the evolving theory.

In the case of this study the empirical research process began with an inquiry into the work organisation arrangements around CAD in the companies. That was encouraged by the fact that CAD systems were, invariably, a well-established technology application. This beginning necessitated a thorough (vertical) investigation of the structures, processes and work flows of the design/engineering functions of the respective companies. The next step involved a (horizontal) penetration of the companies with a view to understanding the design-manufacture interface, communications and organisational adjustments required to accommodate integrated CADCAM into the organisational settings. The integration inquiry was launched on this basis; the investigation was not constrained to CAD nor was it meant to address integration directly, although this would have saved time and effort. It was a piecemeal approach aimed at building an understanding of the companies' historical experiences of introducing, managing, maintaining and developing CAD.

One of the major concerns of the research at the early stages was to try to find organisationally-explainable reasons for the differences found in companies' experience. For example, why did some companies have CAD only, some CAM only, while others had CADCAM applications? Why particular functions computerised their work while others did not? Could these vary due to organisational reasons? How significant were the organisational factors in relation to technical and business factors? It was through questions such as these that organisational issues could be explored. Therefore, extending an initially CAD investigation into production/manufacturing functions was unavoidable. So was tracing the organisational responses and effects of CAM and CAPP applications in the design office.

Before entering the field, methodology planning had already been begun but not completed to avoid being fixated on a readily prepared and detailed research design. This approach aimed to assist the researcher to capture data about problems when opportunities arose, which might turn out to be a source of research issues more worthy of investigation than pre-determined ones. As Whyte (1984: 35) put it:

> "The initial phase of the project should be considered a social exploration. .... the first requirement is to gain some initial familiarity .... establish a social base from which we can continue our exploration until we are able to study some parts of that territory systematically"

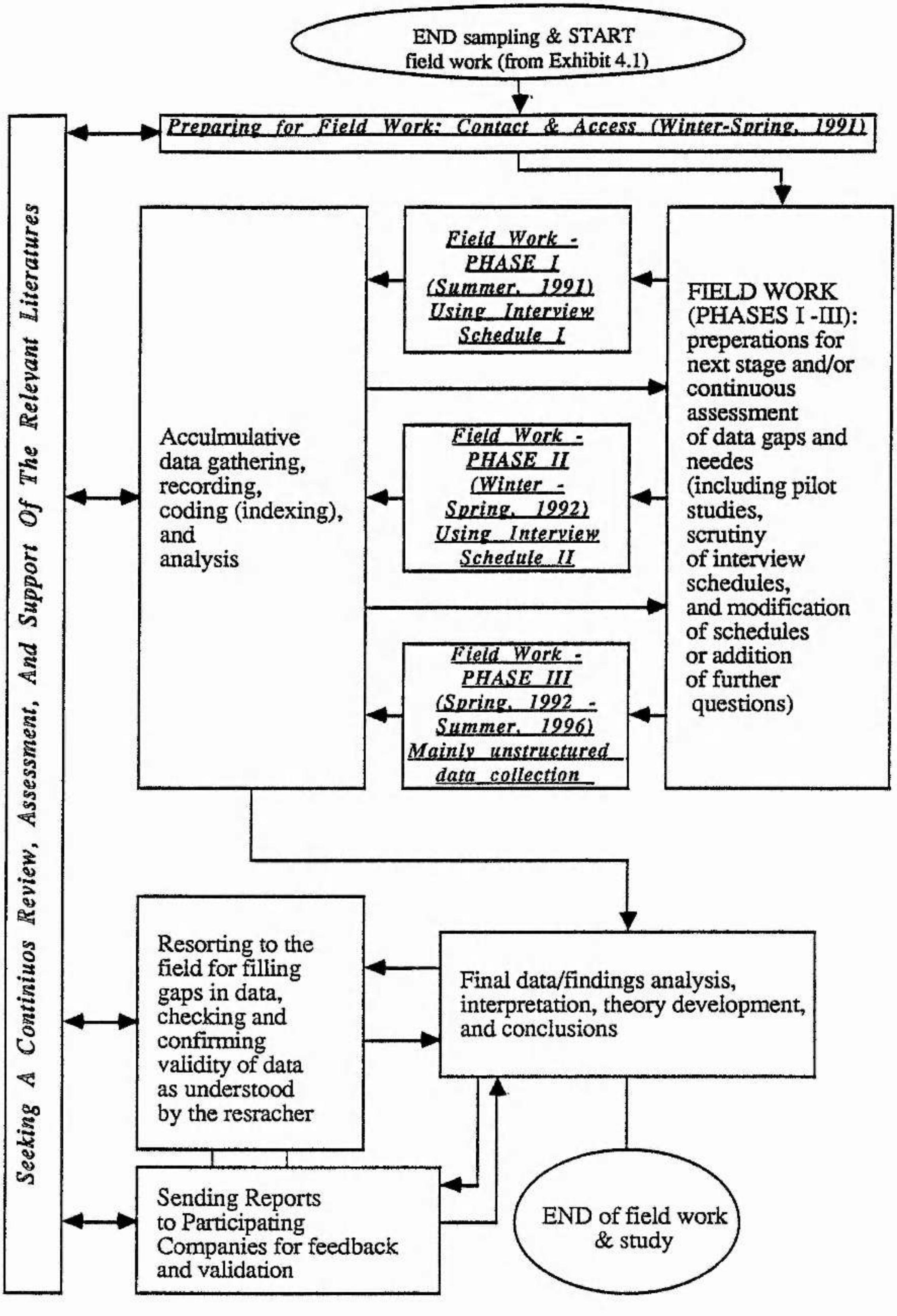

Exhibit 4.4
Field work (including interviewing) progress

As Exhibit 4.4 shows, the entire field work comprised three major stages of concentrated effort in the field: Phase I (Summer, 1991), Phase II (Winter - Spring, 1992) and phase-III (Spring, 1992 - Summer, 1996).

The researcher's three-phase strategy can be summarised as follows:

* Phase I:
Each of the companies was visited once during phase I. Each fact-finding visit included an interview with the "official" gate-keeper of the company in concern. Consequently, frequent visits were made during the following phases. Multiple interviews were sometimes conducted during a single day. Other data-collection techniques were also applied. A semi-structured Interview Schedule I (see Appendix B) was used on-site in each of the cases. Its objectives were to:

1) Collect personal interviewee data to put different accounts of given information into context.
2) Collect more general company details to fill the data gaps from the previous invitation questionnaire.
3) Decide on the area of integrating technologies to be investigated. Whereas the invitation questionnaire aimed to identify potential areas (e.g. CADCAM and MRP II), the aim at this stage was to make a final decision.
4) Find out what issues were encountered in the selected companies' experiences of introducing CADCAM. The purpose was to guide further research design via recording the issues that were of concern to the informants with a view to "grounding" the rest of the research design process in the data emerging from the field.

Up to the end of phase I methodology was not yet formalised strictly, although outlines of it were being synthesised gradually in the researcher's mind and research diary. Consolidating a firm base for open and continuous data gathering was the main priority at this point.

* Phase II:
Interviews in phase II were more detailed; phase II was the most systematically structured part of the investigation. Semi-structured Interview schedule II (see Appendix D) was devised to guide the most detailed stage of data collection in the research. It was designed on the basis of the above mentioned assumptions and tentative questions. Each of the interview schedule questions drew, both directly and indirectly, on, and was therefore theoretically linked to, more than a tentative question, as shown in Exhibit 4.5. It consisted of nine sections.

Interview Schedule II (Content)		Tentative Research Questions						
Section:	Questions	1	2	3	4	5	6	7
I	01-03	✓					✓	✓
II	04-08		✓			✓		
III	09-24		✓	✓	✓	✓		
IV	25-35		✓	✓		✓		
V	36-37		✓	✓		✓		
VI	38-41	✓	✓			✓		
VII	42-47	✓			✓			
VIII	48-61	✓					✓	✓
IX	62-62	✓	✓	✓			✓	✓

Exhibit 4.5
Linking intreview schedules II questions to the tentative questions of the research

The objectives of each of the sections (see Exhibit 4.5 and Appendix D) could be summarised as follows:

1) Section I aimed to collect detailed background information about CAD/CAM as an investment project in terms of time of acquisition, cost, and technical specifications. This section was placed in the beginning of the schedule in order to smooth the flow of the interview by giving the interviewee an opportunity to begin by talking about something well known to him without committing himself to more sensitive comments about himself, his colleagues or the company at large.

2) Section II aimed to achieve a description of how the DEM process was conducted in the interviewee's respective company and how this had been affected by the introduction of CAD/CAM in work flow and organisation terms.

3) Section III aimed to build an understanding of how the process of change unfolded in the organisation in terms of adoption, formulation of objectives, implementation, formal justification, upgrading and development, and inter-managerial relations.

4) Section IV aimed to explore possible organisation-wide effects of CAD/CAM on work organisation, employment, recruitment and training as perceived by the interviewee. The specific implications of CAD/CAM for the engineering and manufacturing functions were targeted.

5) Section V focused on the possible impacts of CAD/CAM on job design. It took a micro view to complement the information gained from section IV.

6) Section VI aimed to establish the effects of CAD/CAM on industrial relations.

7) Section VII aimed to build an understanding of the interviewee's own evaluation of CAD/CAM, as investment project areas, in terms of stated objectives and his notions of success and failure.

8) Section VIII was devoted to integration. It aimed to reveal how the interviewee conceptualised integration, establish the company's position vis-a-vis integration, learn how early integration thinking had begun in the company, identify the difficulties that were faced, and how the company approached CADCAM integration in the historical context of its technological evolution in this area.

9) Section IX aimed to collect personal interviewee information to put the interview in context. This section was placed at the end of the schedule due to the relative sensitivity of its questions to the interviewee. As will be explained in section 4.13, towards the end of an interview, invariably, rapport was established and more sensitive questions

appeared to be more happily acceptable than if asked in the beginning. The researcher learned this from his experience of the first few interviews. This question was designed to maximise informant reliability measures in terms of assessing the informant's position in the social structure of his respective organisation. As Whyte (1984) pointed out, this would be likely to shape his/her perceptions, recollections, and descriptions as conditioned by his/her personality. The researcher had to be aware of subsequent implications for the reliability of the informant as an accurate reporter.

* Phase III:

Phase III also involved the use of Interview Schedule II but to a lesser extent. It mainly involved an unstructured approach to data-gathering. The data collected during this phase had to be supported by asking many open questions and some unstructured parts which did not appear on the schedule but were raised in accordance with the theoretical development of data sampling, coding and analysis. Four features distinguished data-gathering during phase III, namely that it served to:

1) Fill the gaps in the data already gathered from phases I and II.

2) Clarify the vagueness of some data details, which was discovered during data coding and analysis.

3) Provide an extensive period of time for monitoring the progress of the integration process as it unfolded in the companies; phase III was devoted totally to data collection on CADCAM integration.

4) Help with the more advanced stages of axial and selective coding in developing the substantive and formal theoretical propositions on CADCAM.

Field work was an effective learning process as far as the researcher was concerned. During its later stages, as interview and observation questions were capable of being directed by the emerging theory, the researcher became able to ask direct questions bearing on the categories. These could thus be answered sufficiently and fairly quickly, as suggested by Glaser and Strauss (1967).

The field research process was supported by relevant literatures throughout its progress, as was discussed in Chapter 1. Other "technical and "non-technical" literatures, as termed in a GT frame of reference (see Strauss and Corbin, 1990), were used to support the research. Technical literature comprised published books, research papers, and conference proceeding reports which served as background materials against which the research's findings were compared. It was used: 1) for stimulating theoretical sensitivity, 2) as a secondary source of data, 3) for stimulating questions, 4) for directing theoretical sampling, and 5) as a supplementary validation.

Non-technical literature, on the other hand, comprised company correspondence, manuscripts, memos, records, reports, commercial catalogues, newsletters, technical product drawings and design information documents as well as other materials that could be used as primary data or to supplement interviews and field observations. Much was learned about the organisations, their structures, and how they functioned, that was not visible immediately in observations or interviews (see Strauss and Corbin, 1990).

4.10 Testing Data Collection Instruments

Interview Schedule II was the main research instrument in this study. A critical examination of it was necessary to test and improve the quality of its constituent questions and the style of its presentation. This effort concluded a five-month period of its preparation, development and refinement .

As mentioned in Chapter 3, five academics (including the two co-supervisors) [14] and three neutral doctoral students were requested to play the role of an interviewee and a peer examiner and provide a critical feedback before field work started. To begin with, a pilot study was carried out as a way of testing and enhancing interviewing skills; one company[15] was visited and its general manager interviewed. Also, a mock-up interview situation was simulated before entering the field: one of the academics[16] was willing to spare about two hours for a test interview which was based on Interview Schedule I. That was followed by a critical evaluation. Criticisms were taken into account and acted upon. These two measures were based on the assumption that an academic and an industrial assessment would both be required simultaneously for a balanced evaluation of the content of the Schedule and the presentation style of the interviewer.

The invitation questionnaire and Interview Schedule I were much simpler, shorter and, by far, less vital in terms of the data they sought to target. Their credibility implications were much less significant in the context of the methodology followed because they were used to collect basic company background information which was later continuously completed, revised and updated whenever a need arose. Therefore, only

[14]Three of the academics were members of staff at the *Department of Management, University of St. Andrews* and the other two external academics. Both groups were chosen so as to provide, collectively, an evaluation of content and presentation style.

[15]This was among the 20 "accepting" companies but not included among the ten cases because it did not meet all the criteria specified in section 4.3.

[16]A member of staff at the *Department of Management, University of St. Andrews*; he was not a supervisor but chosen as a neutral academic.

the study's two co-supervisors' critical feedback was sought to guide the testing and enhancement of the two remaining research instruments prior to full-scale application.

4.11 Data Collection and Interpretation Procedures

Data collection, analysis and interpretation procedures in any study would depend highly on a range of factors, including: (1) the circumstances in which the data is collected, (2) the nature of the data available and the researcher's own interpretations of such data, (3) the experience of the researcher, (4) the many contingencies that affect an individual researcher personally or a team of researchers, (5) the character of the audiences for whom research is written and published, and (6) the scope and generality of the theory for which the researcher aims (see Strauss, 1987: 24).

In summary, the objectives of the data collection and analysis procedures utilised in this research could be summarised in two points: (1) "data reduction" (i.e. bringing the collected data under control in the form of "manageable chunks") and (2) "data interpretation" (i.e. bringing "meaning and insight to the words and acts of the participants of the study") with a view to theory generation (see Marshall and Rossman, 1989: 114).

It is obvious that data analysis would form a crucial part of any research process. Analytic procedures would fall into five modes: ".... organising the data; generating categories, themes and patterns; testing the emergent hypotheses against the data; searching for alternative explanations of the data; and writing the report" (see Marshall and Rossman, 1989: 114). Similar exercises were undertaken in this research, though not in a predefined or orderly manner involving a preconceived sequence of procedures, as could be recollected from Chapter 3. GT could be distinguished from other qualitative approaches not only by the relative unpredictability of research phases, which they might tend to share, but also by the "differences per stage in the combination and permutations of operations (theoretical sampling, comparative analysis, theoretical saturation .....)" (Strauss, 1987: 24).

Joint, cyclical data collection, analysis and interpretation meant that resumed collection, at any moment, was informed by current analysis which yielded further interpretation opportunities. In turn, the emerging theoretical categories guided further data collection, causing and orienting the resumption of data using the same or a more suited data collection method. Interpretation was the most demanding part of the triangular cycle since it involved the development and attachment of meaning to data and the communication of such meaning as clearly and convincingly as possible.

The following section will describe the data collection methods used in the field research in the context of the overall design of the study described in Chapter 3.

4.12 Data Collection Methods

In this study choice of data collection methods was made on the assumption that it was in day-to-day reality that behaviour patterns would manifest themselves, more so than in formal interviews. A longitudinal research design was, therefore, justified to capture such complexity; to observe normative behaviour simultaneously with rational decision-making and to comprehend how managers followed their own mental structures resulting from their training, relationships, contacts, and perceived realities. As explained in Chapter 3, questionnaire methods were considered inappropriate for this research because they could not reveal such things. Choice of research methods was aimed at understanding and interpreting real-life situations, which necessitated personal attendance on the part of the researcher in the organisational settings concerned, together with formally gathered interview data.

Ten methods were used to collect field data. Each of these methods contributed to an integrated data-gathering strategy. The methods could be presented around the researcher's main field work activities, as follows:

* Guided Tours (of company sites, offices and factories)
* Visually-aided Talks (about general company background information and specific projects and initiatives of interest to the study)
* Demonstrations (on computerised system software or/and shop floor machinery)
* Interviews
* Observations
* Examination of Company Documents
* Formal Group Discussions
* Informal Discussions with individual Informants (including socialising)
* Telephone Conversations
* Postal and Fax Correspondences

Flexible research methods and semi-structured interview schedules enabled the researcher to take a careful account of variations among individual informants due to differences in age, personality, position, profession, qualification and former work experience. Without such flexibility, the subjects of the study could only have afforded to take a passive respondent's role. Through this approach, however, the researcher was able to take advantage of specific situations as they unfolded. For example, the researcher encouraged those informants who were especially knowledgeable and/or interested to become particularly active by showing keen enthusiasm to listen to what they had to say, without being unaware about dangers of potential biases inherent in relying on a single informant. By seeking an informant's active help, intensive collaborative relations with a few key informants were developed, which served to enrich the data and deepen the analysis.

Combining observation with interviewing was useful; for example, it improved reliability (see Bryman, 1989). Observations alone could not reveal what people were trying to accomplish or why they acted in the way they did; interviewing alone could not provide a sufficient explanation of the underlying dynamics in certain situations unless the researcher knew in advance the rewards people were seeking or the penalties they were trying to avoid. In other words, observing guided the researcher to important questions he wanted to ask the respondents, whilst interviewing assisted him in interpreting the significance of what he observed.

After each interview or visit data was systematically recorded, indexed and analysed at that point in time, as will be explained in more detail in section 4.14. Final analysis and interpretation of the findings was based on an accumulative process of data-gathering, recording, indexing and analysis, which began from phase I. Interviewing formed a very important aspect of the field research process. It would thus deserve more clarification of the procedures followed in interviewing. The following section will address issues such as these.

4.13 The Interviews

Interviewees included selected managers in charge of technical functions and in technical support positions placed at varying senior levels in their respective organisations (see Exhibits 4.6 [a] and [b], 4.7 [a] and [b], and 4.8).

Informants were selected on the basis of their working relationships with the computer technologies concerned[17]. Engineering and Manufacturing personnel were identified in phase I and interviewed systematically during phases II and III in the primary cases.

[17]As Exhibit 4.7 [a] and [b] show, only five out of the 35 informants interviewed (14%) occupied positions in areas other than in the two main functions in concern. These individuals had to be consulted or interviewed because some of them occupied official gate-keeping positions (e.g. in Cases 1, 4 and 9) while others were approached to provide missing relevant information needed for data analysis.

Exhibit 4.6 (a)
Informants classified according to formal position: primary cases

Company	Chief Executive	Fun'al. Director	Dept'al. Head	Technical Manager/ Super'r.	Engineer/ Technic'n.	Total no. of Informants
1		*MKD	*MFM *PEM	*SSM *DBI	*ACE	6
2		*OPD	*DNM	*DSM (CAD)		3
3		*OPD *TLD		*PDM		3
4			*TGM	*ESM *DOM		3
5			*MPM *MSM	*DSM *CSE		4
TOTAL:						19

KEY TO EXHIBIT 4.6 (a) and (b)

ACE:	Architectural Engineer	MGD:	Managing Director
CSE:	Principal CAD Support Engineer	MKD:	Marketing Director
DBI:	Data Base Inspector	OPD:	Operations Director
DEM:	Design Engineering Manager	PDM:	Product Development Manager
DNM:	Design Manager	PEM:	Production Engineering Manager
DOM:	Drawing Office Manager	QAM:	Quality Assurance Manager
DSM:	Design Services Manager	TGM:	Training Manager
ECE:	Electronics/Electrical Engineer	TLD:	Technical Director
ESM:	Engineering Syatems Manager	TLM:	Technical Manager
MFM:	Manufacturing Manager		

Company	Chief Executive	Fun'al. Director	Dept'al. Head	Technical Manager/ Super'r.	Engineer/ Techni'n.	Total no. of Informants
6	*MGD		*DEM *TLM *QAM	*PDM		5
7			*DNM		*ECE *MCE	3
8			*OPM		*SPE *CME	3
9	*MGD			*PDM		2
10		*TLD	*TLM		*ECE	3
TOTAL:						16

Exhibit 4.6 (b)
Informants classified according to formal position: secondary cases

Exhibit 4.7 (a)
Informants classified according to functional specialisation: primary companies

Company	Design/ Engineering	Manufacturing/ Production	Others	Total Number of Informants
1	*Architectural Engineer *Data Base Inspector *Syatames Manager	*Manufac'g. Manager *Manufac'g./Prod'n. Engineering Manager	*Marketing Manager	6
2	*Design Manager Design Support (CAD Manager)	*Operations Director		3
3	*Product Development Manager *Technical Director	*Operations Director		3
4	*Drawing Office Manager *Engineering Systems Manager		*Training Manager	3
5	*Engineering Design Services Manager *CAD Support Engineer	*Manufac'g. Systems Manager *Materials Manager		4
TOTAL:				***19***

Company	Design/ Engineering	Manufacturing/ Production	Others	Total Number of Informants
6	*Product Dvt. Manager *Senior Design Mgr. *Technical Manager		*Managing Director *Quality Assurance Manager	5
7	*Design Manager *Electronics Engineer *Mechanical Engineer			3
8		*CAM Engineer *Operations Manager *Senior Prdn. Engineer		3
9	*Product Development Manager		*Managing Director	2
10	*Electronics Engineer *Technical Director *Technical Manager			3
TOTAL:				***16***

Exhibit 4.7 (b)
Informants classified according to functional specialisation: primary companies

Exhibit 4.8
Informants classified according to formal management stratum in the ten companies

Hierarchical Level / Job Capacity	Number of Senior Level Informants	Number of Middle Level Informants	Number of Supervisory Level Informants	*SUB-TOTALS:*
Mainly Managerial Executive Roles	7	18	3	*28*
Mainly Technincal Support Roles	0	2	5	*7*
SUB-TOTALS:	*7*	*20*	*8*	*TOTAL: 35*

Formal interviews[18] required sensitivity in responding to individual informants' styles. The researcher aimed to strike a balance between the issues that informants felt like talking about because they were of vital importance to them and those which the researcher believed should be addressed in the best interest of the study, which sometimes appeared to be of little interest to some informants. Therefore, the degree of "directiveness" in the researcher's style of interviewing varied from one interview to another according to: (1) the nature and style of the informant concerned and (2) the progress (or lack of it) from one idea to the next. Wherever informants expressed strong attitudes towards other people, organisations or situations, it was important to probe them for reports of experience to help the researcher understand how such attitudes had been shaped.

Most interviewees started talking in a guarded way when they were interviewed for the first time. Their later remarks tended to be more frank but not necessarily more accurate. It should be said that rapport-building was time consuming in some cases[19].

In formal interview situations the interviewer deliberately kept the opening of the conversation away from evaluative topics by starting with simple conversations about non-provocative topics of general interest[20].

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[18]Formal interviews were important for this research for the following reasons:
a) Acquiring firsthand information from key and high-ranking persons playing key roles in leading technological change in their respective organisations was facilitated.
b) Interviews were an effective way for yielding a high percentage of returns from most correspondents. They enabled the researcher to motivate respondents to give full and accurate answers as questions were directed to them as individuals.
c) Emerging questions of crucial theoretical significance to the research were directed personally to respondents in such a clear way as to avoid misinterpretations and misunderstandings that would probably be more likely to arise in research methods not involving interactive conversations. Interviews offered an opportunity for asking more relevant questions and, in some cases, a greater number of questions too.
d) The quality of interview data improved considerably with time; accumulative rapport and orientation of the respondents helped the securing of acceptable findings.
e) Interviews provided flexibility in responding to various styles of personal presentation. A researcher's sensitivity should facilitate a continuous observation of a respondent's reaction; accordingly, the topic of discussion could be changed or the research problem explained further.

[19]Invariably, however, in a first interview a respondent would take a long time to become more oriented to the topic of investigation. Consequent interviews took less time and became more efficient as the respondent's orientation increased.

[20]Interviewees were invited to make descriptive statements to make them feel more relaxed since their descriptions of certain phenomena did not always match the researcher's. For example, one interviewee once insisted: "..... You might describe this as unique whereas I would describe it as flexible!" (Case 6). First questions in an interview would be about what their jobs entailed, how their jobs fitted into the whole production process, what their job histories were, and/or what the specifications were of the technology systems they managed. In so doing, the interviewee was invited to talk about things which were close to him personally and not "pushed" to reveal his/her inner feelings about the company or any other touchy topics.

Sensitive evaluative questions were asked later on during the course of an interview. However, the researcher still had to wait patiently to ask such questions until the respondent's confidence had grown sufficiently. In some cases this process went beyond a single interview but took a considerably shorter time in others.

To guard against the possibility of "cooling-off" on the part of an informant, he should be contacted further for a casual discussion or interview soon after the first social encounter. Continuous liaison was especially important with those identified as key informants who observed significant events and were more perceptive and reflective about them more than others. As the study proceeded, the researcher sought to get such special informants more involved in the research by encouraging them to learn precisely what the research was looking for. This was done with full consciousness about the dangers of relying too heavily on any single informant.

The researcher had to make sure that he understood whatever had been said by an informant; even by interrupting and checking him/her. The words not only had to understood at "face value", which might reveal the nature of a problem and its solution in the eyes of the informant, but also an extra effort had to be made on the interviewer's part in seeking enlightenment about the social processes of recognition, decision and choice of actions. The latter could be of more interest to the research than the problem itself or its proposed solution.

4.14 Data Recording, Analysis, and Coding

The following three subsections will explain how the data gathered during the course of the filed work was recorded, analysed and coded.

4.14.1 Recording: Method and Procedure

Data recording was an important consideration from the outset. Tape-recording was the major technique used in the field, particularly during formal interviews. Note-taking was also used whilst on site and after each visit, which helped in subsequent report writing. Which techniques to use and when depended on: (1) the nature of the data to be recorded, (2) the data collection method involved, (3) the degree of formality associated with a particular situation, and (4) the stage of development of the study. In certain circumstances it was more important to give full attention to the informant than to take notes; the researcher aimed to activate interviews by asking questions, clarifying vague points and, thus, achieve the required output of an interview.

In short, tape-recording was preferred in formal interviews because note taking interfered with the flow of the interview and yet could not capture its whole atmosphere. All the formal interviews conducted by the researcher were both tape-recorded and transcribed using a transcription machine[21].

4.14.2 Analysis: Method and Procedure

At the early stages of the field work the emphasis was on data collection. As the process progressed, however, the balance changed as more coding and analysis became necessary. The researcher analysed the material at various times: immediately after leaving the field and sometimes during the evening between successive days of data collection (see Glaser and Strauss, 1967).

In open, axial and selective coding and analysis of the data the main emphasis was on action and interaction of and between individuals and groups with the integration process as the central phenomenon in focus.

4.14.3 Coding: Method and Procedure

Coding is considered at two levels in this section; first, at a level pertaining to how participant companies' and individuals' names were coded in order to maintain the confidentiality of such information (as explained earlier on in this chapter, section 4.6); and second, at a level pertaining to the analytic and interpretative procedures which were used to formulate and present the findings, including the techniques for indexing the data collected. The former concerned the specific actors under investigation in this research and their respective organisations. The latter concerned the data collected for analysis. The latter type of coding would form an important element of any qualitative research (see, for example, Creswell, 1994; Miles and Huberman, 1984; Strauss and Corbin, 1990) .

Firstly, the data analysis process resulted in the construction of a data bank containing information on actors, both informants and those who, although the researcher did not meet personally, played a vital role in their respective companies' experiences of change and whose contributions were crucial for answering the research's questions, such as former key managers and company founders. Information contained in the data bank was obtained either directly from informants or from published and unpublished company documents.

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[21] In the experience of the researcher, a full interview would typically take between six to ten times of its actual duration to transcribe. A two hour interview, for example, would take about 12 to 20 hours to transcribe manually or directly word-processed, depending on: (1) the quality of recording, (2) the clarity of the respondent's accent, and (3) the learning and analytical pace of the researcher. This confirmed Whyte's (1984: 114) description of transcribing as " an exceedingly time-consuming task, even for an experienced stenographer". Transcription took longer when it was combined with coding and analysis as the researcher attempted to do such activities simultaneously.

Secondly, the analysis process involved coding of the data gathered. Coding involved those "operations by which data are broken down, conceptualised, and put back together in new ways. It is the central process by which theories are built from data" (Strauss and Corbin, 1990: 57). Coding was meant to: (1) yield theory, (2) strengthen the rigour of the research process, and (3) force out the biases and assumptions brought to the research process and those that might have developed during it. In other words, coding of the data served to "provide the grounding, build the density, and develop the sensitivity and integration needed to generate a rich, tightly woven, explanatory theory that closely approximates the reality it represents" (Strauss and Corbin, 1990: 57).

A protocol was developed for coding. It involved all transcribed interviews as well as archival materials. The quotations presented in this thesis could be traced to the documents they were extracted from[22].

Coding will be explained further in the next section in terms of its three stages of development: open, axial and selective.

4.15 Open, Axial and Selective Coding

Open, axial and selective coding procedures were carried out, progressively, during the course of the research. Open coding was associated with open sampling which aimed to uncover as many potentially relevant categories as possible. This included the sampling of persons, places and situations with a view to gathering the most relevant data during the early stages of Phase I.

Axial coding followed open coding. The properties and dimensions of the data which had been broken down into categories during open coding were reassembled in new ways during axial coding using relational and variational sampling procedures. The phenomenon under investigation, the causal conditions associated with it, and the particular context in which it was embedded became much clearer during this stage. This resulted from the uncovering and validation of relationships between subcategories, categories and the phenomenon. This was possible as a result of answering the questions repetitively raised on the data gathered and using the appropriate purposeful action/interaction strategies deployed in handling the data already available and pursuing further data.

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[22]The protocol was used for data analysis purposes. Using the protocol for the purpose of presenting quotations in this thesis was carefully considered and tried at first. However, this was changed. It was thought that it would be both unnecessary and confusing. Instead, the appropriate case's serial number only would be cited for reference purposes at the end of a quotation.

Action/interaction strategies were affected, however, by sets of intervening conditions, or "the broader structural context pertaining to a phenomenon ..... the broader and general conditions bearing upon action and interaction strategies" (Strauss and Corbin, 1990: 103). These were not properties of the phenomenon but, rather, conditions outside of the phenomenon itself that nevertheless affected the way it was handled in either a positive or negative manner. Therefore, the researcher had to do his best in contending with the intervening conditions to secure collecting the best quality of data in the interest of the study, particularly during the axial and selective coding phases of analysis.

Four distinct analytical steps were simultaneously used during axial coding. These were:

1) Relating subcategories to a category by hypothesising relationships between them and the phenomenon.
2) Verifying resultant hypotheses against actual data.
3) Resuming the search for properties and dimensions of categories and subcategories.
4) Exploring variation on a preliminary basis in preparation for selective coding.

Selective coding followed axial coding. It was concerned with integrating the categories uncovered to from a set of grounded theoretical propositions. Five main steps were involved at this stage, but not necessarily followed linearly (see Strauss and Corbin, 1990: 117-118). These were:

1) Explicating the story line.
2) Relating subsidiary categories around the core category.
3) Relating categories at the dimensional level.
4) Validating those relationships against data.
5) Filling in categories that needed further refinement and/or development.

Once the core category was identified, the next step involved determining its properties and dimensions and relating the other categories to it. Hence, the other categories would become subsidiary categories. Resultant propositions would then be checked or validated against the data which they fitted sometimes but not always. When they fitted the data they were maintained. When they failed to fit the data, however, further theoretical sampling was required in order to identify the reasons for the lack of fit with the data, with a view to validation of the resulting theory.

4.16 Summary

This chapter described the details of how the field research was conducted. It began with a description of the basis on which the companies researched were selected, distinguished between primary and secondary companies, and explained about the progress of the research process and the main activities involved in it.

It also clarified important points regarding the interview schedules used and explained the measures taken to insure the validity and reliability of the main interview schedule.

It gave a particular attention to the methods and procedures followed in data collection, coding, analysis and interpretation. Coding was described both in terms of data about the cases (i.e. concerning companies and individual actors) and data from the cases (i.e. as required to answer the tentative research questions and develop theoretical proposition through open, axial and selective coding).

Field work activities, interviewing in particular, proved to be an extended learning opportunity to the researcher. A great deal was learned about the ten companies, the change processes concerned, the organisational structures and processes that affected change in positive and negative ways, and the actions and interactions involved as well as the contextual boundaries surrounding them. It would be difficult to imagine that such a rich picture could be achieved using any other methodology.

One important thing should be said, however, about the field work methodology followed: it was a labour-intensive approach indeed in terms of the frequency of visits, transcription of interview materials, and coding and analysis of the resulting data which was voluminous and difficult to handle. The longer the time spent on a study like this, the more likely that the researcher would refine his/her understanding of the phenomenon under investigation and develop a more tested theory.

One important practical advantage of this methodology, nevertheless, became abundantly clear at the end. The researcher could afford to appear less intrusive than in the case of action research or participant observation by building trust and continuity into the research process progressively with time. The accumulation of such trust and continuity was very important in helping the researcher gain a greater degree of access to "protected" data that could further improve the quality of his understanding and thus that of the resulting theory.

CHAPTER FIVE

Findings, Data Analysis and Discussion - I: Introducing the Cases in the Study

5.1 Introduction

This chapter aims to introduce the cases in the study. It paves the way for a thematic presentation and analysis of the data collected on the ten companies (in Chapter 6) by providing background information about each company separately. This will involve elucidating some key company details in order to lay out the foundations for the comparative analytical context required for the purpose of cross-case data analysis in Chapter 6. Each company's engineering and manufacturing activities will be briefly explained in relation to the DEM technology applications they use in their operations. The history of technological change in each company will be addressed in terms of CADCAM. The emphasis will be on the organisational effects of the 1970s/80s investments in CAD and CAM systems and the consequent organisational context for further investment in integrating such systems.

The present chapter assumes a dual role pertaining to the experiences of both the primary and secondary cases in relation to their position vis-a-vis CADCAM integration under the conditions brought about by the emergent context of the 1990s. Therefore, it will be divided into two sections; the first (section 5.2) deals with the primary cases and the second (section 5.3) with the secondary cases. This chapter concludes with a summary comparing the key features of the integrating and non-integrating strategies.

5.2 The Primary Cases

This section focuses on the integration process as it is managed in the respective experiences of the five primary cases (Company 1 to Company 5). It covers a case-by-case presentation of the relevant findings relating to the above-mentioned historical and current aspects of the CADCAM integration process and the organisational issues associated with it.

* <u>*CASE STUDY ONE: Company 1*</u>

Company 1 is a wholly-owned subsidiary of a giant manufacturer of speciality chemicals[1]. The company, which is the subject of investigation in this case, is one of

[1]The holding group was established in 1888. It is now one of the largest independent groups listed on the UK Stock Exchange, with operations in 27 countries. The group's marketing performance has improved since the early 1990s. According to the chairman, this achievement has become possible =

several independently-managed subsidiary companies owned by the group and controlled through five autonomous international divisions located, geographically, according to global market areas.

The company was formed in 1969 to supply advanced photomasking services[2]. In 1986 it acquired another photomask manufacturer and operations have since been carried out in the company's only factory in Glenrothes, "Scotland's Silicon Glen". The company is the only one of its kind in Scotland:

> "I would guess we are very untypical as a company ..... There are only two other mask shops in Britain [other than in Scotland] and the number in the world is probably a few hundred."

The company's UK market constitutes about 30% of its business. Hence, senior managers often complain of challenging "inflationary and exchange types of problems" encountered in international trade.

With 95 employees, Company 1 is the smallest of the primary cases in work force terms. Although business performance has suffered a decrease in demand from its customers in the defence electronics market since the beginning of the 1990s, the company has continued to be profitable over the last few years.

The company's mission is clearly defined as "providing a service to the semiconductor industry". Very little creative design work is carried out in the company because the manufacture of photomasks is invariably based on customers' specifications. Customer firms in the semiconductor industry tend to be larger and more powerful than Company 1 in terms of bargaining transactions. Therefore, the design engineers' role is basically concerned with coding up customers' drawings. Most of the work carried out within the design department consists of processing customer-supplied data by converting it from a given format to a suitable machine format for manufacture and inspection.

Customer orders are quoted on an individual basis, but data processing jobs have fixed prices for most customers. On receiving a potential customer's inquiry, CAD and data processing department staff would assess the work needed and quote a price. If the customer accepted the offer, then data would be sent back from the sales department to the CAD department so that work on the order could begin. Machine-readable instructions would then be sent to the manufacturing department to begin and control production operations according to schedule.

= due to "the enlargement and extension of the group" during the 1980s, which "brought about a transformation in the scale and breadth of operations".

[2]Photomasks are specialist tools used for the manufacture of PCBs. High precision patterns are printed on pellicles to customised PCB designs and supplied in batches to customers in the semiconductor industry.

The company utilises high-precision process technology. An intensive TQM program is in application with a view to involving people across and at all levels of the organisation. The aim of this program is to "get things right first time, because we can't afford non-conformities - very expensive". The great emphasis that is placed on quality throughout the company can be understood in terms of the complexity of a finished photomask which incorporates a combination of intricate artistic input and precision engineering.

Seven separate but inter-linked CAD systems are deployed for 2D drafting purposes. They include a combination of *VAX, SUN* and PC hardware equipment and *VMS, DEC, VWS, Princess*, and *AutoCAD* software packages: "There is a sort of historical progression here. In 1986 we got *Princess*. It was the first graphics editor ......". Multiple software packages were needed in order to address different customers' data formats.

The shop floor takes the form of separate clean-room production environments, each of which is designed for a specific manufacturing or inspection process and accommodates one or more computerised machines which could be classified into six main categories with respect to the purpose for which they are used: 1) electron beam equipment, 2) optical equipment, 3) inspection equipment, 4) laser repair systems, 5) mask-cleaning system, and 6) pellicle attachment and repair machines.

Computerisation has played a vital role in the company's operations. The Principal Architectural Engineer has worked in the company since 1976 and is, therefore, in a good position to describe the changes that he has experienced in process technology in particular:

> "Basically, the whole manufacturing has changed significantly since '76. So what was needed at the front end is different to what we need now. .... Tolerance requirements are different. In '76 tolerances were .... + or - 50 microns and it's down to + or - 0.5 micron and even tighter. .... So there's a big difference ..... "

Technological change in this case is a continuous response to continuously changing customer demands. This is held to be vital for maintaining established customers' "credibility". This attitude prevails among managers of various disciplines and at all levels.

It could be said that investment in CAD began in 1974 when a simple digitising system was introduced. The next major step was taken in 1985 as the first *VAX* machine was introduced together with a graphics editing software. It was then the first and only work station.

A unique feature of the evolution of computer-based technologies in this case is progress by accumulation and expansion, rather than by replacement, as is the case with the rest of the companies. Whenever a need for change in an existing system is recognised, new software or/and hardware components are added in order to satisfy an emerging customer's data processing requirement by using a data format that is compatible with the one used by the customer in concern. Such a situation is justified on the basis of management determination to sustain sound business relations with long-established customers who have the commercial power to dictate conditions or else turn to other photomask suppliers. Therefore, the present configuration of process technologies could be described as a "collection" of accumulated choices that have been made frequently since 1974.

However, it should be noted that the present Systems Manager, who joined the company in 1989, and thus was not here when his predecessor selected and managed the introduction of CAD in 1985, criticised the latter for the lack of "a proper evaluation of an attentive type" and "a comprehensive analysis of what system to go for", because he "wasn't intellectually strong". When a detailed explanation about the history of CAD development in the company was sought, the former even suggested that the latter went for the only system he knew about at that time because "some body tried to sell him it".

Continuous change in technology has forced redeployment and retraining of employees. New work groups have frequently been formed and assigned new responsibilities. This has been often unproblematic due to the company's relatively small size, relatively flexible structure, and friendly inter-personal relations.

Eight people work in design and data processing, four of whom are regular CAD users enjoying free, unstructured access to the system. They rotate jobs amongst them in a remarkably flexible and informal manner. No specified responsibilities are allocated and jobs are far from being standardised in terms of working times and job specifications.

Integration has been taken seriously by senior management over the last six years. System interfacing efforts in the company aim to develop the existing network of CAD systems, which is itself linked to other departments and to customers' networks. CAD was linked to inspection in 1990 and to manufacturing a year after:

> "The problem started when data started to be too big for tapes. So that's what made us transfer the data to make us oriented towards manufacturing requirements rather than the reverse."

In this case integration could be addressed at two levels. Firstly, management have recognised a need for design and manufacturing engineers to work more closely together than ever before to consolidate a simultaneous internal communication. The close co-operation requirements imposed by the nature of the product development process were an influential factor behind this development.

> "There's something that makes us very weak: [it] is that our application is so specialised and having to manage how to manufacture is a big thing as far as transferring data from design to manufacture."

Therefore, a formal decision was made by the company's Board of Directors that engineers of all disciplines should meet fortnightly to " solve out any engineering-related issues". CE is devised as a means for consolidating communication to improve concurrency between design and manufacturing

Secondly, a large degree of external dependency on customers has pressed management to consider integration at a business level. Engineering and inspection staff now have to work more closely with their counterparts in customer firms to insure early involvement in product development. From a senior management's point of view, the company's business interests have necessitated this concurrency arrangement on the part of their staff.

More than half of the orders received at present are channelled already via an electronic network that is interlinked with customers' organisations. Further integration is pursued.

In 1993 the company experienced a change of personality at the top following the resignation of its Managing Director. He was succeeded by the former Operations Director who found a greater favour with many engineers and middle managers. This was apparently because he adopted a more democratic leadership style which encouraged participation in decision making. His appointment seems to have improved the company's chances for a faster transition towards integration. Optimism and high expectations of the integration process remain to be a unique characteristic of the leading technical managers in this case.

* ***CASE STUDY TWO: Company 2***

Company 2 is a wholly-owned subsidiary of a multinational industrial group quoted at the London Stock Exchange[3]. It was set up in 1915 on a green field site in a Kirkcaldy

[3]The holding corporation is involved mainly in the leisure and hotel industry. However, it operates an industrial wing which invests in manufacturing machines for the television and film industry as well as measuring instrumentation for military aircraft applications. Company 2 is one of the companies which form this industrial wing.

industrial estate. Still on its original site, the company produces a wide range of lighting and other electrical products including luminars and control desks[4] .

The company's organisation is lightly structured with a five-man Board of Directors, an eight-man middle management team and a supervisory level. The Board of Directors is headed by a Managing Director and includes Finance, Marketing, R&D, and Operations Directors. The Operations Director is responsible for manufacturing, warehouse and distribution operations both in Scotland and at another plant in Rome, Italy.

The work force consists of 130 direct workers. Indirect employees in various technical and administrative areas add up to about 100. Most of the direct jobs, especially in assembly, are performed by less skilled female workers, to the extent that the assembly section of the factory is known as the "girls' area" or "where the girls work".

Senior management describe Company 2 as being marketing-led. The average for luminars' design life cycle is ten years and is slightly shorter for control systems. Typically, the marketing department specifies a customer-demanded product and engineering then writes the appropriate specifications, designs, and develops it by creating a prototype which it sends to manufacturing. This process is repeated on average once every 12 to 18 months. Redesign and modification work on existing designs is a routine practice and changes with almost every new order.

Production output tends to be of medium to small batches and one-off jobs at times. Luminars are designed and manufactured completely in the Kirkcaldy plant whereas control desks are designed in London but manufactured in Kirkcaldy. Major operations on the shop floor include CNC punch pressing, machining, welding, extrusion, and casing and assembly of finished products. The factory was set-up according to CM principles so that AMT would be operated by workers performing their tasks in small cells[5].

The company's CAD system consists of a *CIMlink* software application package and *SUN* hardware. The system network comprises five 360 workstations and one *Spark-I*. The system is used only for 2-D drafting purposes[6].

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[4] Luminars are used in, for example, studios, exhibitions, and camps whereas control desks are used in disco, theatre and stage applications.

[5] This work arrangement is known in this case specifically as "SPUs (Special Purpose Units)".

[6] For in-house part and assembly design and for reading drawings from the company's London and Los Angeles design offices.

On the manufacturing side the company has introduced automatic insertion machines (AIMs) for "populating" bare PCBs. AIMs form the bulk of the CAM system. Other aspects of CAM include CNC applications.

CAD was introduced in 1989. The then Operations Director, who is now the Managing Director, was "more computer-biased" than other senior managers and succeeded in persuading the Board of Directors to invest in CAD and CAM.

A young engineer was appointed for this purpose, who had gained CAD experience working for a consultancy company. Since his appointment he has been responsible for CAD in his formal capacity as a CAD Manager. The first task assigned to him was to evaluate the CAD market in the light of the company's design requirements. He went about his task by participating in seminars, attending demonstrations, and visiting various suppliers. The company then formed a small cross-functional committee to make a decision. The existing system was then chosen on the basis of his justification report.

The two main objectives in introducing CAD were defined as: ".... (1) to improve the speed of the design process to manufacture and (2) to improve the accuracy of the documentation". Both the Design Manager and the CAD Manager are satisfied that the first stated objective has been met. However, they admit that the company is "still behind" in utilising the documentation objective, because of "the lack of resources to work on it".

CAD was set-up such that three full-time design draughtsmen would work on it continuously. Two work stations were set out for engineering and administrative purposes and a work station is used exclusively by the production engineering department for retrieving drawings from R&D. Some design drawings are passed either by tape or through the network to and from the company's London design office. Most of the original design work is done on CAD, although traditional design methods are still followed in redesign and modification work on older designs which were prepared prior to the introduction of CAD.

The company had only seven people working in design prior to CAD: two design engineers, two draughtsmen, a manager, a secretary, and a technician testing product quality. The number increased to 11 with the appointment of a CAD supervisor and another draughtsman, engineer, and a mould-maker. This increase is not simply due to CAD, with the exception of the CAD supervisor who is assigned the responsibility for the system, but is more a response to increased demand on the design function as a whole.

The responsibility for CAM is not as clearly defined as that for CAD. It is shared by a team of manufacturing managers who are answerable to the Operations Director. The latter explained that the company's goal in introducing CAM was to "run the business with a customer orientation". According to him, this goal was defined in terms of getting greater control over the business, cutting cost[7], improving production methods, reducing stock levels and thus improving liquidity performance, and improving the information support for manufacturing processes.

Three major unions are active in the company but industrial relations have not been significantly affected by the introduction of new technology. Senior management's simple but apparently effective philosophy on managing change with the unions emphasised a two-way communication style:

> "It's a communications problem. It's the need to actually keep people informed of what actually you are doing, why you're doing it, where they figure in this, what part do they have to play in it, how it's going to change the way they do their jobs, the rewards for the job, the way they're expected to participate in the whole organisation."

Staffing levels have not been affected as a result of introducing these technologies. However, the introduction of CAM caused major changes in the way work was designed around the machines apparently to give employees a sense of ownership of the new technology. Factory work was therefore reorganised along functional lines in place of the product layout orientation that had existed before. Assembly facilities were also rearranged to accommodate the operational requirements of the new automatic insertion machines on the shop floor.

The company moved from there to a matrix type of organisation with the introduction of MRP-II. More attention had to be given than ever before to ergonomics in designing jobs around the new technology. Most of the supervisors involved in production on the shop floor became essentially "sustaining engineers rather than production engineers" (i.e. involving mainly tasks of monitoring automated manufacturing processes).

During an interview with the Design Manager he admitted: "I don't think we are particularly organised well". Senior managers have attempted to relax a traditionally functionally-structured organisation and restructure the flow of the design-manufacturing process into a matrix form since the early stages of the present research. This has been introduced gradually in the name of CE with a view to reducing production lead-time. The driving force behind CE in this case is the London-based R&D Director who co-operates closely with the Kirkcaldy-based Operations Director in

[7]In this case management is clearly aware that its cost-saving strategy must concentrate primarily on material and overhead costs (constituting 60% and 24% respectively of overall costs incurred). No effort was wasted in trying to justify CAM on the basis of reducing labour cost (only 16%).

its implementation. Both are supported by the company's Chief Executive Officer who is enthusiastic about CE and believes strongly in its integrating and efficiency-improving capability.

A greater utilisation of the "downstream benefits of CAD" could be realised through CADCAM's potential capability of using information from drawings to automatically directly control machine tools on the factory floor. However, financial constraints, coupled with a short-term planning horizon would not facilitate a rapid transformation towards integration, as the company's most senior manager contended:

> "There is no question at all it [i.e. CIM] will bring considerable advantages but it also brings considerable cost, 'cause trying to put together that sort of package for a small manufacturer with a small batch work is extremely difficult .... Frankly, we can't justify very much better."

A period of about four years has passed since these words were uttered and relatively little progress on CADCAM integration has been achieved. On reflection, the same senior manager went on to explain his views in a somehow self-critical manner:

> "The captains of the UK industry look for a much shorter-term return on capital investment .... just looking at cash flow etc., etc. It's a problem of attitude. ..... If one compares this to the Japanese who take a longer view of investment ..... we are typically looking for two to three years. This is far too short .... and this, I think, is having a dampening effect on the ability of the manufacturing companies in the UK to be able to invest in these technologies."

Against this background, a strong commitment to integration on the part of the CAD Manager could not have made a great difference. He recommended *CIMlink* in 1989 because it was suitable for integration. His vision, however, has not materialised to any considerable extent. A major reason for this is the lack of senior management's support for his initiatives in a hierarchical command and control organisational structure where orders "come down from above [i.e. the Board of Directors]". In one instance he openly complained about senior management's manufacturing-biased orientation:

> "Well, we're controlled by manufacturing. We have a manufacturing-led basis. They specify the product and we have to design, and from there we write the specifications. And we then design the product from the basics right through prototyping ..... "

He added that this inclination has made design inferior to manufacturing. This is a unique characteristic of this case and could be found in none of the other nine cases. Another reason could be structurally explainable. That is, the R&D Director is assigned the ultimate responsibility for CAD and the Operations Director for CAM. They both find it difficult to share responsibility for a cross-functional CADCAM project in a traditionally functional organisation and more difficult to contribute financially to it from their limited departmental budgets.

Both Design and Manufacturing Managers, however, look at integration as a priority. They realise the cultural and political challenges that are implied from their past experience of introducing another integrating technology into the company, namely MRP-II: " .... the whole process of moving toward this is going to actually change the actual way the organisation looks". In this context, the attempted matrix type of organisation could be described as an integrating mechanism. The long-term plan is to create a single data base for the entire organisation, which will be centred around the proposed MRP-II system. However, the existing CAD data base will form the reference point in designing the new data base management system which will directly satisfy the information requirements of engineering, design, manufacturing, and production. Indirectly, it will be used by all other functions in the company (e.g. purchasing, marketing, and quality control) as their source of information support. Therefore, as the integration process progresses in the future, design restrictions will be determined by the present CAD configuration which will form the core of an integrated CADCAM system.

CE was an important project launched from a design point of view to provide an organisational framework for integration. However, it has encountered obstructions from manufacturing managers who, despite of their influence in the company, could not have succeeded in leading it because the product-related information data base was controlled by design. In this respect, the Design Manager stated:

> "What we have tried to do is to develop this [referring to a hand-drawn work flow chart] into a simultaneous engineering ..... I would say we've been trying to do it [i.e. CE] since [i.e. for] 10 years now .... to reduce the lead-time, but the problem is that the project leader has not been given the direct responsibility or the resources to do it. .... It will never get anywhere as along as they continue to reject the person who [?], and that's changing ..... "

Continuous inter-functional struggles to control the integration project required strength, authority, and commitment to prove oneself and try one's best to come out victorious eventually:

> ".... the project leader needs to be strong as well. He needs to sell himself to the team with the same ..... commitment as a department manager. ..... I think if they have comfort with the department managers .... that over and above the other things. They would probably have a few victories, which would be necessary in their struggle for [i.e. to be] a leader ..... "

Nonetheless, recent progress on the integration process has allowed the company to link its London and Kirkcaldy design offices through a wide area computer network. This is another potential area for integration in this case, which is currently being investigated for further development.

* ***CASE STUDY THREE: Company 3***

Company 3 is an Edinburgh-based manufacturer of electronic security equipment with marketing centres in England, France, Germany, Italy, Australia, and the USA. It is a wholly-owned subsidiary of a giant British corporation.

A relatively young business in an increasingly growing industry, the company was set up in 1973 by the holding corporation in response to a declared market interest in security equipment.

The company's broad product range covers numerous applications from simple home security to specialist high-risk security applications[8]. Three detection techniques (i.e. passive, infra-red, and microwave techniques) are used in manufacture. However, the company is best known for being one of the world's largest manufacturer of passive infra-red detection devices which contribute 80% to its total business. Subject to fluctuating demand levels, flow production on the shop floor yields on average 2.3 million units per year.

The company is organised in terms of seven "lines of business", each of which supplies a specific family of products to its respective market segment. It is led by a five-member Board of Directors and employs 400 people, 350 of whom work on the Edinburgh site.

Senior management regard cost-saving as its main "competitive edge" and, hence, cost-consciousness tends to dominate decision making in this case. For example, the Technical Director, who has been one of the key architects of the company's cost-control strategy since 1973, contended: " .... cost now is everything - these units, we worry about taking pennies off manufacturing cost". This feature of the company seems to have been strengthened over the last few years because of the early 1990's recession which was "hurting" and "left the firm totally flat" since "this is the first recession in my long experience in this industry that has actually hit it. Normally the security industry has been immune to recession".

Historically, the company has had a glorious technical reputation, one that was built on its engineering team patenting the pioneering of the infra-red sensing technique. The company was competing with a US firm to develop the technique independently and succeeded in winning the race. It became the first company to put its theoretical knowledge into practice by implementing an innovative set of production, assembly and packaging rules for building the technique into the appropriate product line.

Productive activities in Company 3 are essentially assembly-oriented. Products are designed to suit the processes deployed on the shop floor. Marketing-identified customer requirements are channelled through the group's top management team to specialist research companies which respond by designing products that appeal to

[8] In, for example, military installations and nuclear power stations.

targeted market segments. Fundamental R&D work is carried out at four research companies belonging to the holding group. Basic product components are designed in-house and their manufacture subcontracted for assembly. Management's policy in this area is motivated by the desire to be flexible in utilising alternative vendors' state-of-the-art manufacturing techniques whilst not buying any of them:

> "We decided very early in our life not to manufacture ..... Our philosophy is not to manufacture anything that can be made efficiently in another plant."

Consistent with its cost minimisation objectives, the company has introduced JIT and Kanban techniques for production planning and control with a view to minimising stock storage and handling costs. Assembly operations are performed, as in the case of Company 2, by less skilled female operators who form 50% of the company's work force. Assembly operations are designed for an automatic assembly line and include CNC machines for PCB population, automatic gluing of "populated" boards, and oven-heating of glued populated boards to cure the product at this final stage of production. Lastly, a 100% final inspection is carried out by "the girls" in this case as well.

This company uses a *Visula* CAD system run on an *Apollo* work station for mechanical and electrical drawing. The hardware comprises eight work stations and the system is used merely as a drafting tool for mechanical and PCB drawing. Only recently did the company begin to utilise the system's 3D modelling capacity in response to persistent pressure from customers.

The company found itself under pressure to introduce CAD mainly because of its business environment in a growing and rapidly changing industry that is governed strictly by external regulatory agencies:

> "We're very regulated. There's a lot of external approval authorities who lay down rules and say: 'your products must comply with these rules'. They keep changing the rules so we keep changing the products to stay compliant."

The history of CAD implementation in this case could be summarised in terms of a four-phase evolutionary process. A simple PC-based CAD system was first introduced in 1984 with a single VDU and a drafting software package. The company moved up from this stage to add *CADStar* for electronic drafting. The third phase witnessed the introduction of a more complex system, Visula, which overtook the original system. The fourth and current phase involved the addition in 1995 of a *Hewlett Packard* modelling system in response to persistent customer requests. Within these four "big steps", however, there has been "a lot of evolution". For example, the company started with *Visula* version 3, is now operating version 5.1, and is preparing to upgrade this over the next year, which will require a more powerful hardware than the company has available at the moment.

The Technical Director is the key individual in managing this incremental change process with his team of engineers, draughtsmen, and technicians. His experience in this regard was summarised as follows:

> "The way we introduced it, we got a small PC. We had a simple system and we chose one draughtsman who was quite keen on computing, he was used to playing with home computers. We involved them [i.e. all draughtsmen] before we made a purchase and we said: 'we're looking at CAD, we think it can do this for you', and one of the guys was very keen, he thought: 'yeah, go for it', so we bought the machine and said: 'here you are, see what you can do with it'. So he played with it, but we deliberately chose a package which was very, very easy to run ..... it was basic, but it allowed them to draw on the machine, just a drafting package ..... And there was only a little [time] passed before other draughtsmen came along and said: 'we want on to this machine, we see the benefits - this guy is turning far more work than we are and he can fix mistakes and if we have them we have to start doing it again'."

As interest in CAD grew rapidly among the draughtsmen, the Technical Director found that he had to regulate the tasks of an increasing number of system users in his own way. For example, nobody was allowed to use any computer language other than the purchased drafting software:

> "The first rule we made when we purchased PCs was that there was no languages. It was forbidden to write programs, took *BASIC* off them. You were not allowed to write programs on the *IBM*. You can only buy one, because the price of the software is so small by comparison. We can buy it [i.e. a simple software] for about £400. I can only get half a day's work from an engineer for £400 and he certainly can't write a package for [i.e. in] half a day."

Beginning with a simple system was advantageous to the technical department in avoiding formal bureaucratic procedures of justification since it was "a very little risk for the company". The department had to demonstrate that if expensive mistakes could be avoided, which they could in this case, then the machine would easily pay for itself sooner or later. Justification became a problem later, however, when more expensive systems were proposed: "What was difficult to justify was the big system. .... There was quite a battle for MRP, there was a battle even on CAD".

The "battle" took place despite the fact that the *Visula* software was supplied free of charge by another subsidiary of the holding corporation, which specialises in software development. Therefore, when Company 3 decided to upgrade its CAD system it had no choice but to accept the parent company's software:

> "The group has a centrally determined policy ..... on which CAD systems could be used. So if you wanted a CAD system there was no choice: this was the only one available, you had to use it ..... "

The company maintains a close relationship with *Edinburgh University*'s Engineering Department for advanced CAE services, such as FEA, which are sometimes needed, instead of buying the technology. Management's purchasing-oriented policy persists here and is echoed in so far as CAE is concerned: "if we have a problem we seek a service contract" to avoid high maintenance cost.

CAM comprises a range of computerised equipment which could potentially be integrated into a CADCAM system. These include CNC machines, surface mount machines and AIMs for PCB population and a computerised oven used for curing finished products. On the production management and control side, the company uses an *IBM 44MAPPICS-II* for its MRP-II system to manage its production planning and control function from order to production and delivery. Responsibility for MRP-I is assigned to a Production Manager who has managed the system since it was installed in 1981. *MAPPICS-II* was introduced in 1991 and it had taken about nine months for the company to make it fully operational.

The company's main CAM integrating equipment, surface mount machines, were introduced in the late 1980s. The design-manufacture link has been helped by *Visula*'s ability to communicate directly with the surface mount machines. This has eliminated the need for repetitive programming. It has also minimised errors which were very common before. However, much of the technical difficulty in integrating CAD with CAM could be traced to the independent selection and implementation of each of these systems historically.

Apparently, CAD has hardly affected the work organisation in the design area. CAM's effect on the shop floor has been minimal in terms of staffing levels. There were a few "recessional layoffs" but these could hardly be causally linked to CAM. However, job design considerations on the shop floor generally and around surface mount machines particularly were treated seriously by the company's team of industrial engineers who introduced CM and TQM techniques.

Such changes, however, were rather difficult to justify under existing accounting convictions, as could be inferred from what the Operations Director once said:

> "The finance guys are there. They measure, measure, and measure, and tell what you've done wrong. That's it, to the point where they started telling me where I was going wrong. ..... Once you show them the measure - you know you should never give them a measure - because they come back and kick you with it ..... We call them the lancers ..... accountants, yeah, they are the guys that come out in the battlefield and stab the wind after the battle is over ..... they take a very classical approach to it - you know: return on capital investment, short term. They aren't looking at five, six [year] payback. They want payback within two years. In fact sometimes they want it within a year, which is very tight ....."

It is noteworthy that in senior management's experience, computerisation has affected users in a negative manner by making them more system-dependent, passive and subdued:

> "It has negatively affected people, culturally, because people are system-dependent: instead of people driving the system, the system is driving the people and that's bad. People stopped thinking for themselves and just said: 'this is silly, the machine says we must do it, we cannot reverse that!'. ..... I would feel happier if people were upset about what the machine

did, but because it happened so slowly, people have just gently shifted the position to a sort of dependence, not anger. I don't think they're even aware about it. They don't question it! "

Perhaps this could be described as a form of mental conditioning which users have been through as a result of working for the computer, rather than with it:

> "..... people just became less innovative. They aren't just driving the problems the way they used to do. We had people who were not exposed to computer systems and used to manual systems for production fixing. These same people now no longer did it in [i.e. with] the same vigour and they haven't noticed this specifically. It happened so gently. ..... They could change the paper system very easily but the mentality, that's come from the use of computer systems. Inflexibility has been carried across the people's minds. They became inflexible in all they do [i.e. did] ..... "

CAD and CAM systems in this case were introduced in order to improve flexibility of the business as a whole. Formal justifications singled this out as a major objective. It is ironic that while this has been achieved to a degree which is satisfactory to senior management at least and hence improved the company's performance in its external market environment, it has resulted in an unanticipated internal side effect. The work force's flexibility level in handling their respective jobs seems to have decreased considerably as their work tasks became more standardised, routinised, and repetitive in nature. It could not be said that management is entirely responsible for this situation. Technology vendors' pressures upon the company are partly responsible because they constrained management's ability to design technology in one way or another:

> "We do have rules that say when we buy software like *MAPPICS* we cannot change it, only use *IBM*-authorised changes, because if you start changing it yourself *IBM* won't maintain it and if you have problems with it, you're stuck and the whole company comes to a halt. So for good reasons we say: 'that is what you have to work on'."

Although CADCAM integration feasibility was taken into account when introducing *Visula*, admittedly it did not constitute an "essential component of the choice". A potential CAD-CAE link, however, was not contemplated in the early 1990s because "a need for it was not yet laid down".

The company has begun an effort to integrate CAD with the surface mount machines on the shop floor to "eliminate error and take out risks". The recent introduction of the modelling system is looked at as the CAE link between design and manufacture. The PCB design machines are 99% compatible with the surface placement assembly machines and have been made to interchange information electronically, although small adjustments still have to be made because the various equipment is manufactured by different suppliers who use different specifications. The use of interface standards would greatly facilitate full integration, but prohibitive cost and concerns about security and reliability issues still delay a decisive move forward in this direction.

* ***CASE STUDY FOUR: Company 4***

Company 4 is a Dunfermline-based subsidiary of a logistics systems division of a giant UK defence electronics group working closely with the Ministry of Defence and abiding by its standards. This 500-employee company is part of the group's logistics systems division[9].

The company is a supplier of customised automatic test equipment (ATE). Its role within the corporation is to provide solutions to testing problems encountered by aircraft and missile manufacturers seeking to test their products for functionality prior to dispatch. Tests are carried out on manufactured weapon and radio communication systems. The company's single product takes the form of a computer test program or, more often, a "turn-key" ATE "solution package". Such a product is unique in that it tends to be singularly tailored to the needs of a specific customer and, once produced, the same equipment may never have to be made again. An ATE also has a relatively long order-to-delivery lead-time; it typically takes the company between three to four years before delivery.

In 1993 Company 4 expanded as a result of a take-over by the holding company of another corporation. It now has a large design office in Edinburgh and an additional production facility in Glasgow[10]. This subsidiary is a model example of a relatively small company which is entangled in a huge nationwide bureaucratic organisation. Middle managers' unhappiness in these plants was expressed explicitly, for example, in terms of their directors' inability to "make decisions themselves" because "they will be looking South [i.e. the Corporation's headquarters] for direction".

The defence industry has not yet recovered from the recession of the early 1990s. A declining demand, due to so-called "peace dividend", has resulted in frequent downsizing with many redundancies since 1991. This situation raised serious issues concerning job security and mistrust between management and workers increased: "everybody is under stress, suffering from uncertainty". Such was the pressure on the company's Managing Director in 1992 that he had to issue a public statement to assure employees that "no further redundancies are budgeted". Yet, many people in the

[9]The group's organisation comprises several divisional units, each of which specialises in supplying a specific range of high-tech electronic products to the defence industry.

[10]The take-over seems to have resulted in "three different cultures" to be found simultaneously within the company with each of the three Scottish sites appearing to have its own distinguished culture.

company find themselves "inclined to shut up and close their mouths and not to criticise management"[11].

Nonetheless, the company's orientation towards defence has been subject to reconsideration since the early 1990s. Strategic rethinking over the last five years has focused on commercialising some of the company's facilities to supply civilian markets. The first radical change in this direction came in 1995 as the company won the first contract with a US leisure aircraft manufacturer.

Following the take-over, the company inherited a huge design facility in Edinburgh. The office, which is run by a manager who has worked in it for the last 28 years, provides essential drawing services. The bulk of creative engineering work, however, is carried out on the main site in Dunfermline and comprises mechanical and electronic hardware and software design.

Like Company 3, this is essentially a design-and-assembly enterprise. About 50% of the work force are classified in the company as designers. Most of the components used in final assembly are purchased rather than made in-house. Some assembly work is carried out in other factories belonging to the corporation.

Engineers start on a new project by designing specifications for their customers who often have insufficient time or expertise to do so themselves. This is done on the basis of a vague customer's description of a testing application request.

Up until 1995 an outdated, 18-work station CAD system was housed in the drawing office facility from where drawings were produced and sent to Dunfermline. It was useful because it stored some of the old designs which were still in demand until then. The acquired firm was resourceful enough to develop this huge CAD system independently. It was among the first movers towards CAD in the early 1970's. However, in 1995 the system was scrapped and a new one introduced in its place.

CAD and CAE are strictly separate functions in this company. A CAE system is placed in the main site in Dunfermline and managed by a different person. It is used for electronic hardware and PCB design of product components.

A CASE (Computer-Aided Software Engineering) system is in application only in this company. It is used in the design and development of product software since this forms

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[11]Passive collective resistance to management plans, which resulted from the "big gulf" between management and employees, found expression in the refusal of many shop floor workers to collaborate in implementing a £3m TQM program which later came to be regarded as a failure by management themselves.

a critical part of the company's product. Traditionally, hardware design used to form about 70% of the total engineering work. However, software technology has gained ground at the expense of the hardware development work. This shift has been in CASE's favour since the ratio has now reached around 50-50. As a result, more hardware engineers are now being retrained to become software engineers.

The first major investments in computer technology, other than in the administrative area, were in CAD and CAM. The company, however, transferred its CAM facility to the Edinburgh plant due to reorganisation at the corporate level. Therefore, dimensional, test, and drawing data are communicated bilaterally between the Edinburgh and Dunfermline sites.

To begin with, a simple CAD system was introduced in 1987 into the drawing office for mechanical drafting as the company was under "a bit of pressure to go for CAD" from within the group. The introduction of CAE system followed in 1990.

Formal objectives of each investment were identified in terms of satisfying business demand, improving product quality and reducing design cycles which have dropped from 42 to 15 months on average between 1991 and 1995. As confirmed by management, such objectives have been subject to change because of a rapidly changing technology market:

> ".... it's the market that is in its infancy, really, it's an evolving thing. The CAE tools, CAD tools were here five years ago, but it's evolving and tools that we have now are quite old and outdated compared to the tools that you can buy now ..... "

With a rapidly changing technology market, leading technical managers have learned from their past experiences of technological change, particularly in this bureaucratically organised enterprise where formal justification procedures have persistently constrained their ambitions:

> "Certainly my [the Business Computer Systems Manager's] perception has changed of what these tools need to do and can do. It's become more complex, it's become more universal, if you like. These tools used to be point solutions - you know - if you needed to draw a circuit or a diagram or you needed to design a printed circuit board or something like that, then you bought up tools to do that. But the tools now are quite different. Tools now are top-down system design ..... "

The introduction of CAD was not "a big issue" in the organisation, unlike CAE which found "a certain reluctance and it was a cultural change". The two main technical managers admitted they had to struggle "to change the culture of the work force" in the process and that the task of changing users' attitudes was both difficult and messy.

In the light of this situation, it was not surprising that the Training Manager admitted that there was a lack of education concerning the newly introduced technology on the part of management:

> "I should say that in the drawing office you should spend money on education, not training, but education to tell people what this meant to them in the long term, but we didn't. We let them find out! That caused a few problems ..... "

The strategic thinking behind the integration process in this case was best summarised by what a high-ranking pro-integration manager said once in an interview in 1992:

> "[The] objective for me is to get away from point solutions. All of these tools are point solutions: the CAE tool is there to draw a circuit diagram, a CAD tool is to draw a mechanical diagram, a simulator is to simulate an object. So all are solutions to point problems and I want to put solutions that are universal solutions .... You still have point solutions. They are still tools that you need, but there's an overlying structure that sits on top of that that allows open systems, if you like, free access of data, open to every one. So the guy on the shop floor or the guy in the storage can access the information directly from this design information."

In spite of all the technical, financial and political difficulties encountered in this company, it remains to be a distinguished case in the study as far as the issue of integration strategy and implementation is concerned. The dynamics of the integration process in this case deserves to be singled out and analysed further with a particular emphasis on the forces acting for and those acting against change, both from within and outside the organisation, whose lively interaction gives the case its distinctiveness.

The integration process as experienced in this company will be discussed in greater detail in Chapter 7 (section 7.4). A conceptual model will be used to illustrate Company 4's experience in contrast with that of Company 10 which adopts a non-integrating strategy. The emphasis will be on the social processes that are involved in the dynamics of the strategy process in both companies, the internal and external factors that influence a company's decision regarding whether to integrate or not to integrate, and on the factors that influence an on-going integration process, both positively and negatively.

* _CASE STUDY FIVE: Company 5_

Company 5 is a wholly-owned subsidiary of a large multinational manufacturer of computerised cash machines[12]. The company was set up in 1946 on its current Dundee

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[12] This bureaucratic corporation was set up about 115 years ago in the USA and has since been in business. It used to be the world's leader in its respective market but lost that advantage to *IBM* which took over another firm to form a more powerful corporation. In 1993 the corporation attempted to strengthen its position through a merger with *AT&T* (the US equivalent to BT in Britain). The corporation is organised in terms of autonomous subsidiary companies, each of which contains both design and manufacturing activities "under the same roof" and tends to supply a complete range of products to worldwide markets.

site with 7,000 employees to design and manufacture teller and interactive self-service cash machines for the financial market. However, it suffered a series of contractions in its work force due to a persistent decrease in demand.

With 1,400 employees at present, Company 5 is the largest of the ten companies in the study and is managed by a six-member Board of Directors, presided over by a Managing Director who reports directly to the corporation's Ohio-based headquarters.

Company 5 is the sole exporter of its brand product to export markets throughout the world[13]; it always "wants to be first in [the] industry to use technology and to reduce design-to-market time". Nationally, the company dominates 65-70% of the UK market. This equals 25-30% of its total output.

The size of the engineering team in this case reflects a massive volume of work on the mechanical, electrical, electronic, and assembly aspects of product design and development. Such is the size that the engineering function is represented at the company's Board by two Directors[14] who are both supported by a devoted engineering services department consisting of 26 highly skilled technologists in charge of a diverse range of support activities.

The company's production activities have changed significantly since it was established in 1946. Then, it used to design and make all component parts independently, whereas now its policy is to buy as many components and sub-assemblies as possible and to make only the essential parts in-house. This is motivated by a desire to focus on the company's core manufacturing activities for the main parts of its products with a view to strengthening its core technical skill base.

Monthly demand forecasts are sent to the company simultaneously by the corporation's regional marketing organisations in North America, Latin America, Europe, and the Pacific. Production planning staff then work out forecasts for units to be produced and quote standard lead-times. Production schedules are adjusted accordingly, subject to the annual financial plan concerned.

Bare PCBs are supplied regularly by a major Scotland-based vendor. About 75% of the boards are populated in-house using automatic insertion machines. Assembly operations follow in the light of information received from design.

[13]Japan is the only exclusion in the company's export market because it has "its own totally unique specifications".

[14]A Mechanical & Electronics Design Director and a Software Design Director.

Direct workers constitute only 600 people while the 800 others are classified as white-collar support employees and are divided equally between engineering and manufacturing. The company's batch production set-up yields on average 80 to 90 units per day. As in Cases 2 and 3, most of the direct workers are involved in assembly lines.

The CAD system in this case is the largest and most complex in the study. It consists of 35 *VAX* work stations arranged via a local area network (LAN) among five separate but co-ordinated departments: (1) mechanical CAD, (2) electronic CAD, (3) assembly design CAD, and (4) technical publications. Modelling and engineering analysis form an essential part of the engineering function's operations in this case. They are carried out on specifically-designated CAD work stations but using specialist software.

CAD software, *DDM*, was developed in-house. The company's top engineering team is planning to scrap the existing CAD system and introduce a new one that is especially designed for integration with CAE and CAM.

A simple CAD software was initially introduced in 1984 with six work stations which were increased to ten the following year as more engineers were converted to become CAD users. At present 25 work stations are in use: "There was resistance from the users who [had] never before used CAD, but there was a learning curve and they got on with it".

DDM was not selected for introduction into this company but it was imposed on it by its holding corporation. In response to a question on what system assessment process preceded implementation, the Principal CAD Support Engineer replied:

> "There wasn't one. We had to use *DDM* because it was used in the US plants and we had no choice but to introduce *DDM* because it's compatible with the corporate choice, so that our system can talk to theirs and vice versa."

Work around CAD was organised by setting up four groups: (1) CAD users group: (2) system administration group, (3) hardware and software support group, and (4) CAD development group.

The last of these groups consists of three senior professional engineers and three other union-oriented engineers. Three unions are active, one of which represents managers and professional groups. In this case they are noticeably influential. Hence, they had to be invited to participate in planning for CAD and CAM before their introduction and are currently represented by three of their active members in the new CAD development project. This formal group has reflected a definite political significance since its formation in 1985. It serves to release some of the pressure management has been under since it hired two experts for the task. Union activists argued that two people should not be left to make decisions on behalf of 60 users and insisted that the unions should be involved.

The Principal CAD Support Engineer has been in close contact with some senior managers in his capacity as the leader of the users' group. His job seems to have forced him to work under some computer illiterate managers, a relationship which he finds stressful:

> "Some departments are very political. .... Management has grown up a little bit astray, for management to keep track of what CAD users are doing ..... It would make life a little bit easier if they were at the same level. That's what I find in all the experience I've had. It's very difficult for the design engineers to put one over on me because I know the system .... and I know the design side of knowledge as well ..... The gap between management and technical staff widens ..... "

Management were also criticised for the lack of attention they gave to proper training for CAD:

> "To them [i.e. the users] CAD was a wilderness. Just to install the system and put them on a two-week course and say: 'come on, lads, get on with it!', which, on reflection, is a very irresponsible thing ...."

The company has also invested heavily in a new surface mount facility in order to be able to "populate" PCBs in-house instead of subcontracting this aspect of the business. CNC is another main part of the CAM facility which could potentially be interfaced with CAD. MRP was developed by the mother organisation and has been in application in Dundee since 1976. It has been subject to frequent upgrading operations.

In this case another "mental conditioning" phenomenon similar to that reported in Case 3 was experienced by senior management. It concerned a negative man-machine effect of computer system work environments on individuals' psychology:

> "What's really happened is that, systemwise, the people [who?] looked at the system and if it told to them to do something, effectively they will do it. Originally, they used to question, question, question. They tend not to question. They tend to say: 'If the system says I need x, I need x'. So they work to the system .... I don't know! "

A two-year program is planned in this case for a piecemeal integration process. It is named the "Computer-Integrated Business (CIB) program". Its aim is to "improve communications between all those people who are interested in the process of product development".

In the integration philosophy that dominates engineers' attitude in this case, CAD should be justified in terms of its "downstream" benefits to a manufacturing enterprise as a whole:

> "People tend to justify CAD systems on how quickly they could produce drawings, but you don't want to produce drawings really - you want to produce information that could be used by other people. ..... The biggest single gain we've had has to be on the manufacturing side. We're taking the information the designers have created on the system to use for part information processing .... What used to take weeks we do now in a matter of hours. That's our biggest gain. .... CAD was a success if you look at it from a manufacturing point of view, a big success. On the engineering side, yes but not as much as one [had] perceived ..... "

Senior management seem to have learned a lesson from their failure in the past to recognise the need for combining the design of a new technology simultaneously with the design of a suitable work organisation around it. They seem to be determined to avoid this in their CIB endeavour. From their perspective, achieving an optimum utilisation of technology is no longer the driving objective of change. They now realise the cost of neglecting to balance efficiency with organisational conversion:

> ".... the pitfall of that: you can lose the overall vision and the optimum use of resources. And also you may find that a particular Development Manager doesn't improve his process. .... he can be used to having done things in a way which I haven't done before. So you lose the appetite for change and you don't have anybody outside to say: 'Oh, do you know actually you can use this or you can use that or you can do that'."

Implications for the whole organisation are incorporated into the new CIB vision and have been felt already among employees:

> ".... one of the things is that people [need] to take a wider perspective of the job they do ..... They've got responsibilities other than the production of a drawing or whatsoever. People need to be aware. OK, they might have to do a bit of extra work. However, by doing that extra work somebody else will get paid back many folds. I think once you go to multi-functional things then people will see the wider implications of what they do ..... "

The launching of a new CAD system in the near future will probably constitute a significant milestone in the development of the company's CIB project which is led by the Engineering Design Services Manager who happens to be the leader of the radical integrationist current in this organisation. He once criticised his opponents by saying: "Conservatism, traditionalism! The thing is - you see - .... [their attitude is] 'We made the last product this way, what do we have to change for?'". It would be likely that CADCAM integration would be given a considerable boost in the next five years since the new system is being designed so as to incorporate CADCAM integration principles.

5.3 The Secondary Cases

In contrast with the previous section, this section focuses on the lack of integration as found in the five secondary cases (Company 6 to Company 10). It covers a case-by-case presentation of the relevant findings relating to the historical and current aspects of the stand alone CAD and CAM systems and the organisational issues associated with them. This will facilitate a subsequent comparison between the key features of the integrating and non-integrating approaches (section 5.4).

* *CASE STUDY SIX: COMPANY 6*

Company 6 is a family-owned manufacturer of electrodes and electrochemical sensors[15]. It was established in 1973 in Auchtermuchty, a small village in Fife. This is the smallest organisation in the study with a total of 35 people. The company's products are marketed worldwide through a London-based sales office.

Despite its relatively small size and remote physical location, this company is remarkably strong from a marketing performance point of view[16].

In August 1991 the company was taken over by an American firm after 18 years of independent existence. The owners of the business decided that a take-over of the company would provide it with better conditions in terms of stability, support, and competitiveness in a global market dominated by giants.

Subsequently, the holding company itself was acquired by another US firm in 1996 for similar reasons. So, this was the second take-over experience from the point of view of Company 6 within a period of five years.

The company's organisation is distinguished for its flexible structure and relaxed working atmosphere[17]. Governance of the company is the responsibility of a Managing Director who represents the proprietary family, a Technical Director, and a Secretary. The work force consists of 20 people, 16 of whom are highly skilled female workers, unlike in Cases 2, 3 and 5.

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[15]Sensors are used in a wide range of industrial and research applications and are manufactured both to standard and to customised specifications. Laboratory ancillaries used in association with electrodes for chemical analysis purposes are also marketed by the company. Products are supplied to customers in the laboratory, water, pharmaceutical, power generation and industrial market sectors.

[16]For instance, in 1991 it was the recipient of a special award for marketing presented by *ScotBIC*, the *Scottish Business-in-the-Community* institute. Upon nomination by the *North East Fife Enterprise Trust*, the company won the award in the face of competition from 67 entrants.

[17]The advantages of a small-sized organisation on the Auchtermuchty site include job rotation among shop floor workers to overcome boredom and the lowest level of division of labour at all levels of responsibility. The Technical Director best described his company as being a small organisation enjoying a:

> "... high level of communications .... so it allows things to be done quickly. This hopefully means higher efficiency. ..... We don't say: 'you're design, you're design', and that's part of the company culture. ... it is team work .... but there is a lot of individuality as well."

A typical electrode consists of a hollow pH selective glass tube filled with a specific chemical, depending on application, and a compact measurement instrumentation. Glass parts are made in-house whereas instrumentation components are purchased and assembled.

Manufacturing takes place in a clean environment using conventional mouth blowing techniques. Solutions are filled for internal and external cells to achieve equilibrium. Production batch sizes vary considerably from one-offs to 500 units. On average, orders take three days to delivery.

The design process in this company is fairly static. It induces minimal creativity. Most of what are called new product designs tend to be a variation of an existing design. CAD in this case is used essentially as a tool for manipulating stored design information by the only qualified design engineer who is also the only user.

Design work is largely unstructured, unlike manufacture which is increasingly being structured and standardised following the second take-over. Some reorganisation of the manufacturing function was necessary before the company could be granted British and international quality standards[18].

The company uses mainly *AutoCAD* software on a single workstation for 2D mechanical and electronic drafting purposes. A CAT system is also used on the shop floor for quality assurance purposes.

Selecting, implementing and using a CAD system was delegated completely to the only Design Engineer in the company. The objective was to "produce good quality drawings which are easy to maintain and can be reproduced fairly easily".

The introduction of CAD in this case was a "low-key" issue and concerned virtually a single individual. The CAD experience in this case is closely associated with him, rather than with the company as a whole. How the system has been utilised is, therefore, highly dependent on his personal perceptions, skills, attitudes, and enthusiasm. Indeed, the Senior Design Engineer uses it in his drawing work and perceives it to be almost his personal property in a small company which lacks a design department of any size.

[18]These are BS 5750 and IS 9002. Management had no choice but to reorganise the manufacturing function in order to conform to such standards which are highly valued in industry, not least from a public relations point of view.

The system appears to be under-utilised in this case. Had it been a larger company it could have been used more productively perhaps:

> "Realistically, the time it takes to assess different softwares is significant ..... it wouldn't be cost-effective to, in terms of the resources that we actually have. It's very tempting to try out softwares but you actually don't need the best; you need something that works ..... "

Whether a single-user's pursuit of CAD utilisation falls short of what may be regarded as reasonable or he manages to drive the technology successfully in line with the objectives of the business, the company's entire experience of CAD will be affected. It is evident that this situation constitutes a high degree of dependency on an individual manager who is authorised by the organisation to act on its behalf. This means that the outcome of introducing this technology in this case is subject, to a large extent, on this actor's steering of the project.

This situation raised the question of whether there could be an organisationally-defined set of CAD objectives in this case. If such a concept existed, would it be present in this user's mind? If the answer was yes, how was it perceived by him? Such questions were asked progressively and their answers received during the course of the field work. In conclusion, it appeared that unless something went catastrophically wrong in the implementation process, which would appear highly unlikely in the case of a £5000 CAD investment, then there was little incentive for the proprietary family to follow up what this person was doing on its behalf as long as they trusted his technical competence and moral conduct.

At a personal level, the Design Engineer's singular role with CAD has placed him in a position of critical responsibility in the organisation:

> "If you have a computer system with a lot of data on it you automatically get problems: what happens if the computer doesn't work one day and you become stuck? .... So what are you gonna do if the system fails? ..... "

From a job design point of view, his unique expertise in this area seems to have caused him a quantitative job overload. To him, this means he has to maximise his "discipline" to insure security, ease of retrieval and a continuous backing up of CAD-produced information. He is also conscious that he may soon become unable to cope with an increased workload if extra CAD users are hired:

> "I have to get things pushed up to me because I know about them. I mean what could happen, and it, it hasn't happened yet, is that everybody could come to me with a drawing and want an explanation in a computer form. It could be, and I'll have to be aware of that and refuse it .... "

Therefore, he believes the company should train more people to supervise the system for him. According to him, ownership of the system should also be encouraged so that perspective users could be competent and confident enough to deal with their drawings independently.

It should be noted that CAD is much less vital to Company 6 than it is to the other nine companies in the study. According to the Design Engineer, the company had an "overrated" emphasis on CAD; it could even continue doing business without it if complex electronics designs were to be subcontracted.

On the manufacturing side, a major project to mechanise mouth glass-blowing operations on the shop floor was launched in the mid 1980s. It failed:

> "We did have anther project which failed quite a while ago. It was involved in, instead of blowing glass, to get reproducible glass. We actually got to one of the universities, I think it was *Dundee*, to looking and actually trying to blow glass mechanically. Now what we found was a lot of problems in weight and weight errors .... and, eventually .... it sort of didn't work and we threw that out and decided to get into the testing end of the equipment ..... "

The company computerised its testing function in 1989. The project aimed to measure Hydrogen ions in electrodes and to monitor finished sensors' functionality. The results of this CAT system were so encouraging that the company decided to expand by introducing new features into the system six months after installation. It boosted morale and renewed confidence in technological change after the failure of the earlier project.

Integration in this case is particularly difficult because the design-manufacture link is organised such that there is "very little functional overlap". Hence, the amount of information that could be usefully shared between the two functions is limited. Therefore, isolationist attitudes have been adopted by managers under these conditions:

> "I don't have any ownership of the kinds of products that are tested on the automatic testing equipment. .... I don't have any real feel for, I mean, how they are testing it out. .... I don't know how it [the quality testing function] relates to design ..... "

If one takes the usefulness of CADCAM integration for granted, it seems that the future of integration in this case will be rather bleak without radical structural changes in the manner in which the two functions are organised, particularly if such pessimism continues: "I feel we have a less than even chance of getting significant integration in the foreseeable future".

The Design Engineer himself admitted that he did not have any experience in this area. Rightly, he also expressed doubt about its relevance to a company with a single CAD user:

> "I don't have any experience with CADCAM. I mean I only see it working in exhibitions. I have my doubts .... - and maybe this is just being conservative .... about really whether it is possible or desirable to really have it as a completely overflowing system. ..... I have my doubts ... about global, more encompassing integration because I think there can be horrendous problems of implementation."

Small size is the central feature of Company 6 and progress on the integration process depends, to a great extent, on its ability to expand to such an extent that the potential technical or business benefits of integration become comprehensible.

> "With our existing level of staffing I don't foresee that we can attain a reasonable level of staffing [for integration]. What we have to do is to employ more staff and get them familiar with [the] work."

* *CASE STUDY SEVEN: Company 7*

Slightly larger than Company 6, this is another small family business employing 50 people. However, this remains to be an independent, single-site company situated in a purpose-built building in a modern industrial estate in Dunfermline, Fife.

The company was set up in 1947 by the present MD's father to supply coal scales to the then active mining industry which constituted a major component of the local economy. Its traditional strength has always been in supplying industrial platform scales and weighbridges used for weighing loaded heavy vehicles and fork lift trucks weighing up to nine tonnes. Weighbridges are still exported to developing countries in Africa and the Middle and Far East.

The company has moved towards light weight household scales in order to compensate for a declining demand from the coal mining industry. The present product range covers a variety of electromechanical and electronic weighing equipment such as bench, shop, bathroom and kitchen scales. Most of these products are marketed in the UK.

Organisationally, the senior management team consists of a Managing Director and his wife, who both represent the proprietary family, and a third non-relative senior executive. A management team is responsible before this Board for finance, sales and marketing, customer services, and administration.

Only 16% of the total work force can be classified as direct workers with a total of eight workers: six males working on metal fabrication operations to make heavy weighbridges and two females performing assembly operations in a clean room environment.

Company 7's engineering team consists of four designers: one electronics, two mechanical, and one structural who are supervised by a more senior Design Manager. This group is likely to expand soon as the company is seeking to recruit one or two other graduate engineers.

Weighbridge orders are usually one-offs, but sometimes could be up to six units. Industrial platform scales are normally ordered in batches of six units. Management's strategic direction appears to be moving towards smaller household goods as an area for targeted market expansion: "we are certainly heading towards that direction".

Production of industrial platform scales and weighbridges involves metal fabrication techniques including welding large ferrous components to create bridge structures. Heavy steel contents of weighbridges are purchased on a JIT basis for assembly to avoid costly stock accumulation.

The shop floor is divided into two main areas: manufacturing and spraying. After sub-assembly a bridge gets transported to the painting area for spraying. Final assembly then takes place by incorporating an electromechanical scale into the manufactured machine. Assembly operations constitute a significant part of the production activities.

PCBs are used in the assembly of the electronic components of weighing equipment. Their layouts are designed in-house but their manufacture subcontracted. On arrival from a supplier, bare boards get populated in-house and then assembled into finished pieces of equipment. Outer casings of finished indoor and household equipment are also designed but their extruded aluminium casting components subcontracted.

Like Company 6, this company's CAD system comprises a simple *AutoCAD* software and two PC-based work stations for mechanical drafting. For PCB design a *Racal* software is used on a single work station.

The Technical Director is responsible for technology investments in the company. However, the Design Manager has been more instrumental in the introduction and management of CAD specifically. He is more informed about CAD because he has been in charge of the system since the purchasing decision was made. He has worked for this company for the last 13 years and was the first graduate design engineer to be appointed during the early 1980s.

In this company, as in the case of Company 6, implementation could be described as a process that terminated after the system was installed and made operational. The Technical Director was "the leader at that time [i.e. prior to installation]", but now, as the Design Manager put it: "well, it is not so much a project now, just running it now, which I do".

The CAD story in this company began in 1989. There were only two engineers then, who both:

> ".... saw the benefit of it and then [naming a fellow engineer] came along and he had already used CAD at the University. ..... We went to a couple of demonstrations, but I think *AutoCAD* was so far ahead than [i.e. of] anything else ..... "

The Technical Director's personal role in authorising the selection of *AutoCAD* was influential because he was the one in a specifically-formed team of three (which was assigned the task of system evaluation), who could "sign the cheque" in the end. The team's decision to purchase a system of its choice was taken almost instantly. No formal justification procedure was required.

From the team's view point, a major advantage in selecting a popular, user-friendly software such as *AutoCAD* was the abundance of training programmes associated with it. These are normally offered by software suppliers as well as at local colleges. So popular is *AutoCAD* that it has become synonymous with CAD to many people.

In this case training on the system was offered at an extra cost by the supplier. However, the team members found the system so easy to use that they thought they only needed to supplement their enthusiasm for personal learning with evening classes.

CAD's objectives in this case included improving efficiency, presentability of drawings and documents, increasing control over document management, and improving security. In the experience of users, CAD has provided a greater flexibility in modification and redesign work. It turned out that CAD enabled designers to design PCBs themselves. They used to rely on an independent external consultant for this purpose before. This was an unanticipated advantage of CAD. CAD also helped improve the exchange of information with vendors and subcontractors who happened to be *AutoCAD* users. Improved publicity was another unforeseen benefit of CAD. With the passage of time its value to the company seems to have become clearer:

> "We gained a lot of potential customers .... by showing them around. Yes, publicity and it looks good [i.e. better] for the design department and the Board to use such equipment than if you get an old man [sitting] in the corner using a slide ruler, you think immediately that the company is a bit antiquated!"

In the design department the two *AutoCAD* work stations are shared by three mechanical engineers. Flexible access to the work stations should be available to users whenever a need arises, "apart from fights breaking out to get onto them!".

As in the case of Company 6, the introduction of a simple CAD system increased the efficiency of drafting. It hardly affected work organisation to any significant degree:

> "It [i.e. CAD] didn't change anything really. It was just a tool to help us in drafting. Like before, we just treated CAD like using a calculator instead of a slide ruler!"

However, further increases in efficiency could not be easily achieved because of the constraints of being a small company with limited resources.

Company 7 has relatively low computerisation priorities. The Design Manager insisted that there was "no need to invest in new technology other than CAD". The company follows a pragmatic philosophy in dealing with new technology in general. Ironically, the key individual person behind computerisation in general and CAD specifically stated:

> "... what we tend to do is we do every thing manually until there comes a point where you're screaming to get somebody else to help you and then, if you weigh up the cost you think: 'yes, it's cheaper if we get this guy a software package and a PC', and then it develops from there .... until there is another crisis, yeah!"

Computer applications are perceived to be "electronic solutions" to problems that may arise any time. In this sense computerisation is a reactive, rather than, proactive action. No prior planning precedes it. It could be argued that many of such problems would occur as a result of insufficient planning and control in the first place. It is evident that the companies in Cases 6 and 7 regard the issue of CADCAM integration as both irrelevant and inapplicable to their organisational settings.

* *CASE STUDY EIGHT: Company 8*

Company 8 is a Dunfermline-based subsidiary of a UK defence electronics corporation. It was established in 1975 to supply PCBs to the telecommunications, data communications, and aerospace control divisions of the corporation. A strictly Fordist style mass production line was set up to supply the defence market during the cold war era[19].

Since the early 1990s, nonetheless, the company suffered "horrific" effects of the recession as well as a general decline of the defence market worldwide. The results mounted to a 50% drop in demand in 1990 alone. In the summer of 1992 a senior Production Engineer commented that the company did not "have much future left in this industry". Indeed, since the beginning of the 1990s the company had been "fast looking for commercial applications for electronics". Eventually, it ceased to exist in 1994 in view of the considerable decline in the international arms race following the end of the cold war era: "it would have needed a much more lucrative market to survive". Factory equipment was sold "secondhand" to another company. The work force had been downsized repeatedly before the closure but some of the remaining 47 employees were offered alternative jobs within the corporation.

Company 8 was a manufacturing-led business with a minimum of original design work carried out in-house. Design information was mainly received from other sites via a

[19] It dominated about 30% of the British market at that time.

modem on films, magnetic discs or tapes. Extended product life cycles meant that some of the older designs could have had up to 25 years in service. Design information had first to be checked against design rule parameters and prepared in a format suitable for the machines on the shop floor.

Manufacturing began with the preparation of the appropriate phototools, CNC control profiling and machine tapes for a given production cycle. Multi-layer PCBs were made with operations including hole drilling, surface preparation, electric photoplating, chemical washing up, and electrical testing of finished boards.

The major technology emphasis in this company was on CAM, rather than CAD[20]. Three work stations of a *Computervision* graphics manipulation system were in use with a *Scietex 280* software for phototool production from magnetic tape design information. An *IBM* modem was used to transfer floppy disk input into and from a laser scanner plotter. Historically, CAD was introduced in 1980 into the Corporation and CAM in 1984:

> "…. it came to a point where it was the case that one must invest very, very heavily or close down …. it was a matter of survival, because technology outside has changed dramatically. The requirements of design have changed closely, closely enough and we would have to maintain the requirements of our customers."

A distinguishing feature of the company was the fact that it was the first PCB manufacturer in Britain to utilise CAM technology in its industry. It was an innovative experience in an industry where CAM applications did not yet exist in the early 1980s. In this case the company sought to customise a technology that was developed originally for use in the textile industry. The purpose of this initiative was to help improve productivity and quality of pre-production engineering activities[21].

The role of the company's founder came up strongly in this case, particularly with regard to his organisation's learning innovation experience. One of his contemporaries summarised an innovation story full of initiative and adventure:

> "My previous boss, he had read an article about the newspaper industry …. and there was a company in the States who made that particular type of machine. ….. My pervious boss asked them if it was possible to apply the technology that they were using in that field to make artwork for printed circuit boards and they said: 'Yeah, we don't see why not, although we haven't done that. Give us a year and we'll come back to you'. They had come back to us in about a year. They had developed a machine: …. 'if you like we can send test tapes over now'. ….. Then started the problems! We weren't computer-generating anything we needed. How to transfer information to their machine? What format of information? What language do they

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[20]The company also used a CAPP system based on a single work station to produce process routes for tool manufacture on the basis of CAD information. This involved phototool manufacture, CNC control profiling, and machine tapes.

[21]In the context of manufacturing industry's culture, this is known as the "front end" function.

> require it in? All these questions had to be answered and we didn't know where we were! We didn't know the questions to answer, never mind what the answers were!"

That was the first outstanding innovation attempt. It was deemed a failure. The innovator then went on for a second attempt after an extensive literature research. This time he approached *Scietex*, a European-based vendor of CAM technology to the textile industry :

> "We went down the line for about six months investigating whether they could do what we wanted done and at that time they had a resolution of a thou. Then *Scietex* came along and they guaranteed a 1/2 thou ... which is twice as accurate. We sent a test tape for *Scietex*. They copied it and we got it right first time."

A formal "capital application" report justifying the introduction of the system had to be compiled as a matter of routine. It outlined the advantages of using CAM in artwork generation and explained the commercial implications of such advantages.

According to senior management's own estimation, such objectives had been met to a reasonably satisfactory level up to the end of the 1980s. CAM had assisted the company in this respect by improving quality, productivity and consistency due to a "much less operator variance on the product".

The introduction of new technology had often been associated with job redundancies in this case. For example, the introduction of CAM caused many skilled workers to leave the company in protest or get redeployed elsewhere within the corporation. Older people were more affected as they refused to change their traditional work methods. On the other hand, three new employees were selected and recruited for CAM work from a youth training centre attached to the corporation.

Trade unions' reaction was one of fear that technology would jeopardise workers' jobs but management accused them of inability to assess complex skill requirements for operating, supervising and managing a new technology due to their lack of knowledge. Nonetheless, many workers were laid off between 1990 and 1993 and those who survived were understandably worried about their future and blamed the Government: "It is unbelievable; I mean I don't think the Government has replaced anything that was used during the Gulf war".

Industrial relations deteriorated further as management insisted on increasing the pressure on workers to make them improve their performance with the technology. CAM users united behind their leader, the Senior Production Engineer, and insisted on involving the supplier in this apparently internal conflict in order to prove to management that they were competent enough to "understand and tell management what the real operational requirements of the system really were". This move proved to be a success from CAM users' point of view in that it gave management a measurable proof of the union's claims that the information which was available to management lacked accuracy in the first place.

Ironically, the company had to regret its innovation on CAM since it was left with an outdated system at a time when its critical financial position would not permit upgrading the system or purchasing a new one in place of it. As CAM became much more established in the PCB industry, many competitors introduced industry-customised systems which became more available at increasingly competitive prices. Such systems performed the same operations *Scietex* performed but "20, 40 , 60 times faster".

An organisational context for integration was encouraged in this case as CAM forced a closer link between design and manufacturing:

> "I've got a closer relationship with a much wider band of management personnel ..... What [do] I mean by that? Well, I didn't have an awful lot of contact with the design office managers prior to the CAM system coming in. I had to liaise much more closely with the design office managers to understand their CAD output and for them to understand my CAM input ..... "

Integration was an important priority of the company during the 1980s. An ideal CIM system was considered but had become suddenly less significant with the start of the 1990s as the question of survival in the market place began to dominate:

> "[Naming the corporation] a long time back had a blue sky vision they could link the whole PCB factory and serve it from the front end system. They will download all the intelligence required from the CAD system to the CAM system that will drive all the machines for the plotters, bare board testers and anything else that could be controlled from a computer. ..... We've been talking about it since [i.e. for] ten years now. .... Things are moving forward in that field but very, very slowly and because at the moment there is recession, recession tends to slow up research and development because there is not enough money to spend for new equipment, and because not enough new equipment are [i.e. is] getting sold there is [i.e. are] less people pushing for more interfaces ..... "

Technically feasible integration areas included networking CAD with the *Scietex* system, the drilling machines, and the CAT system. However, that was no more than an ambition which appeared to confuse some senior managers:

> "We haven't got that and we are a long way away from it. ... It is a plan that we are considering but our growth is not such that will support that plan. So, we need a lot more business before we can contemplate the project ..... The only problem is that perhaps we need to do it to get growth. It is that crossroads in a sense: that we will not get any more money invested until we get more profit, but perhaps we won't make more profit until we get more money invested!"

Organisational problems that confronted integration efforts in this company would be perhaps characteristic of subsidiaries of larger organisations with strict bureaucratic budgetary controls. For example, when a question was asked about why the conceived CIM vision had not been implemented to any significant degree, the answer was:

> "Well, who is going to pay for it? Out of which department's budget is it going to be financed? ..... You know, Directors are people just like you and I. They have limited budgets."

Such a situation manifested itself clearly in prevalent budgetary control practices that reinforced departmental independence at the expense of the notion of an integrated corporate personality:

> "Companies don't spend enough money for integration proper. I know what I'm talking about inside this building, I have no concept what the Design Engineer wants over in the other building .... but he doesn't have any concept of what I have to go through to produce what he wants either ..... ["So maybe you recognise the need surely for a closer integration?"]. Well, we try but, within the company, that's very difficult because we each, individually, have budgets to control what we do. Once he's designed that board and it's left the design office, his budget that's it, closed .... he's done his bit. ..... That's where integration falls apart even in this size of a company which is not terribly big in world terms."

In 1994, nevertheless, attempts to integrate CAD and CAM systems terminated with the closure of the company.

* <u>*CASE STUDY NINE: Company 9*</u>

Company 9 was set up in Glenrothes, Fife, in the late 1970s to design and manufacture computer hardware parts. Up till 1992 it had been a subsidiary of a UK public corporation with operations in Britain, the USA and Singapore.

This company, like Company 8, suffered a period of uncertainty due to a major change during the summer of 1991. The company ceased to trade in 1992 due to bankruptcy. In this case, however, the company's creditors appointed an accounting firm to receive it. Through a receivership agreement the receivers had either to sell off the business as a "going concern" or resort to liquidation.

It turned out that the appointed receivers decided to retain some of the assets and sell the design function's capacity to a foreign company. Therefore, Company 9 became from that point in time a "new start-up" organisation. Its ownership transferred to a Singapore-registered 200-employee company which bought both the Glenrothes and the Singapore sites, but the Florida site is "completely gone". Major reorganisation of the company therefore became necessary[22].

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[22] During the course of the field work it emerged that the progress of this organisational change was significant in terms of its implications for the subject matter of this study.

Prior to 1992 the company's markets used to be mainly US-based. Marketing orientations, however, changed towards the Far East because of the company's new Singaporean nationality and its strong business connections in that part of the World.

Indeed, receivership caused many of the resources of the company to become redundant. Prior to 1992 the Glenrothes site was organised in terms of three separate sub-units with a total of 165 employees, of whom 43 were qualified engineers. The number of employees reduced dramatically to just 15 after 1992, including nine engineers, five administrative personnel, and a Managing Director who used to be responsible for a specialist product design quality assurance function.

Mechanical design is carried out completely in Glenrothes whereas PCB artwork is mostly subcontracted. On average, a product design cycle in this company takes about a year. The first step in a typical design cycle involves receiving information from sales and marketing before general product specifications could be determined. Design engineers begin by reviewing such specifications to prepare a cost estimate and work schedule. On approval, a proposal is then transferred to hardware and software design engineers for their approval before being transferred to manufacture.

The company uses a *CAD S4* system for 3D mechanical design on a single work station, one that is supported by added storage capacity. A *Viewtrack* PCB system is also used for electronic design. 3D Modelling was necessary because customers were "worried about resonance .... vibration and that kind of thing in the mechanical structure". The need for product prototyping continued despite the use of a 3D modelling package on a CAE system. This was necessary from the point of view of manufacturing which experienced problems without prototyping in the past as resultant CAD information could not be processed on CAM or could not be transformed into a physical product within its available capacity.

A single-work station with a *Viewtrack* PCB artwork layout package was first introduced in 1986. Two more work stations were added soon after that. *CAD S4* was introduced in 1988 for mechanical design.

CAD was justified on the basis that it would increase efficiency and enable designers to use modelling packages for prototyping and simulation reasons. The CAD expectations of "speed[ing] things up, check[ing] the artworks in-house and mak[ing] modifications at a much faster turnaround type basis" were apparently met to a satisfactory degree. However, an outstanding technical problem still persisted:

> "We were always disappointed at the level of verification that the system could actually carry out itself, because you know in generating an artwork there are a number of design rules that need to be followed in terms of track width, spacing, just simple connections around the PCB

that have to be made, and we were always disappointed that the system was not 100% at picking up faults."

The introduction of CAD forced management to recruit an experienced CAD user and to hire an engineer for maintenance. System users had to be more independent following the take-over. They had to "do all of it" by themselves due to a shortage in resources and personnel. The new management team found that they had to redesign their information system, retrain their personnel, and reorganise their functional structure through consolidation of formerly separate functions to cope with the new circumstances.

Integration was considered in the past but has not been implemented to any degree in this case:

> "We have thought twice about it. The investment is too high and to get exactly what we want does not seem to be possible. .... We have taken the best of very small bits we could get and used them. We have not tried to implement an all-embracing communication system."

The justification given for this stance was in terms of structural instability which discouraged heavy investment on integration: " We are changing our structure very fast" and, therefore, it would be "not suitable" for the company to "go for a large investment". From an organisational point of view, continuous change and anticipation of acquisition or take-over eventualities increased doubts about the future of the company.

From a technical point of view, what makes interfacing the design-manufacturing link exceptionally challenging in this case is the nature of the product in concern:

> "I could see if our CAD system could design that base casting, if we had a vendor who could take a CAD tape and then produce that from a CAD tape rather that a bit of paper, then yes that would be an application for us too. And it's more likely to be accurate. It doesn't rely on somebody else interpreting a bit of paper, it's gone directly from the CAD system to, to the machine shop, if we could get a vendor that could take a CAD tape. .... As I say, the output is several different vendors and then all the pieces come together at the manufacturing side, at assembly, so we're designing a lot of individual pieces which are later assembled."

* <u>*CASE STUDY TEN: Company 10*</u>

Until 1993 Company 10 had been a wholly-owned subsidiary to a Washington-based corporation quoted on New York Stock Exchange. As the Technical Director put it during an interview with him in 1992: "We know it very well: they are the bosses - provided we produce the required profit figures we are left alone". The company's name and ownership then changed in 1993 following a management buy-out; it became a "totally British business" as the subsidiary's Directors bought it from its American owners: "We are now a very, very small team indeed".

The company supplies three product families: (1) tachographs (used for measuring heavy vehicles' mileages), (2) multi-purpose digital system counters, and (3) petrolum sensors (exported to the Middle and Far East for use in underground fuel storages). These products differ widely in size, function and purpose.

Tachograph customers include major vehicle manufacturers throughout Europe, such as *Skania*, *Volvo*, *DAF*, and *IVECO*. Western Europe, rather than the US, is now the company's main export market for tachographs, rather than the USA, "because there is no legislation [making the use of tachographs compulsory] in the US". At any rate, the early 1990s UK economic recession seems to have had a negative effect on the company's performance:

> "We've been recessed .... It wasn't totally worldwide, but it hasn't been certainly confined to the UK. We've seen a down turn in the truck market in virtually every company apart from Western Germany. And the Germans sold their old trucks to the Eastern Germans and then bought new ones themselves ..... "

The company's marketing strategy process has recently focused on the tachograph product line with a strong orientation towards the European market and away from the Middle and Far East markets. Historically, this goes back to the early 1970s as Britain joined the then Common Market. At present tachographs must be fitted on trucks and heavy vehicles by legislation in Europe.

> "... we came into the of tachographs round about in 1973-74 when the UK was thinking about going into the Common Market .... We knew that if it went into the Common Market then there would be a requirement for fitting tachographs. We did go into the Common Market, there was a requirement, we have been making tachographs ever since ..... "

Company 10 is a 370-employee company led by a five-member Board of Directors. It was set up in 1948 in Dundee, Tayside. The company's engineering design function consists of 15 staff, including both engineers and draughtsmen, supervised by a Technical Manager who reports to the Technical Director. Its role is to provide product design information both for internal manufacture and subcontracting purposes.

Company 10 is a "do-it-yourself" enterprise by tradition, where most product components are manufactured in-house, deploying a wide range of operations, including die-casting, milling and drilling, machining, grinding and taping, plating, plastic moulding, and painting. Recently, however, the factory has been reorganised with a view to creating specialist manufacturing cells in an attempt to rationalise operations and reduce stock costs: "It's basically [naming the company], a do-it-yourself company; all the processes are made inside the company". Production is of a "one-off" type with the exception of the tachograph line. Tachographs are manufactured at an average rate of 50,000 units annually.

At present the company operates *AutoCAD* for mechanical drafting on five *IBM*-compatible PCs. Integrating technology on the shop floor has been improved recently by introducing new computerised plastic moulding machines with a view to integrate them into the company's mainframe system.

The company's CAD experience began in 1985 by introducing a *CADplus* system to help in schematic design work. However, severe limitations of the system were experienced, particularly with respect to electronic circuit drafting. It was scrapped after four years.

The present Technical Manager criticised both his predecessor and senior management for introducing *CADplus*:

> "We had tried in 1985 to get CAD. We did it wrongly. There was £25,000 set aside in 1985 and the Engineering Manager, my predecessor at that time, I don't know how he did it, but he basically went out .... and got a commercial company to have a look and say: 'Right, this is what we want'. ..... We just got the ones which the distributors could supply us with and [naming his predecessor] chose between .... *CADplus* and .... *AutoCAD*, and he chose *CADplus* because they had a lot of similar parts and he thought the parametric facilities that existed with *CADplus* would be a good thing. However, he never took a look at the training aspects, the documentation associated with it ..... The other Directors went along the MD's suggestion that CAD was an 'electronic drawing board', and, in actual fact, it slowed us considerably because it was a struggle to make this thing work ..... "

After what was deemed a failed CAD experience a single work station with *AutoCAD* software was introduced. This time there was "a lot of obstruction from the finance department because they stomached out £25,000" for *CADplus*.

The Technical Director has mastered an evolutionary process of its implementation:

> "It's taken us a long time to put in because we were very careful. We saw a lot of people spend a lot of money and not get very far. .... the thing was we had two things to do: we had to get information up on the system relative to the products we were making, as well as put new products on the system and we also had a training program with the engineers involved, and what we couldn't afford to do was to put all the engineers off at one time and train them on CAD and then put them on again. So, we went very carefully. ..... and we gradually built up the system ..... "

AutoCAD was proposed to the then parent corporation. There was some scepticism as to whether it was going to give the type of productivity promised: "people were promised ridiculous things". Therefore, an external consultant was hired to prepare a formal assessment report on the proposed system. Although this was "quite an expensive" task[23], it was justified, from the point of view of design, to persuade the

[23] A three-month feasibility study was carried out. It resulted in a 30-page report submitted in August 1987 on the "technical and economic case for introducing a CAD system in the design office". The *NEL* (*National Engineering Laboratory*) was hired in this case for the purpose. The report's conclusions were: (1) the company would benefit from the introduction of new technology in the form of a CAD system, (2) a single work station CAD system with 2D draughting software would meet the design requirements for the *VRC8300* series Tachograph, (3) the total cost of such a system would be =

corporation's senior management that further costly mistakes would be avoided. Design management resorted to involving a third independent party because:

> "I wasn't wanting to make the mistake that my predecessor made. ..... I was wanting someone who knew and had much more experience than myself to say: 'That package won't do the kind of work you want to do'. .... Now, I wanted a neutral person, someone who wasn't trying to, to sell me his own package ..... "

The company's objectives in introducing CAD were spelt out by the Technical Director who seemed content that these were met satisfactorily:

> "The main thing was to try to facilitate getting through engineering changes when necessary and modifications when necessary .... we could react very quickly .... be flexible .... and there was one thing .... we could hopefully cut the reaction time."

However, in the experience of the users in general, CAD improved productivity of redesign, but not that of original design work.

The introduction of CAD has hardly affected the organisation of work in any significant way since it was merely used as a "tool to help us in the design side". However, the Technical Director found that his methods and intensity of control over the design department's work changed with the implementation of *AutoCAD*:

> "As soon as you start having your drawings in an electronic format then the control of it becomes different. I would say it becomes more difficult ..... So, we've had to put some discipline in there .... some checks into the system and a method of operation and also we've also got to make sure that people keep a back-up just in case somebody switches [the] electricity off."

In this case there has been an increasing emphasis by integration enthusiasts on the potential advantages of linking CAD to the company's mainframe system:

> "We have been sort of looking at an integrated set up ..... I think we are getting towards the thing [i.e. CAD] talking to other parts of the set-up .... that was the second part of the exercise. The first part was to get better customer reaction and then the second part which we are just coming to is to look at the whole of the system within the place and look for some integration ..... "

In this case, however, the integration enthusiasts are a powerless minority of relatively young but highly qualified engineers who happen to be employees of this organisation where compulsory redundancies have been the norm for a long time. In the early 1980s the company employed 1,400 people. Management has consistently downsized the organisation by firing what it regards as unneeded employees on a "last-in-first-out" basis. The result is that it is the younger and more adaptable people that are sacked every time. Age averages of the work force and of managers in this company are higher than averages in industry. Investment in human resources is almost an alien topic to senior management's thinking.

= between £29,500 and £47,600 depending on the system chosen, and (4) the system would result in an effective cost-saving of £40,364.

This situation has created tension between senior management and those young engineers who reject such attitudes and feel threatened by them, some of whom once said: ".... if I thought they understood the first thing about the human resource approach to staff development I would fall off my chair, I promise you!". According to this younger group of employees, the personnel department has played a major role in running the company: ".... rather than recruitment and development, they tend to be looking at how to monitor people and get rid of people".

In this case there is, clearly, a generation or "mental" gap between the integration enthusiasts and senior management, as will be explained further in Chapter 7 (section 7.3). In this connection, a leading integration enthusiast once talked very critically of senior management:

> "[It is the] lack of computer know-how: they say: 'Oh, yes, yes, we have to .... use the computers to work smarter, other companies do do it' .... They're making all the right noises but a little of them actually know enough about it to offer any guide lines ..... There is only one person at the board level who could actually use the computer in the slightest way. ..... They say: 'Yes, yes, we want it to happen but [naming a Director] and I will do it in our own time'. ..... They themselves are [afraid?] to even [say?]: 'Oh, it will be great if it could do that or do this' in case they say something silly .... what a stupid thing - it's not just technically possible! Their knowledge is at such a level .... I don't think they would contribute ..... "

How wide the gap is between the two groups can be illustrated by another example of how the integration enthusiasts blame senior management for blocking their initiative to develop the company's CAD system into an integrated set-up:

> "We've had all sorts of problems trying to integrate our *AutoCAD* into the company's system. ..... The only obstruction I might see are the Directors! .... again, it's top management. They've cut [up] the organisation first so we've got all these ongoing activities for the computer integration to take place. It would require some of their people not to be doing some work to do the computer integration work."

In particular, senior management is criticised for being traditionalist and unwilling to learn and adapt. It should be said that the pro-integration group of engineers look seriously at learning as an essential element of their career development experience. Many of these engineers seem to enjoy learning "the hard way" as they put to use whatever theoretical and practical skills they possess:

> "You keep learning ..... I was coming at week ends and early in the morning .... I do much of the customisation work .... *CADplus* in one way was a disaster from the point of view that it .... didn't do the job for us. On the other hand, we learnt a lot ... from mistakes that we made from [i.e. with] that package. .... if we hadn't had it I don't think some of the benefits that we've had with *AutoCAD* we would be seeing these benefits now. We learnt expensively before and we haven't made any of the same mistakes again."

Nevertheless, in this case resistance to integration remains uncompromisingly strong at the top of the organisation. No positive decision has been made at the senior management level to adopt an integrating strategy. The forces against change in this case seem to have outweighed the forces for change, so far at least.

The experience of this company with regard to the lack of any progress towards integration will be explained further in Chapter 7 (section 7.3) using the study's conceptual model. In this respect, the experience of Company 10 will be contrasted with, and analysed against, the experience of Company 4 which adopts an integrating strategy.

5.4 Summary

This chapter presented background information on the cases in the study and, thus, provided the first basic account of the data that was collected on the ten companies during the filed research. Case presentations were divided into two groups corresponding to the primary companies (Company 1 to Company 5) and the secondary ones (Company 6 to Company 10) . In essence, the difference between the two lies in four fundamental questions: (1) Should existing or potential CAD and CAM systems be interfaced for a more effective flow of information between the design/engineering and manufacturing functions? (2) Should these functions be integrated organisationally as part of the interfacing process? (3) Should company-wide organisational integration mechanisms be developed around CADCAM so as to extend its benefits beyond these functions? and (4) Should long-term business objectives be reviewed in the light of, and aligned with, CADCAM integration since CAD and CAM are perhaps two of the most important strategic technology applications for any manufacturing concern? The primary companies' responses to these questions are positive; thus, they have adopted what can be called an integrating strategy. The secondary companies' are negative; thus, theirs can be described as a non-integrating approach.

The crucial difference between the two positions lies in the fact that by adopting an integrating strategy the primary companies have formally decided to develop the core of their technical set-ups in favour of integrated CADCAM. The integrating strategy they have followed for the last few years shows a positive line of accumulative action in a direction which is significantly dictated by the technical requirements of integration as a long-term project. In so doing they find that they have to introduce organisational changes, some of which are unpopular to some individuals and groups within their settings. Yet, the trend towards integration persists despite resistance. This partly reflects a determination on the part of the leading change agents to mobilise their organisations towards integration in spite of the psychological, organisational and political challenges involved. In contrast to this position, the secondary companies have not adopted CADCAM integration formally, nor have they seriously attempted to do so. It can be said that they have been indifferent or that they have taken a passive approach to integration for the foreseeable future at least.

In conclusion, one important point should be stressed regarding the organisational implications of the two positions. The integrating strategy adopted in the primary cases is bound to induce a high degree of transformation (for better or worse) with regard to the manner in which working relations have been shaped historically, not only between different individuals and different groups but also within a single group. Ironically, if it is not managed skilfully, an integrating strategy may mean a greater convergence in technology hardware terms but exactly the opposite in organisational and social setting terms. The level of uncertainty associated with technical change is much higher in an integrating strategy as individuals and groups are expected to adapt to continuous change.

By comparison, the situation is different when it comes to a non-integrating approach. Assuming that an integrating strategy will not be adopted by the secondary companies in the near future and that unanticipated turbulent events will not arise, a non-integrating approach *per se* does not entail such uncertainty and, thus, can be regarded as a more conservative and stable strategy. It is an approach that may avoid - consciously or unconsciously - potential threats to the existing social order in the secondary companies.

The next chapter will build on the data this chapter provided, concerning the cases but will involve a cross-case analysis of the data in the framework of the tentative questions of the present research.

CHAPTER SIX

Findings, Data Analysis and Discussion - II: Answering The Tentative Research Questions

6.1 Introduction

This chapter will compare the case studies with each other and in relation to the main orienting theoretical issues under discussion. It will provide answers to the seven tentative research questions as found grounded in the substantive contexts of both the primary and secondary cases.

This chapter will conclude with developing conceptual insights that will be used effectively in the following chapter which presents a theoretical conceptualisation of CADCAM integration as a process of change and illustrates the social processes associated with it.

6.2 Addressing the Tentative Research Questions

This section addresses the seven tentative research questions as presented in Chapter 1 (section 1.4). Questions 1 to 6 are equally relevant to both the primary and secondary cases and question 7 is relevant only to the primary cases.

1) Why do manufacturing companies acquire CAD and CAM Systems?

Not surprisingly, all the companies studied tended, formally, to justify the introduction of CAD and/or CAM systems on a "techno-economic" rationality basis[1]. As Wilkinson (1983) pointed out, the most commonly claimed rationale for the introduction of new technology was the belief that technology was intrinsically worthwhile and could not fail to bring economic benefits. Formally, the companies declared that they sought to rationalise their engineering and manufacturing operations by "equipping ourselves with such technologies" in order to "..... be a) competitive, b) supply [..] goods in time, and c) supply [..] to the required quality standards" (Case 8).

Company 5 was unique in that its justification was based centrally on maintaining its market reputation by being a "first mover" (see, for example, Mueller, 1993) towards

[1]One notion was explicitly emphasised in all the companies studied, namely that any profit-seeking action, or at least any that was perceived as such, would justify the existence of a profit-making organisation operating in an increasingly competitive market environment. The techno-economic rationality perspective stressed that CAD and CAM systems were introduced in this light. It could be inferred from this that, from a management point of view, pursuing survival and profitability through improved competitiveness would uphold management as a "profession".

such technology in its industry. Being a first mover meant being a "technology leader" to senior management. The company did so because it aimed to preserve its reputation as a subsidiary of a giant multinational corporation. This was the only exception among the cases. Formal justification in the other nine companies pictured such systems as "tools" that should be utilised to improve profitable performance.

Nonetheless, the widespread presentation of such systems as a means to desired ends was rarely matched to the vital question of how their true value to a manufacturing company could be utilised. That is, how their potential benefits could be realised through a successful implementation that would help improve competitiveness in the "current climate of increased world competition .... and the unified European market", given the proposition that "it is imperative that British companies continue to improve on all aspects of their service in order to compete both at home and overseas" (Case 6).

With time, such systems had come to be regarded by users, middle and senior managers alike, though to varying degrees, as essential parts of their businesses. Case 6 excluded, all of the companies studied made it clear that they could no longer survive in business without them:

> "..... it's generally true of CAD, CAE and manufacturing software that if you commit your company to it there is no way back. You're committed as part of a long term development .... You can't reverse !" (Case 3).

In addition to the practical benefits anticipated, however, such systems were often deemed necessary for maintaining or improving company image with customers: " ..... if we didn't have it we wouldn't have the credibility" (Case 1).

Each interviewee pointed out between two and four reasons why his company introduced CAD / CAM. Various separate, but overlapping, emphases of justification were given. These were what sociologists, after C. Wright Mills (1940), would call "vocabularies of motive" (i.e. rationalised and readily available accounts that people typically use to make sense of certain contexts). These ranged from inward-looking operational motives stressing potential technical benefits (e.g. "improving maintainability of design information" [Case 6]) to externally-oriented strategic motives emphasising potential economic gains (e.g. "improving business flexibility" [Case 4]). Formal justifications consisted of a combination of both in most cases.

Two important observations should be stressed here, namely: (1) a respondent's position and (2) their functional specialisation influenced the way they answered questions pertaining to justification. Whereas technical managers stressed operational and control motives, more senior managers insisted that their motives could not be isolated from the strategic business aspirations of the companies they directed. As

Currie (1989) pointed out, engineering managers could not always perceive technological change as part of a strategy plan drawn by top management. Design managers focused on how CAD would, for example, "shorten design cycles" (Case 7). Manufacturing managers highlighted CAM's potential for improving "production methods" (Case 8) through: (1) increased efficiency, (2) higher speed of prototyping, (3) cost-saving[2], and (4) enhanced quality and reliability.

The question of cognitive processes of individuals and groups involved in decisions about introducing CAD /CAM was borne out. Variuos meanings existed in a single organisation. The significance of subjective meaning in designing technology and organisation could not therefore be ignored[3] (see Scarbrough and Corbett [1992], Weick [1990] and Brown [1995]).

Some of the engineers who were interviewed during the course of the research confirmed explicitly that an individual's professional background would have implications for their approach to conducting their work tasks: “I wouldn't be an engineer if I wasn't optimistic; you can't be a pessimist and be an engineer, nothing works then” (Case 10). It would seem reasonable to suggest that the influence of various occupational cultures[4] within an organisation would contribute to the multiplicity of meanings that could be found in it:

> “..... in the engineering technical magazines that you get, people who are at the top level .... engineers, by and large, are aware of state-of-the-art. They also go to exhibitions and they see these things: you can use that, you can use that. So you get a lot of ideas ..... " (Case 10).

By the same token, the idea that an organisation would have a single homogeneous culture would be invalidated by the more realistic proposition that a dominant sub-culture, or a set of "publicly and collectively accepted meanings" (Pettigrew, 1979: 574), would prevail from amongst various competing sub-cultures. The roots of these sub-cultures could be traced to the various formal and informal groups which make up the social composition of the organisation. Such groups could be classified according to professional as well as other less verifiable and more politically-explainable criteria. Indeed, Brown (1995) noted that legitimacy for information technology systems, in general, was often sought through political processes whereby symbolism was used to

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[2]For example, a CAD feasibility study in case 10 stated: "The system will result in an effective cost saving of £40, 360".

[3]See Porter (1983) for the argument that strategic vision and direction (as influenced by a particular meaning or set of meanings) are vital in the management of technology as a strategic resource.

[4]See Gregory (1983).

manipulate actors' understandings of proposed systems by feeding radically different information to each group of actors regarding investment motivations and implications.

The implications of comprehending a multiplicity of meanings in an organisation for answering the present question on why CAD / CAM systems were found to be acquired were important in that they highlighted the fact that formal justifications were only publicly and collectively accepted but by no means universally agreed upon. Exhibit 6.1 shows the formal justifications in the ten cases. Formal justification statements were formulated and developed by the researcher over a period of time on the basis of the various respondents' replies recorded during interviews with a view to defining public and collective meanings. In some cases these echoed written justification reports which were prepared and submitted to senior managements in all companies except in Cases 6 and 7. No collective justification decisions were made in these two cases, but, instead, delegated individual managers made purchases on behalf of their companies.

It was rather surprising that the reason given formally for computerisation in Case 5 was because such technologies were "the future". The Company, however, did not appear to have investigated or questioned how to maintain its worldwide reputation by securing "the future" through being a "first mover" towards CAD and CAM. Those responsible for initiating the purchase of such technologies appeared to have decided that such technologies were required first and then to have justified them in terms of their superiority over existing equipment and work methods.

The relevance of the institutional literature in organisation theory (e.g. Meyer and Rowan, 1977; Scott, 1987; 1995; Zucker, 1977) to the notions of rationality found to be dominant in the cases revolves around the suggestion that "rationality" is often culturally induced by and through "mimesis". That is, for institutional theorists (e.g. Meyer and Rowan, 1977; Scott, 1987; 1995; Zucker, 1977), rationality is a function of the common understanding of social reality which is constructed in such a way that ingrains, and is reflected in, rationalised formal structures. Technology, to begin with, is socially constructed by actions of designers, technologists, investors and other interested parties but, once developed, it will tend to become institutionalised (Orlikowski, 1992).

It should be noted that system interfacing was an important element of the justification process in Cases 4 and 5 but not so in the rest of the companies, including the other integrating cases in which concerns about integration emerged later after the systems had been introduced separately. In Cases 4 and 5 integration was incorporated into the original system designs since in these two cases in-house design was carried out, as will be explained in the following section.

Exhibit 6.1
Formal System Justifications

Primary Cases

Company	Size (No. of employees)	Industry	Reasons Given for the Acquisition of CAD, CAE and CAM Systems
1	95	Photomasks	* Improving business responsiveness * Maintaining credibility with customers
2	210	Lighting & cotrol equipment	* Improving production methods * Improving quality * Reducing cost / stock level with CAM
3	400	Elctronic security products	* Improving business responsivess * Shortening design-to-market throughput with CAD
4	500	Test systems (defence)	* Improving quality & reliability * Shortening design-to-market throughput with CAD
5	1,400	Self-service systems & machines	* Maintaining reputation & credibility * Shortening design-to-market throughput with CAD

Secondary Cases

6	35	Electro-chemical sensors	* Improving design maintainability * Improving business responsiveness * Improving information exchange
7	50	Weighing equipment	* Improving business responsiveness * Improving design efficiency and security
8	73	Printed circuit boards	* Improving quality & reliability * Reducing cost * Shortening throughput time
9	150	Computer hardware components	* Improving management practice * Improving modelling in design * Shortening design-to-market time
10	370	Electronic measurment equipment	* Increasing productivity in design * Improvingbusiness responsivess

2) *How do manufacturing companies design/use CAD and CAM systems?*

Three levels of data analysis were found to be needed for examining the issue of the design / use of CAD and CAM systems. These corresponded to the following questions:

1) What were the technical specifications of each of the CAD and CAM systems in use in each of the cases?

2) What were their respective purposes of utilisation?

3) to what extent was their implementation a process of "tailored" design/development and/or "packaged" purchasing?

Each of these questions will be represented as a level of analysis with respect to the cases in the following four subsections.

* *Technical specifications*

Technical specifications of CAD and CAM systems were investigated in each of the studied companies. In this connection, the data gathered for cross-case comparative analysis aimed to establish a sense of appreciation of the capacities, processing powers and hardware configurations of the systems in use. The investigation also aimed to identify software and hardware similarities and dissimilarities across the cases.

With regard to CAD, *AutoCAD* was found to be the most commonly used drafting package, particularly by smaller companies and those looking for low-cost, user-friendly systems for basic drafting (Cases 1, 6, 7 and 10):

> "The accessibility to training. It's very user-friendly ..... It's a well-established package. *AutoCAD* can be customised quite considerably by the end user. *AutoCAD* has got a very wide user network. ...... Anything other than *AutoCAD* [and] you're almost dependent on training through the distributor ..... " (Case 10).

In addition, *AutoCAD* was found to be the most favoured package by companies with strong US business connections (Cases 1, 6 and 10). In the case of Company 1 *AutoCAD* was but one of seven CAD systems in use simultaneously; like the other six, it was purchased specifically for exchanging design information with certain customers who used the same software package. The package was justified on the basis that any established customer's design requirements should be met by adding a compatible software as long as it could be afforded. Some larger and companies with greater resources purchased more sophisticated but less commonly known packages (e.g. CAD-*S4* and *Viewtrack* packages in Case 9). Some others purchased some but developed most parts of their systems themselves (Case 5). The most self-sufficient of the larger and better resourced companies, however, designed and created its own brand systems almost completely by itself (Case 4).

It should be noted that *AutoCAD* would not support integration as other more sophisticated design packages would because, in essence, it is a drafting package. As the Senior Technical Manager of Company 10 put it:

> "If you are making a selection for a company-wide package computer integration you would not probably finish up with *AutoCAD*...... you then start to run into problems of how you integrate it. .... There will be some people who will say: 'Oh, you've got *AutoCAD*, we'll do something for you, but the chances are .... they will give something which will interface *AutoCAD* to the rest of the system.'" (Case 10).

Nonetheless, CAM systems were found to be much more complex and prone to customisation, via customised tool libraries and tailored menus, since each of the studied manufacturing systems had virtually unique features which distinguished it from the rest: "Everybody [i.e. company] is unique." (Case 6). Therefore, a tailored CAM system was justifiable in every case. Unlike CAD in some cases, CAM systems were invariably ordered to unique specifications and supplied as a "one-off" product to a unique user company. System configurations (i.e. the engineering principles underlying a system's design) varied considerably from one case to another. In the words of the Operations Director of Company 2:

> "Even in a larger company the opportunities and the difficulties in getting CIM in operation are extremely difficult, and CAM [too]. Computer Aided Design is fairly well established but Commuter-Aided Manufacture and its link with CAD is extremely tedious." (Case 2).

* ***Purpose of Utilisation***

The findings revealed that CAD and CAM systems were used for a variety of purposes. The vast majority of the companies used CAD for two major purposes: 2D (i.e. two-dimensional) mechanical drafting and 2D electronic drafting. CAD was also used for design data processing and editing (Case 1). CAE applications were utilised in Companies 3, 4, 5 and 9 for design engineering analysis, simulation and modelling.

CAM systems involved electronic, optical and laser beam manufacturing processes associated with phototool production in Companies 1 and 8 and population and PCB assembly in Companies 2, 3, and 5.

In general, the introduction of computers to the design process changed the means of generating drawings and reports on paper, but it did not fundamentally alter the methods of sharing data and resources across departmental and corporate boundaries. This was much clearer in the secondary cases.

The two main factors contributing to this situation could be summarised as follows:

1) Isolated application-specific software packages with fragmented data models and separate file systems prevailed. The means of building representations fell short of

establishing a common modelling base for the various applications involved in product development.

2) Each of the participants in the DEM processes partially described the product from a specific point of view and with a particular purpose in mind. Various representations were used in different application areas and stages of product development.

Consequently, the use of computers in DEM tended to reinforce, rather than weaken, the organisational fragmentation that already existed along functional lines. This could be explained as follows:

1) The resulting product information was dispersed over various drawings, technical performance calculations, bills of materials and cost estimations.

2) Data redundancies and incompatibilities among partial building representations were hard to avoid.

3) Data and knowledge incorporated in previous DEM projects could not be easily accessed and were, therefore, not effectively utilised in new projects.

*** "Tailored" or / and Purchased Systems?**

Data-gathering in this connection aimed to find out how much of the implemented systems were tailored by unique design and development to match specific company requirements and how much of them were bought "off-shelf".

Invariably, all CAM systems were found to be customised, designed, and developed by specialist vendors to suit the specific manufacturing requirements of user companies. In contrast, only one of the CAD systems in the study was designed and developed totally in-house (Case 4). In Case 5 the system's software was developed independently inside the company. Companies 4 and 5 could afford to do that because they possessed the largest technical skill bases with numerous teams of scientists, engineers, and technologists of diverse specialisations. CAD systems in the rest of the cases were bought "off-shelf" and used as complete "turn-key" systems.

With regard to integration, no initial consideration whatsoever was given to a possible future integration in selecting purchased system components in all the companies except in Company 4 (and Company 5 to a lesser extent). However, later stages of consequent system upgrading and development included purchases of added system components. Then, purchasing was guided by integration trends in the primary cases but not so in the secondary cases.

In the case of Company 4 the initial CAD system was developed internally. It was designed with a view to integration. A similar approach was adopted in Company 5 originally, but the company had to redesign its entire CAD, and CAE systems in order to create a more integrated collective performance of the user departments. The planned CADCAM system was justified mainly on the basis of its advantageous integrating potential to the company.

3) How do manufacturing companies introduce, maintain and develop CAD and CAM systems?

As shown in Exhibit 6.2, the roots of computerisation in the DEM functions of the studied companies could be traced to the early 1970s. Typically, the first experience of computerisation at a company level in most of the cases involved either finance functions (for payroll accounting purposes), sales (for customer order information) and/or production planning (for parts lists and stock control purposes):

> ".... they always start with the accounting procedures because they are easy to define, but I mean the poor ..... production tools chap, we don't know what he wants, so that came later ..... " (Case 2).

The 1970s could be conceptualised as the first phase of the computerisation phenomenon in an evolutionary process of development. The 1980s (i.e. Phase II) was the peak of it in terms of stand alone system applications:

> ".... We brought the thing in stages; we didn't bring in a big package all at once. We started off with a PC and a PC package on it and we, gradually, built up from there as we got experience and we added more work stations." (Case 10).

The 1990s (i.e. Phase III) could be conceptualised as the phase during which the relevance of integration has progressively increased as companies have pursued a better utilisation of the systems introduced during the last two decades: "It's a continuous thing. ..... It's part of an evolutionary thing. We are always developing. We've got to keep doing that" (Case 4).

In general, evaluating CAD and CAM systems prior to implementation was a well established practice whereby assessing the technical requirements of the company concerned and, hence establishing suitability criteria for system selection was achieved or at least targeted. Some companies, however, could not exercise choice in system selection. For example, in the case of Company 5, a *DDM* CAD system was imposed on it for purposes of compatibility from the point of view of the holding corporation whose plants in the USA used it. Company 3 was another example; it did not have to purchase a CAD software but was "given" *Visula* free of charge by another subsidiary of the parent organisation which specialises in software development and, thus it was left with no choice whatsoever on selecting a system which could have been better suited to its own technical requirements.

Exhibit 6.2

Computerisation in Design, Engineering and Manufacturing: a Historic Pattern of Progress

Primary Cases

Company	Chronology of CAD, CAE and CAM Evolution and Growth		
	PHASE I: 1970s	PHASE II: 1980s	PHASE III: 1990s
	Introduction (*) of CAD systems only	Introduction (*), Up-grading(**) or Replacement (***) of CAD, CAE and CAM systems	Integration (****) of CAD, CAE and CAM systems
1	*	* ** ***	* * * *
2		*	* * * *
3		* ***	* * * *
4	*	* ** ***	* * * *
5		* ***	* * * *

Secondary Cases

6		* **	
7		* **	
8		* **	
9		* **	
10		* ** ***	

In the vast majority of cases, implementing CAD was, essentially, a process of imitating other companies' moves towards a used and tried technology:

> "Our MD had been reading up magazines and suddenly: 'CAD is a good thing for design; go and get CAD!' ..... One thing you couldn't miss: the literature that's coming round suggesting that this is the best thing since sliced bread that happened in the engineering industry and everybody appeared to be doing it." (Case 10).

However, Companies 4 and 8 stood out as pioneers with regard to the innovative application of CAD and CAM technologies respectively. In the instance of Company 8, for example, the company's learning experience[5] with technological innovation was particularly noticeable in the British PCB industry; the company was innovative in relation to CAM but imitative in relation to CAD.

Whereas in Companies 6 and 7 no written justification reports were necessary, purchasing decisions were much more formal in larger and more bureaucratic companies. Though not large enough by any universal standard, Company 4 , a 500-employee subsidiary of a giant corporation, is the second largest organisation in this study. Some of the company's middle managers talked extensively about the difficulties they faced in justifying investment in new technology in general and CADCAM integration in particular, as will be explained further in Chapter 7 (section 7.4). In this case every proposed investment had to be justified on the grounds of a cost-benefit analysis as a routine procedure within the corporation's standard four-year equipment depreciation policy. The signature of the corporation's Managing Director was necessary for approval every time:

> ".... We raised a thing called capital application for cost justification ...... It's a document that you prepare and circulate around senior management in the company and then up the hierarchy to the very top of the establishment." (Case 4).

A similar capital application report had to be signed by six different managers in Company 8:

> "There is a fairly strict routine of capital application where we fill in documentation requesting expenditure and we justify that expenditure and that feeds through the normal formal chains. And, yes, we meet with the directors and we do our level best to present to our directors the need for a change .... but, in general terms, they will only react to .... a desire to get more profit." (Case 8).

Historically, in this case the pioneering CAM project had been delayed by bureaucratic procedures: though, according to informants, it was the first manufacturer to commission CAM in the British PCB industry, it only managed to be second to implement it due to a delay in justification procedures. The other manufacturer who won the race was, by contrast, a smaller, privately-owned, and less bureaucratic firm.

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[5]See Bessant *et al.*, (1996); Jones and Hendry (1994); Kim, (1993).

In examining the factors that influenced how CAD and CAM were introduced, developed, and maintained, it should be noted that in most cases only one person, usually the person responsible for initiating the purchase, decided upon the organisation of work around them. These persons included senior design managers taking charge of CAD and senior production managers taking charge of CAM. Such leading individuals may have consulted members of a task team which would have been set up especially for the purpose of implementation under their supervision. They may have been equally influenced by their superiors' wishes or demands. Whatever the circumstances, however, the initial decisions tended to be theirs alone. It could be argued therefore that, to a large extent, the initial choices made in implementing these technologies would have been coloured by these individuals' own biases.

In general, it could not be denied that implementation decision-making processes were influenced by objective elements such as the type of products, the existing structure of work, and the need to rationalise design, engineering and manufacturing operations. However, equally powerful influences appeared to come from the individuals and groups involved, and revolved around such factors as values, attitudes, self-interest, power and competence. It should be pointed out that these factors were influential in making decisions associated with technical change less rational, less stable, and less efficient than might have been expected.

Once introduced, CAD and CAM systems had to be maintained and developed. "Operationalisation" and development of installed systems were often more challenging than initially anticipated, particularly with regard to CAM. For example, the experience of Company 8 in this regard could be summarised in what the Senior Production Engineer once said:

> "We expected the whole system to be efficiently operating within a six-month period of installation. That turned out to be untrue. We were still developing the system two years down the line from receipt. That was because it was difficult for us to understand Computer-Aided Manufacturing Systems as applied to the type of systems we put in. ..... We didn't know what we were looking for, the application engineers or the company that supplied it didn't know our business, so it took us two years ..... " (Case 8).

Maintenance would be essential if a system's intended purposes were to be kept viable over any given period of time. System development work aimed to look progressively into an existing system with the intention of improving its technical performance (e.g. Cases 2, 6, 7, and 10) or, by planned orientation, making it more beneficial to the strategic direction the of the business in concern (e.g. Cases 4 and 5). In this regard, the interfacing of CAD, CAE, CAPE and CAM systems could be conceptualised as a significant area of system development since its declared aim was to allow the whole organisation to benefit from numerous single stamd alone applications. For example, access to CAD-generated information could be made available to all those who needed it outside the functional boundaries of design in order to carry out their job tasks or make decisions (Cases 4 and 5). Nonetheless, the filed research revealed that such thinking was not dominant in the majority of managerial circles in most of the cases. It was rather rare due, mainly, to a deeply-rooted culture of functionalism in the majority of the companies, which encouraged mangers to think narrowly in terms of their immediate departments: ".... the pitfall of that: you can lose the overall vision and the optimum use of resources" (Case 5). The use of CAD under such circumstances was often viewed by design managers as a strictly departmental matter; CAD to them offered "point solutions" to the technical problems encountered in designing a product, rather than a source of information which should be made available to other functions so that "the guy on the shop floor or the guy in the stores can access the information directly from this design information" (Case 4). Invariably, such individuals would need to refer to CAD-generated information in carrying out their contributions to the manufacturing process.

It would be true to say that departmentally-biased, protective attitudes prevailed in most of the companies in the study, particularly in the secondary ones. Those companies which moved seriously towards integration, Cases 4 and 5 in particular, were the exception since integration, by definition, was motivated by, and incorporated, an element of organisational restructuring and a changing of attitudes:

> "We are just initiating major changes into the company .... we are just in the middle now of doing some changes to our development processes to make all of our development more concurrent. And the thing is now you should be seeing overall processing packages because a point solution for an individual manager or an individual process or sub-process does not necessarily give you an optimum global processing solution. In fact, it may be detrimental ..... " (Case 5).

The nature and amount of maintenance and development work varied considerably from one company to another and from application area to another. Preventive and repair maintenance for CAM systems in all cases was found to be carried out by suppliers. Maintenance arrangements for CAD and CAE, however, differed from one company to another. It was interesting to find that most of the primary cases (except Company 2) maintained their systems independently using skills they had within their organisations, whereas all the secondary cases signed maintenance contracts with system vendors and were, thus, found to be dependent on external assistance.

Integration in the sense of interfacing of CAD and CAM systems could, again, be thought of as a special and perhaps most technically advanced step in a system development frame of reference. Such a cognitive inclination was found most clearly among integration leaders in Companies 4 and 5.

4) What are the outcomes of the implementation of CAD and CAM systems in terms of pre-identified objectives ?

An investigation into companies' own assessments in this area revealed that only Company 6 admitted that no clearly-defined CAD objectives had been set out prior to implementation.

Despite an overwhelming emphasis on productivity improvements in the formal justifications given for the introduction of CAD technology in the vast majority of the cases, it turned out that CAD did not increase productivity for a new product design process, drafting in particular. Ironically, there were complaints that it had even slightly prolonged the time involved. This was a common finding across the cases without exception. Despite such complaints, CAD remained to be viewed as "a very useful tool" (Case 4) for consequent design modification and redesign work whereby existing design information could be changed "very quickly" (Case 3); and "it took a fraction of the time it took before" (Case 6).

It could be inferred from the findings that CAD was a considerably more useful tool for companies whose basic product designs required frequent modifications, such as in Cases 1 and 3, than for companies which had a mainly static design process requiring minimal changes to existing standardised product designs, such as Cases 6 and 7. In general terms, however, it should be stressed that CAD's ability to increase the productivity of a design process was not a purely technical issue; legal, organisational and commercial considerations played a significant role in determining how productive a CAD system was in practice by determining how it had been used in the first place. Indeed the whole direction of a professional design practice was not left to the discretion of highly-skilled engineers for technical excellence but was usurped by senior management in a manner which was perceived to be in the interest of profitability:

> "..... if the legislation changes slightly, if our customer changes his design a little bit, how do we process changes to keep our product compatible with legislation and the competition? ..... And usually, his [i.e. special customer's] product is out there. His product is at the leading edge of technology and .... [he says to us] : 'We want a tachograph that can do these things' .... So we have to take his tachograph apart and find out in more detail what that performance specification is. But, of course, you cannot do it the same way, so you are very much constrained as an engineer. He chooses the best layouts, if you were to sit down with a blank sheet of paper I would think that nine times out of ten you would design the mechanisms .... in the same way that he has done ..... you will tend to follow the same avenue as a good engineering practice, but then again if he's taken [out] a patent of [i.e. for] doing that by that method, then you have to achieve the same thing but by an alternative method, and that is very, very difficult to do because good design practice tells you to do it that way but you're not allowed to do it that way." (Case 10).

In technical terms, although no doubts were explicitly expressed about the appropriateness of such technologies in their particular settings, eight out of the ten companies experienced various practical problems with the technology. This would indicate that the companies might have benefited by carrying out more rigorous assessments of their needs and the equipment available prior to the decision to purchase.

Nevertheless, many managers learned lessons about how to deal with similar technical problems in managing future technology projects. For example, in the case of Company 10 the first CAD system, a *CADplus*, which was introduced in 1985, represented a case of failure and a "costly mistake". Yet, it offered the company a significant learning opportunity for the technical managers in charge of innovation.

Given the number of companies who experienced technical problems, it was not surprising to find that a significant proportion also had economic problems with the implemented technologies. However, not all those who had technical problems also had economic ones, and vice versa. Technical problems brought about economic problems for a number of the companies. The issue was not simply whether companies benefited financially from CAD and CAM technologies. Had the outstanding technical and organisational problems been overcome, some could have benefited more. The answer had to be that a better financial return on their investments could have been achieved in a number of cases.

It should be mentioned that technical and financial problems in the primary cases delayed integration, particularly in the less integrating cases (Companies 1, 2 and 3) which shared a common characteristic with the non-integrating companies, namely a smaller organisational size: "We don't really have the resources to drive the system as you might expect anyway" (Case 6); "..... being a small company, money is quite a factor!" (Case 7). This finding confirmed the proposition that "small firms are generally quite slow in adopting ... CIM technology" (Arcelus and Wright, 1994: 411).

5) What are the impacts of the implementation of CAD and CAM systems on manufacturing organisations?

Discussion in this section will focus on four interrelated areas of the organisational impacts experienced in the ten cases as a consequence of the implementation of CAD, CAE, and CAM systems. These include: (1) employment, recruitment, and training implications; (2) the design of jobs associated with these systems; (3) the effects of implementation on industrial relations; and (4) impact on inter-functional relationships.

** Employment, Recruitment and Training Implications*

Contrary to popular views that computerisation would lead to unemployment, it was found that only in a single case had the introduction of CAD and CAM systems resulted in layoffs[6]. This exception was found in Company 8 with CAM. Elsewhere, no conclusive evidence whatsoever could be found to support a clear-cut relationship between such systems and organisational downsizing. Salzman (1989) also found that CAD investment decisions were not associated with declines in levels of employment and that electronic CAD software did not decrease the need for skilled PCB designers in the US firms he studied. The employment levels of drafters were not affected, nor was the demand for drafters reduced relative to engineers and other white collar employees.

Even in Case 8, the situation was not a straightforward case of massive replacement of human for machine work. Management's intention with regard to CAM, which was made explicitly clear, was to use it as a means for increasing control over work through a deliberate act of deskilling labour, getting rid of as many workers as possible, and thus reducing cost. Managerial philosophy in this case was to counteract the demands resulting from increased competition by maintaining complete control over the work force. It was dominated by thinking in machine terms only. Human labour was viewed from this perspective as a source of problems caused by inefficiency and unreliability. The main concern here revolved around adopting a long-term view of automating the production process, which would go beyond the life span of highly skilled individuals in whom knowledge and expertise were trapped.

The position in this case was diametrically opposed to the "human-centred" (or "anthropocentric") principles which would call for a greater attention to be given to the human element by "putting people into the centre of production" in place of adopting a "technocentric approach" to the design of technology and jobs around it (Uden, 1995: 84)[7]. In contrast to this dominant attitude in Company 8, senior management's attitude in Company 3 was different:

> "Within this company we view data bases as being a tool, not to have power in themselves. ..... The real power is in the skills of an individual and we try to use the computers to do things we cannot do by hand and we try to encourage our work force to understand that they are in control and not the systems, [to] use their creativity and the system is there to help them ..... The purpose is to allow more use of talents, of unique skills ..... " (Case 3).

Compulsory training was imposed in Case 8 on the then new system for all shop floor workers who used to follow the "traditional method". The individuals worst affected by this decision included older people who neither had any computer skills nor were prepared to learn them. Older designers were less interested in learning the technology

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[6]Company 5 had a history of downsizing. Staffing levels shrank from 7,000 to 1,400 during the 1970s due to dwindling business demand. In spite of this, CAD and CAM systems did not impact employment levels in any obvious manner.

[7]See also Badham (1991) and Brodner (1990) in this connection.

and had less desire to become regular users. Management selected CAD users who were younger by an average of about nine years. These were directed specifically towards new design projects. By doing that management selected the path of least resistance. It was clearly the case that older people refused compulsory training on the then "new system" because this to them meant a loss of job autonomy. Consequently, management did not hesitate to "release" them. In return, they were offered vacant or newly set-up positions elsewhere in the organisation. Although some of them were happy to accept such an offer, others preferred to leave the company and look for a job elsewhere, while still others decided to take this opportunity to retire at once. In this case no more than 26 workers lost their jobs out of a total of 148 employees.

Youth was, evidently, a significant factor in empowering a new class of designers to the detriment of older ones, as could be inferred from a self-told story of a graduate engineer in his mid-30s:

> "These guys are engineers, 20 years more experienced than me or 20 years older than I am, so they have a lot more experience than I have, except when it came to the computer and some of the mathematical techniques. Most of these guys are *HND*-qualified, although again that was a long time [ago], 1950s type *HND* and they would go many years later for *Chartered Engineer* certificates. I come from a university. I don't have as much practical experience .... although I think I have a mathematical approach to jobs that they don't have ..... they occasionally come up against the odd computer problem and 'there must be a better way to do this on the computer and: [naming himself], how would you do this?'. And I think I get asked more questions of how I would tackle a piece of work whereas before when we worked on the boards I had to ask them the questions because they were much more experienced than I. It's changed that aspect ..... " (Case 10).

In some cases "experts" had to be hired especially to manage system introduction or to teach staff how to use newly introduced technology: "We had to create a responsibility for CAD" (Case 3). In other cases, there was no need for hiring people from outside. Huge systems, such as the CAD systems implemented in Case 5, required the appointment of highly qualified CAD specialists who could lead the process of implementation, organise work around the system, and provide the required level of technical support.

With regard to training, different arrangements were sought by different companies. In some cases certain middle managers were concerned that senior management gave due attention to training but not to education. As the Training Manager of Company 4 put it:

> ".... that's the hardest bit - to educate people ..... very, very difficult to get the message over about the need to educate. ..... I am fearful that that message will not get across adequately and they [senior management] will be perfectly happy to spend a 100% on the hardware and the software, 50% on the training, nothing or 10% on education. I believe that education is even more important than training, because if people aren't committed they'll beat the system; they will not let a machine beat them. So I'm concerned, I don't know how to get my message across better ..... " (Case 4).

In Case 5 some technical managers showed concern that the training provided, which was aimed mainly at developing operating skills, was necessary but insufficient; they believed this should be coupled by specialist training courses in order to develop skills associated with managing newly introduced technology as well as transformational skills associated with its implementation:

> "Obviously we need to have more training, not just [on] the actual use of the system but in the changes, in the development process too. ..... The thing is that it is very, very difficult - unless you have a very good knowledge of the developing processes on CAD .... - it's very difficult to do any evaluation before and after because you are never comparing like with like. ..... We need to get training in process changes: why are we changing the process? What are the benefits of concurrent engineering? What are the benefits of solid modelling? We need to train people in those aspects as well." (Case 5).

Training programs were often provided by leading technology vendors. Company 4 could afford to be self-sufficient in training without needing external assistance, due to a massive technical skill base available at its disposal. Different types of training programs were organised to meet skill needs for operators, users, supervisors, managers, programmers, and technical support personnel. The introductory training programs varied, therefore, according to the intended purpose of training, from basic 2-day "hands on" to advanced three-week full-time courses aimed at selected individuals with an orientation towards specialist skills.

It should be mentioned that training correlated highly with organisational learning, particularly in Cases 4 and 5, the companies with the largest technical skill bases in the study. In these cases vendor training on new technology was needed initially but, with the passage of time, individual and organisational learning[8] allowed them to be self-sufficient in providing more advanced training independently "in-house":

> "It was initially [acquired] as part of the capital purchase program and once you get a certain amount of learned knowledge in, then we try to use our skills to train, but there are specialist courses and so on ..... There's no way you can take those new tools unless you have the knowledge." (Case 4).

> "There's the basic training given by the software vendor as part of the installation. .... the other thing is that we will have a couple of guys as well who will become more skilled because they will be the application support group and also they can handle and do ad hoc training and as they develop extra functionality they can get trained in there. .... once the environment got bigger and a lot more people got trained then it was a lot easier as other users had a lot more experience, so they could relate and learn what not to do." (Case 5).

* *Job Design Impacts*

Job design impacts of CAD and CAM systems could be discussed at two levels, from the points of view of: first, those who supervised and managed technology, and second, those who used or operated it. Investigation in this area aimed to understand

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[8]See Attewell (1992) and Kim (1993).

how the introduction of such systems affected task complexity, variety and interdependence for the individuals involved[9].

*****User / Operator Jobs***

In general, individual system users/operators tended to be initially cautious about new technology. This was more true for CAM than CAD cases: ".... if you're going to be a mechanical engineer you're going to be a mechanical engineer and CAD comes as a secondary part of it ..... rather than you're a CAD operator" (Case 5). However, those who had not refused to work with new technology as a matter of principle tended, in general, to adapt to it gradually. In Cases, 3, 4, 5, 6, 7 and 9, they even tended to ask management to introduce more of it:

> "We've got into a stage where rather than people saying we don't want machines, they are now saying we want more machines .... they became dependent on the system ..... " (Case 5).

> "Each of the engineers wants to have more automation tools than ... he [already] has in. I have constantly had requests for more PCs and more software and more systems requests." (Case 9).

In human terms, outcomes were mixed: some of the jobs created were good, some bad, and some indifferent. The highly subjective nature of job satisfaction assessment was evident from different individuals' responses. It should be studied only in terms of the personalities of the specific people concerned, as one manager pointed out:

> "It depends on what your goals in life are. If further technical understanding is something that turns you on then you get more job satisfaction out of it; if it is something that pisses you off then you won't get more satisfaction." (Case 8).

It should be noted that it was not job content alone that increased, or decreased, job satisfaction. Other elements, such as pay and bonus, status, industrial relations, and informal social relations, also played a role[10]. It might have been expected that job computerisation would invariably increase employee satisfaction. Surprisingly it had the reverse effect in those cases where the change was imposed upon them without consultation or because there was insufficient time to provide the necessary additional training which would have probably made a difference. Nonetheless, in the majority of cases increased skill levels correlated with higher job satisfaction: "..... much more interesting. ..... more productive - you can go home and feel you have produced more, so achieved more. That in itself is a great achievement" (Case 1).

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[9]It was evident that shared commitment, by both user and supervisor groups, was greater when these were involved in the introduction process. This was found to be equally true for different functional groups when all of them were involved during agenda formation and selection as important decisions were made about integration. In line with Scarborough and Corbett's (1992) proposition, it could be argued that the higher the degree of involvement, the more likely a shared commitment would be found.

[10]See Truman and Keating, 1988.

*** Manager / Supervisor Jobs*

Middle level technical managers in charge of design/engineering, and manufacturing functions played a crucial role in promoting technological change; therefore, their role should not be neglected in researching the implementation of CADCAM integration (see Beatty and Lee, 1992). They were themselves affected in different ways by change. So were supervisors and senior designers. CAD made design managers feel that their jobs became more challenging (Cases 2, 3, 9 and 10). CAE and CASE[11] forced a higher level of co-operation amongst previously independent engineering teams (Cases 4 and 5). This encouraged the integration process in these two cases.

No role conflict was found between design supervisors' jobs and emerging CAD managers. Supervisors did not feel alienated form their own subordinates who happened to be CAD users and now turned to CAD managers for consultation and technical support. In general, training was provided for those supervisors who also became CAD users and, thus did not have to experience bitter feelings of passing their traditional supervisory role to a senior designer assuming a new authority. The only exception to this situation was found in Cases 5 and 10 where CAD supervisors were extremely critical of senior management's lack of technical knowledge and interest in integration as well:

> "Management of the whole system's gone a wee bit astray over the last two-three years. ..... It would make life a bit easier if they were at the same level. ..... That's not gonna be easy: to train managers to be more aware technically ..... " (Case 5).

> ".... They don't know enough about it. I know so much more about it .... but it's to me and the Data Processing Manager to do it; it won't come from above. ..... With the MD personally, of the people now on the Board, he is the only one who can switch a computer on and use it ..... in the slightest way." (Case 10).

CAM was found to increase co-operation requirements among system managers, operators and programmers (Case 8). Also, it increased supervisors' job satisfaction and managers' overall control level (Case 8) but made managers' jobs more stressful because of the need to learn extra computer skills (Cases 1 and 8).

A general trend could be identified among the larger companies; the production planning and control function shrank and became less powerful. Its task domain became limited to maintaining CAM, costing, and converting customer orders into production orders. On the contrary, CAD gave the design and development function a greater role than in the past; it became responsible for the maintenance of CAD in addition to its conventional responsibility for product configuration and producing design information and plans for general development.

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[11]In application in Case 4 only.

*** *Impacts on Industrial Relations***

In general, employers took the view that it was their right to introduce new technology as they saw fit and, hence would not hesitate to take unilateral actions on the matter. This triggered fears of worker displacement and unemployment in some cases, particularly in low trust environments (see Deery, 1982). As a result, trade unions were prepared in some cases to take an aggressive stance to insure long-term employment security. However, such action depended highly on the unions' bargaining power which appeared to be rather weak in most of the companies studied. In this regard, the findings confirmed Baldry and Connolly's (1986) observation on the remarkable absence of formal new technology agreements in seven CAD user firms which he studied in Scotland. The craft control traditionally monopolised by unions appeared to be greatly weakened.

In general, CAD systems were hardly faced with any kind of organised resistance. On the contrary, some groups of engineers were found to demand more technology of their managers (Cases 3, 4, 5, 6 and 7). The only exception to this was found in Case 5 where some of the older employees took a unified stance by refusing to co-operate in learning computer skills.

Cases of CAM introduction, however, involved less stable industrial relations and a less efficient form of work organisation. Indeed, in some companies (e.g. Case 8) changes could only be introduced gradually after some months of instability. From the outset, unions' concerns revolved around job security, pay and conditions. Organised shop floor workers and engineers were "invited to participate" in the process, though the extent of involvement differed from one company to another. According to Frohlich and Krieger (1990), the intensity of union involvement in technological change would range from full participation to no participation through negotiation, consultation, information during planning, selection, implementation and evaluation phases. In the cases studied union participation in change revolved around consultation and information but fell short of reaching negotiation. For example, senior management's attitude in Case 2 was that: "people are naturally resistant to change. It's the Machiavellian approach; people always feel they have more to lose than to gain" (Case 2).

Unions' reaction to CAM technology often began with suspecting management's intentions, particularly in those cases where labour cost reduction and increased managerial control through deskilling of labour were explicitly set out as the prime motive for introducing CAM. Worker-management relationships became extremely strained in Case 8 as unions resisted change. Historically, management-union struggles resulted in an empowered management position to the detriment of the unions. This situation caused some individuals and groups from amongst union members to withdraw because they felt that the union could no longer serve their interests with the present balances of power: "they were only interested in our monthly dues" (Case 8). They felt that they had more chances for realising their ambitions if they allied with management. As Sarfati and Cove (1986) pointed out, international employee organisations had campaigned hard to offset the negative aspects of the introduction of new technology into the work place. Yet, the unions in the studied companies appeared to be largely ineffective in co-steering technological change in a direction which would protect their own interests.

It could be said that, in general, the introduction of new technology *per se* had not constituted a serious industrial relations issue in the studied companies over the last 15 years. However, those larger organisations with poorer management-union relations, such as Company 5, were more likely to suffer what Lee (1989) termed a "low trust" atmosphere or culture with negative implications for technological change due to minimal consultation or an early breakdown of dialogue. In these cases unions would be likely to resist but, in the long run, their standing might be considerably weakened due to members leaving or rejecting their leadership. This would be likely to leave them unable to halt the introduction of proposed systems. A period of hostilities would follow during which both management and unions could become losers; management's urge for a speedy improvement in productivity would not be achieved and the unions would stand to lose their influence in the organisation. Managerial strategies could be intentionally formulated so as to exploit technological change as an opportunity to reduce union power. By contrast, "high trust" relationships would encourage union representatives to be actively involved to create, by virtue of negotiation, an enhanced work situation with the new technology (see Clark, 1989; Frohlich and Krieger, 1990; Lee, 1989; Sarfati and Cove, 1986).

In general, the findings did not support labour process theorists' argument[12] about deskilling in the drawing office, namely that CAD, on introduction, would lead to draughtsmen and designers being deskilled (Cooly, 1983). Similarly, the findings did not agree with Baldry and Connolly's (1986) proposition that CAD would cause fragmentation of the social cohesiveness of the drawing office by giving management a greater direct control through a progressive deskilling process involving the storing of data in the memory of the computer rather than in the minds of the draughtsmen. On the contrary, some draughtsmen, particularly younger ones, said they felt that CAD gave them a chance for upskilling. Indeed, some other researchers (e.g. Adler, 1989; Clegg,

[12]After Henry Braverman (1974).

1990; Forslin *et al.*, 1989; McLoughlin, 1989; Salzman, 1989) took issue with such "mechanistic" accounts of analysis based on their critique of the proposed link between Taylorisation and the inevitability of technological determinism. The counter-argument would be anti-determinism and would revolve around reskilling or upskilling, rather than deskilling; CAD changed the skills required to draw but did not transform the engineering knowledge and expertise. Additionally, CAD/CAM created an upgrading trend in the overall skill requirements of personnel both in individual occupational categories and in the balance between occupations and allowed engineers a higher mastery of such tools, whereas CAE shifted skill profile and recruiting criteria upwards.

To imply that power politics in the context of the organisations studied were confined to capital-versus-labour agencies, as the traditional Marxian perspective would stress, would be not only be simplistic but also empirically inaccurate. It would neglect, for example, the role of strategic choices open to management during implementation, the factors influencing such choices, and the effects of such choices on the outcomes of change (see Buchanan and Boddy, 1983; McLoughlin and Clark, 1988). At the same time, it would give no or little attention to livelier power contests among different groups of management, between functional departments, and among groups of workers scoring "political points" against each other: "the traditional Marxian conception of the politics of production as a zero-sum game is no longer very useful" (Clegg, 1990: 216). However, although such livelier power contests existed in different forms in the researched organisations, they would not seem likely to cause existing structures to change radically in the short-term due to the legacy of a long-established management-versus-union industrial relations tradition.

**** Impacts on Inter-functional Relations***

The organisational effects of introducing CAD systems were often confined locally to design functions (in Cases 6, 7, 9, and 10) due to a deeply-rooted tradition of compartmentalised work organisation. It seemed that the rational basis for this tradition had not been subjected to a thorough review since the 1950s and 60s: "They tend to stick to their [jobs?]. ..... It's probably more historical, you know, that's what they've ..... always done" (Case 6). Invariably, the introduction of CAD systems affected design and engineering, or "the front end function" (Case 8) as they were called by their manufacturing colleagues. CAM, on the other hand, affected manufacturing and production. The effects of what was always perceived as a "departmental concern" only rarely transcended the boundaries of the functional department into which a system was introduced. This was truer for the secondary cases in general. Indeed, it was found that Companies 3, 4 and 5 experienced a pressing need for a closer "bi-directional communication" between design and manufacturing managers, as a result of implementing CAD and CAE, to facilitate a better understanding of each other's contribution to the overall work mission being accomplished.

> "..... we need to have more integration, but certainly greater communication .... Without that you can't have concurrent engineering ..... " (Case 5).

In some secondary cases managers on the manufacturing side found it necessary to complain to the Board, through the directors representing them, about the lack of consideration given to the "manufacturability" properties of the products they had to produce. "Front end guys" were blamed for this. Designs supplied by engineering departments were outstanding had they been judged by criteria of pure technical excellence. However, they made manufacturing engineers' jobs difficult because they could not produce the parts as designed, either because they could not make them within the manufacturing capacity available to them or because they were excessively intricate so that they needed longer and more demanding operations which could not be done in time for a competitive delivery, due to tight production schedules. Even in those cases where such complaints negatively affected inter-departmental relations at a managerial level, senior management were rather hesitant in addressing the issue to the satisfaction of the manufacturing managers: "..... they're taking the political, easy way out" (Case 10).

Under existing departmentalised structures manufacturing managers recognised very well that the role designated for them was restricted to producing a product according the specifications outlined by the "front end guys" but not to interfere in how design information was created or changed. As the Senior Production Engineer of Company 8, who was assigned overall responsibility for manufacturing operations, put it:

> "We get only three or four files out of the whole package. We don't get the full design package ... so we can't make head or tail of how the board functions; all what we are doing is making phototools. It doesn't tell [us] how the board actually will function electronically; the design does, but the bits we get don't. ..... you go back to [the] design[er] and tell him he has an error in his design. He has to do it. We don't understand ..... It's his responsibility that the design of the board should meet its requirements. If he fails in that responsibility, only he can make a decision to change it. We can't go around changing his design because we don't know what effect the change we make would have on the functionality of the board. So it's not our business [to] start changing designs; he is the only one that knows how that board functions or should function. He should've designed it to meet that requirement ..... " (Case 8).

Such problems were also experienced in the primary cases, particularly in Companies 3, 4 and 5, but to a lesser extent and compromising solutions were found faster to the delight of manufacturing managers.

A similar inter-departmental managerial conflict was found only in Cases 4, 5 and 10. Historically, in each of these companies, which happened to be among the three largest in the study, a DP (Data Processing) department had been in operation as a management support function since the late 1960s and early 70s. Managers of these departments became increasingly powerful with the diffusion of the computerisation phenomenon as a result of more affordable and more efficient micro-processors. Traditionally, they had controlled all the activities associated with computers in these companies under existing accounting rules. They had been powerful as far as power had been "implicated in authority and constituted by rules" Clegg (1991: 18). As CAD and CAM systems became more widely used in industry, however, DP Managers felt their prestigious position was being challenged or even undermined increasingly due to competition from the "new system managers". In Clegg's (1991: 35) terms, both groups of managers were "implicated in circuits of power whether they intend it or not". It could be seen that the introduction of such systems threatened to disrupt existing power relations in these cases[13].

Such a conflict, which appeared to have originated due to a combination of divergent interests of departmental subunits (see Manske and Wolf, 1989) and differences in defining organisational reality (see Aldrich, 1979), grew and became more personalised with the advent of integration because integration leaders in Cases 4 and 5 looked beyond their immediate functional boundaries for integration. In Case 4 particularly the integration "champion" exhibited charismatic leadership behaviour through outstanding "envisioning", "energising" and "enabling" skills (Nadler and Tushman, 1990: 82)[14]. It was understood by many people in these cases that this would eventually involve the entire organisation in question. In Case 10, for example, the finance and data processing departments had, traditionally, worked closely together. Their strongly coupled relationship seemed to have deprived the technical department of considerable progress towards integration. Interdepartmental conflicts involved attempts to

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[13]As suggested by Scarborough and Corbett (1992: 58):

> "Even in minor applications, existing power structures would be disturbed by the introduction of new technology and, as a consequence, the implementation process would reproduce (and amplify) existing strains and conflicts within the organisation."

Indeed, the influence of various interest groups in initiating and exacerbating conflict could not be ignored. As Aldrich (1979: 91) put it:

> "Conflict within organisations is an important source of organisational variation, as disintegrative and independence-generating forces cause schisms between members, departments, programs, and other subunits. ..... control over resources, and the consequences of control, makes organisational participation a game of high stakes. Members seek their proper share of whatever resources an organisation has to confer."

[14]See also Beatty and Gordon (1991) and Howell and Higgins (1990) for conceptions of change championship.

delegitimise opponents' claims for funding new technology projects by, for example, recalling experiences of failed projects. The Technical Manager explained:

"Our finance department, who really had an influence on the data processing department, they were responsible for computer purchases, they didn't want us to go and buy *Apollos* and *SUNs* ..... so we were pushed really into PC systems. It wouldn't have been my choice .... it was that our data processing department were very closely linked to [the] finance department and the Finance Director at that time was involved in the use of computers wherever they were used throughout the company and they knew PCs, they didn't know *Apollos* and they didn't know *SUN* work stations and they pushed for PCs. ..... There was a lot of obstruction from the finance department .... they said : 'Well, I'm not spending, we're not spending more money, because - you know - without a return! ..... How do you know you can make the new one work?'. ..... There was always the thing: 'you've never done anything about CAD, you've never done anything about CAD!'. I said: 'Well, I have done something about CAD, but you're not prepared to spend the money!' .... When it came up to a little more that £10, 000 they would be able to put up a barrier to it ..... " (Case 10).

Personalised conflicts were not unexpected since the allocation of resources, income, status, and prestige by organisations affected their members' life chances and power in the larger society (see Pfeffer, 1977). DP Managers, who regarded themselves as guardians of their companies' information systems, regarded this as an expansionist behaviour aimed at a territory which had been under their control for a long time. From their point of view, senior management should by no means empower integration leaders who had a vision of an integrated organisation.[15]. It was not surprising, therefore, to find that in such organisational contexts the conflict was highly politicised and caused an impeding intra-managerial obstacle to integration[16]. This was true even within separately grouped work teams within a single function, as could be deducted from the following remark by the leader of one of the design teams in Company 9:

"I drew them separately [referring to a hand-drawn organisation chart] because they are separate. This side reports to the operations managers, I report to the VP [Vice President] - Engineering, who is resident in Florida .... where our headquarters are. ..... There are strong links functionally, there are tensions as well ..... between our departments; our engineers work together, they have to! ..... They mix together, in fact! ..... So there are strong links but we are separately structured ..... " (Case 9).

It was apparent that inter-functional conflicts were worse when: (1) dominant departments made excessive demands on others, (2) the latter felt particularly unhappy about the role allocated to them, which failed to match their expectations, and/or (3) the

[15]This could be conceptualised as another substantive example of "power stripping" from the point of view of DP Managers (see Chapter 7, section 7.4).

[16]Support for this point from the organisation studies literature could be found. For example, Adrich (1979: 97) contended:

"Organisations are not neutral objects, passively responding to .... members' needs, but rather are powerful centres of resources that are bound to conflict. Some conflicts have a purely personal referent, as individuals seek to improve their relative standing by gaining access to a larger share of organisational resources. ..... Other conflicts, however, involve entire subunits and departments, partly because organisational differentiation incorporates such conflict into the organisation and partly because coalitions of vested interests have very different ideas about the uses to which organisational resources should be put."

latter were dissatisfied with their less advantaged status in the organisation due, for example, to differentiated performance criteria and rewards. In this connection, organisational structure would be both "a source of control and communication and a mechanism generating variation and conflict" since "some properties of organisations which give them their strength also contribute to weakening them" Adrich (1979: 93).

Design staff, or "the indirect boys upstairs", were answerable only to the "people upstairs [i.e. the Board of Directors]". They often had an advantage over their colleagues in manufacturing, "the direct boys downstairs" (Case 10), for a number of reasons, including structural and environmental ones, leading to a status of differentiated organisational positions:

> "..... There isn't necessarily a structured route for the design process. There is for manufacturing, because there has to be for *BS 5750*, for the manufacturing process to be structured, but the design process is not structured ..... they tend to respond to particular design work as a one-off each time. So it depends on what it is, who the customer is, and who is doing the design, the response will be different." (Case 6).

6) Why does a manufacturing company seek (or decline) to integrate CAD and CAM systems?

The philosophy of CADCAM interfacing specifically, and integration in general, and its implications for individual job design was best summarised by the leading technologist in Company 5 in the following words:

> "You need to look at your overall global process and if you have to optimise one sub-process to get overall optimisation then so be it ..... but the whole enterprise need to understand that and the department manager - you know - obviously hasn't got to be penalised." (Case 5).

In general, it could be said that the principle of integration was taken more seriously in the primary than in the secondary cases. However, each of the companies tended to define integration in its own way, depending on how it was perceived by its leading change agents in the context of their specific production environment. Hence, it was not surprising that different companies gave different formal techno-economic rational justifications as to why integration was sought. Exhibit 6.3 summarises the reasons given in justifying CADCAM integration in the primary cases.

Integrated CADCAM differed radically from stand alone CAD or CAM systems because integration "is not an off-the-shelf product; it is a concept" and, thus, "what gets integrated with what - and to what level - is very much a local decision related to the specific contingencies of that situation". Therefore, the success of an integration project would depend on "understanding this and having the necessary strategy to relate it to the needs of the business" (Bessant, 1991: 294).

Exhibit 6.3

Summary of main reasons given for pursuing CADCAM integration in primary cases

*"Providing technical support throughout the organisation" *(Case 1)*

"Rationalising utilisation of resources available to company"(Case 2)*

*"Allowing manufacturing function a direct access to CAD-generated database information to eleminating error and waste in production operations" *(Case 3)*

*"Achieving a free flow of information among different disciplines throughout the organisationa through CE" *(Case 4)*

*"Improving interdepartmental communications" *(Case 5)*

The findings supported Dean and Snell's (1991) conclusion[17] that different organisations used different techniques, and used various names for the same technique, when integrating job and organisational designs to achieve integrated manufacturing. The findings also showed that functional integration was not the only axis for assessing an integration project since stage integration and goal integration were also important axes for analysis, as will be explained in the following chapter.

Indeed, it could be said that cross-functional CADCAM integration was not the only type of integration found; intra-functional applications of integration, such as those involving interfacing various computerised systems within a design or engineering function (e.g. CAD and CAE in Case 3; and mechanical CAD, electronic CAD, assembly design CAD, and technical publications departments in Case 5), were in some cases regarded as equally or more important than CADCAM, and thus given priority over it:

> "I agree with the principle of integration ..... I think it's probably almost greater within design than between design and manufacture." (Case 3).

> "Design is the key one and then subsequently we want to link throughout to all the ancillary ones ..... but the key one obviously is if we can integrate our computers for the design and then to manufacturing." (Case 4).

Furthermore, it could be said that cross-company integration was found to be of considerable importance to some companies, particularly in Cases 1, 4, 8, and 10 due to their extremely close collaborative relations with their key customer firms. In Case 10 in particular it was regarded as being much more important than interfunctional integration within the company.

Exhibits 6.4, 6.5 and 6.6 show Bessant's (1991: 55) models of integration[18]. The three models have one characteristic in common, namely that they emphasise that integration is a long-term, multi-phase undertaking. Exhibit 6.6 represents the various levels of integration that could be found in a manufacturing enterprise within an evolutionary process of development from level 1 to level 5:

> "..... it's a very long time ago .... and there's been a steady evolution .... and it evolved into [a] bigger, more complex system over a period of time. ..... We implemented it over a number of years .... I'm a very strong believer in evolution." (Case 3)

> "We will approach it slowly. It [i.e. the integration process] will take years ..... " (Case 4).

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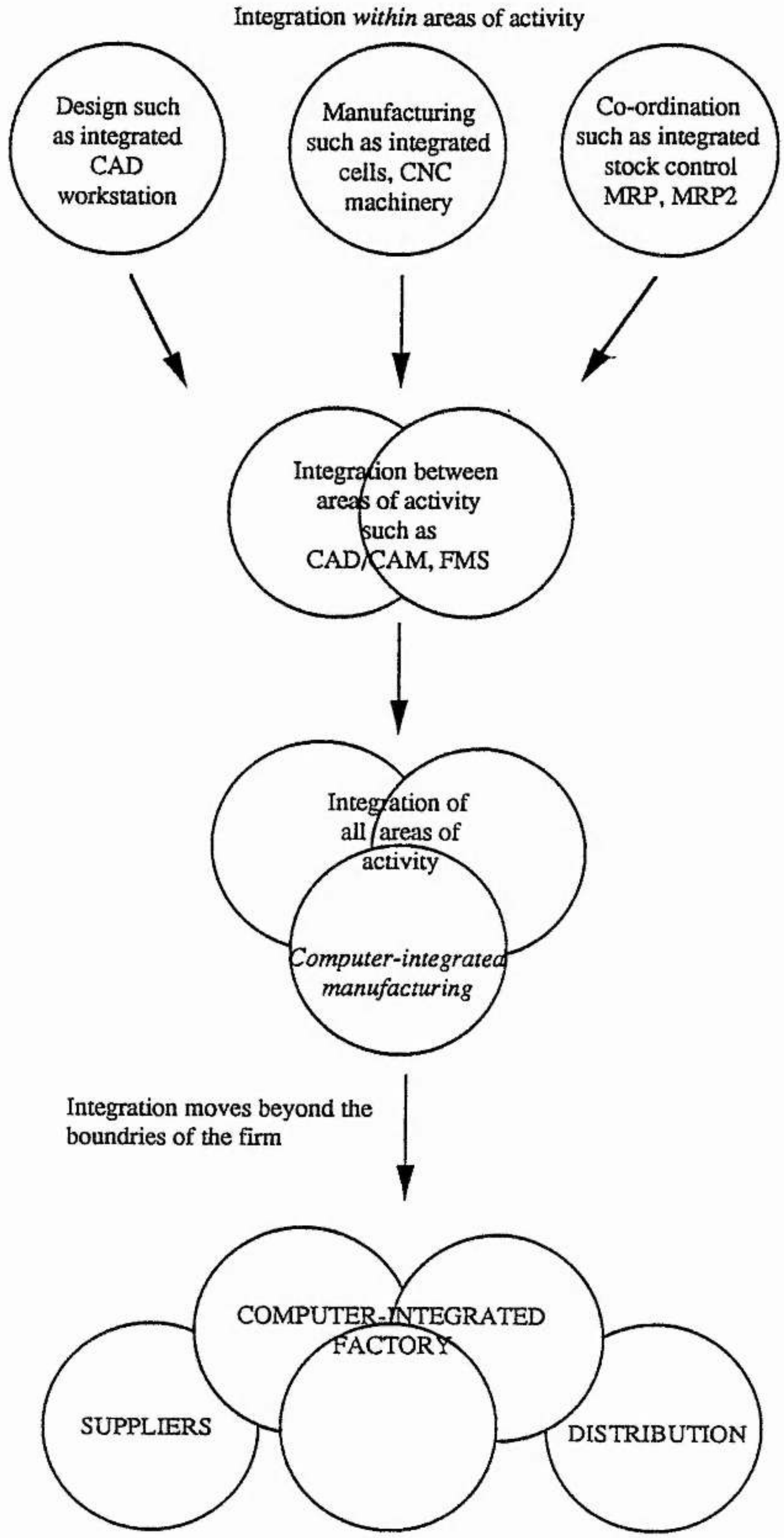
[17] Their study was critically reviewd in Chapter 2.

[18] The convergence to CIM model was derived from Kaplinsky (1984).

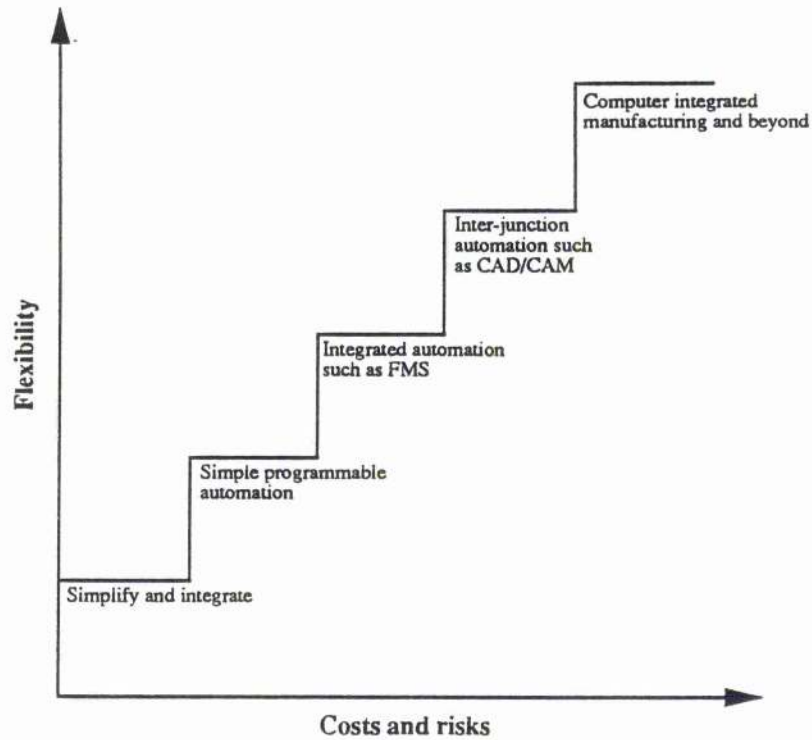
Exhibit 6.4
Convergenece to CIM



Source: Bessant (1991), derived from Kaplinsky (1984)

Exhibit 6.5

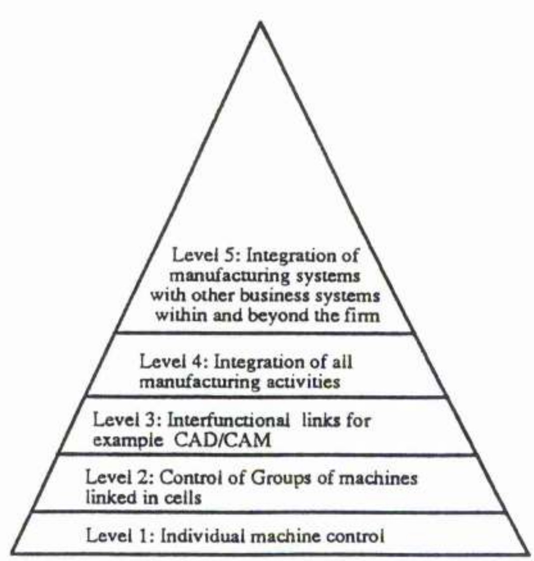
Steps-by-step progress towards CIM and beyond



Source: Bessant (1991)

Exhibit 6.6

Hierarchy for Computer-Integrated Manufacturing



Source: Bessant (1991)

AMT in general and CIM in particular were often described as a "competitive weapon", particularly in larger companies. It should be noted that immense competitive pressures were a crucial factor in driving companies towards CIM; it was not purely a matter of elective natural evolution that they adopted such technologies.

Awareness about product quality was, in general, on the increase in all the cases; the pursuit of responsiveness through flexibility maximisation seemed to outweigh the search for efficiency maximisation through a productivity-oriented culture. Product quality was not only important to outside customers but also internally. Whatever the product being made, it was becoming increasingly important.

Managers looked into their own organisations to make sure they were fit to meet customers' expectations and became concerned about improving their quality performance, not just in terms of finished products but also in terms of the quality of work carried out between departments. Computer managers, for example, had to be told to improve the work quality of the systems they were responsible for, because these offered a service to other employees who happened to be information users.

In this sense, users became regarded as customers in much the same way as external customers to whom finished products were sold. The increasing concern about quality, often expressed in the shape of a TQM program under a "continuous process improvement" slogan (e.g. in Cases 4 and 5), shifted management's attention to the significance of the organisational factors by forcing them to intensify inter-functional communication and co-operation. The aim was to improve quality of service internally and thereby improve the services provided to customers.

Hence, striving to build the concern for quality into departmental work contributions, in response to external commercial pressures, would potentially facilitate further integration at the organisational level. It could have a greater integrating effect, however, had senior management been as enthusiastic about TQM as middle and technical management were, for in most of the cases it was the latter who were assigned responsibility for quality improvement; they took it happily in order to improve operational performance.

The missing link, however, between an improved operational performance and a potential strategic advantage could be largely attributed to the view taken by many senior managers of quality as a strategic consideration whose translation into a profitability gain did not have necessitate personal involvement on their part. They left it to middle managers to implement TQM without them getting personally involved in implementation and monitoring. Although a TQM program would be, essentially, about communication and co-operation among all members of an organisation, the gap of communication which existed in larger companies between senior managers on the one hand the rest of the organisation on the other could not have narrowed as a result. Worse still, some line workers refused to participate in TQM because they believed this, like other senior management initiatives, would not work; it was imposed from above. Some of the middle managers who were selected to champion TQM complained that they neither succeeded in convincing a great number of operators to co-operate nor in filling the communication gap at the top of the company.

With regard to the secondary cases, on the other hand, Companies 6 and 7 insisted formally that integration was not "relevant" to them; Company 9 believed in it, in principle, but admitted it did not take implementation seriously; whereas Companies 8 and 10 thought about it and discussed it as a potential future direction which would have perhaps been tackled more seriously under better market circumstances, but took no practical steps towards its implementation.

Therefore, to reiterate what was mentioned in Chapters 4 and 5, the secondary cases could be differentiated on the basis of their position vis-a-vis technology-induced organisational integration. The likelihood of them implementing CADCAM integration in the foreseeable future was not generally very great, although they varied considerably.

As mentioned above, various justifications were formally given for the lack of integration in these cases, as explained in Exhibit 6.7. The obstacles to integration in the secondary cases were linked to an intricate set of contingency factors. This point will be discussed in detail in the following chapter with reference to groups of factors influencing integration in the primary cases.

As was explained in Chapter 4 (sections 4.3 and 4.5), the question of whether a company should be categorised as a primary case or a secondary one was determined completely by its specific stance vis-a-vis CADCAM integration. The categorisation was created for the purpose of the present research data analysis. Both types of cases were chosen from the same range of the new Scottish electronics industry - both users of CAD / CAM for mechanical, electrical, and electronic engineering manufacturing; both had used CAD / CAM for more than five years; and both used DEM processes capable of being integrated. In essence, the difference between the two categories lay in where each company stood in relation to integration: in general, the primary cases embarked on integration and moved some distance towards realising its potential through an on-going process of transformation whereas the secondaries did neither.

Exhibit 6.7
Summary of main reasons given for the lack of integration in secondary cases

*Lack of "functional overlap" between design and manufacturing technologies	*(Case 6)*
*The business biased towards manufacturing at the expense of design	*(Case 8)*
*Integration costs could not be justified fiancially under difficult economic circumstances	*(Case 8)*
*Lack of senior management interest in integration	*(Cases 6, 7, 8 and 10)*
*Insufficient resources available for integration	*(Cases 6 and 7)*

Of course, it would be important to address the question of why some companies went along the direction of integration whilst others did not. The primary and secondary cases could be compared in terms of their respective technical, economic and organisational characteristics with a view to addressing the above question. In this respect five points could be made:

1) All the primary cases were already users of both CAD and CAM technologies but not all the secondaries combined, readily, the use of both technologies. Some of the secondaries (e.g. Cases 6 and 7) used only CAD because they were satisfied that CAM was unnecessary for producing the types of product they made, although, from a purely technical point of view, they were capable of using CAM and integrating it to CAD without major difficulties. The presence of both areas of computerised applications in the primary cases was a clear advantage to them in that they could advance towards integration earlier than the secondary cases. The fact that some of them did not have CAM in use would not mean that if they did they would have moved instantaneously towards integration. A clear proof of that was the fact that some of the secondary cases were already using both application areas but did not embark on integrating them, and continued to use them as strictly separate stand alone systems to support functional work tasks within an existing structure. In other words, the decision to adopt an integration strategy would never be determined entirely by a company's technical capability of physically interfacing such application areas and setting up an integrated DEM process around them.

2) The vast majority of manufactured products included large numbers of design elements, production activities, materials as well as a diversity of complex data abstracts. Due to the fragmentary nature of existing DEM processes, each company had its own specialised data representation. Developments in the data modelling and database management system markets contributed to a greater desire for data integration in industry in general. Also, a greater diffusion of CAM technology over the last two decades or so and a wish to use data exchange to link CAD and CAM were major factors contributing to the development of more sophisticated data exchange systems in supply today. Data exchange processes, however, had been a practical reality for only about a decade and were not entirely straightforward. Representation and communication of design information remained to be unstandardised and complex, thus forming a major technical barrier to integration.

Efficient data exchange between applications in a company or across companies would be the key factor in integrating design and manufacturing information. The lack of a unique set of standards to fulfil the requirements of a complete CIM system[19] was a major reason why non-integrating companies chose not to take the trouble of adopting CIM[20]. The primary companies took it upon themselves to challenge such a technical barrier with all the other financial and organisational challenges associated with it whereas the secondary companies did not.

3) The type of industry in which a company operated and the type of supplier-customer relations characteristic of such an industry would affect how the company responded to industry-specific standards of quality. In general, the primary cases were under greater pressure to integrate because of the nature of their respective products. With regard to the probability of integration in the secondary cases in the foreseeable future, the competitive and technical pressures on Company 10, for example, were much greater than they were on the other non-integrating companies; it would be likely to have to respond to them sooner rather than later by adopting an integrating strategy and linking CAD to CAM for an integrated corporate performance.

4) An organisation's size appeared to play a vital initiating role in this; the larger the company, the more likely it was to integrate in the near future[21]. Despite the managerial difficulties large organisational size seemed to create, it appeared to be a significant factor in encouraging integration. Results of the analysis of the data on the primary cases (see Chapter 7) also suggested a similar pattern. In the context of the present research data, a primary company, on average, would be about four times the size of a secondary one; on average, a primary company employed up to 521 employees and a secondary company up to 136. Companies 6 and 7, the smallest in the study, were the least concerned about integration. In both cases only a single technology capable of being integrated was found (i.e. CAD). Integration, therefore, had not yet arisen at a technical inter-system level. Although the lack of senior management's interest in integration was common to the smallest and largest secondary cases, the pressures appeared to be greater on larger companies to change. Insufficient resources were the common major obstacle in Companies 6 and 7. Their business operations seemed to be

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[19]See Boubekri *et al.* (1995).

[20]The standards required would cover important areas such as: (1) data communication and networks used in computers in manufacturing environments; (2) CAD systems, robots, and CNC; and (3) CIM architecture design. From a technical point of view, the implementation of an electronic data exchange system could, potentially, facilitate: (1) an increase in the level of inter-functional integration between design and manufacturing, (2) integration of various design teams and, thus, of the design process, (3) integration of design and manufacturing information, and (4) integration of development and maintenance efforts on a manufactured product.

[21]With the exception of Company 8 which would have stood a greater chance for integration than Company 9 and probably Company 10, too, had it not ceased to exist as a business.

well defined and put under a much greater degree of control; their flexible but long-established relations with their customers seemed to have resulted in lower pressures, given them a greater sense of security, and made them think that integration would not be vital, particularly in the case of Company 6 where management expressed their doubt explicitly about the mere plausibility of CADCAM integration in industry. Small companies' perceived lack of need for technology and prohibitive expensiveness were major factors behind their hesitancy to adopt CIM[22].

5) The social and political forces in the primary cases were more strongly in favour of integration, on balance, than they were in the secondary cases. As will be explained in the following chapter, the social processes that preceded and accompanied integration in the primary companies were an expression of a shift in the balance of power in favour of left-wing integrationist forces at the expense of right-wing conservative forces. In the secondary cases such processes had not matured yet and the dominance of the conservative forces, which held on to existing structure and culture, continued.

The following section concludes answering the tentative research questions by addressing the issue of how integration projects were found to be managed in the primary cases.

7) *Where applicable, how does a manufacturing company manage the integration of CAD and CAM systems in the context of its accumulative experiences in this area of technical change?*

Approaches to the management of integration processes in the primary companies were diverse indeed; there was no single method, nor was there any standard course of action. Nonetheless, each integration effort involved a long-term process of change with CE at its centre. This involved a replacement of a sequential flow of work whereby each department contributed to the DEM process at a certain stage of a product development cycle with a different one whereby each department's contribution would be made to correspond to other departments' simultaneously:

> "Whereas before the drawing or whatever was with the designer, and the guy in manufacturing never saw it until he released it. Nowadays if he wants to call up the part that that guy designed and have a look at it and make some form of comment as to whether it is good or bad to manufacture. It also changed group set-ups as well where [the] manufacturing [department] are a lot more involved at the early stages of design. They can make comments whether the part is easy to manufacture. When we were in the drawing board system that didn't work. That was the old ... drawing-over-the wall scenario ..... " (Case 5)

One of the major difficulties associated with the fragmented nature of the manufacturing companies in the study was the flow of information in all phases of the DEM process.

[22]See Arcelus and Wright, 1994.

Problems of rapid exchange of information amongst diverse departments and organisations were compounded by the many kinds of data needed by each contributor to a product development project. Problems became worse in those cases when a strict departmental policy on how design information should be managed over the long run was adopted, as could be inferred from what a Technical Director once asserted:

> "We have agreed with [the] manufacturing [department] now that one year after product launch the design will be frozen. And unless there is an external requirement to change based on a customer or an external approval agency or the unavailability of a certain component no design change will be made even to help manufacturing processes improve. They have one year to get it right for themselves, thereafter no changes will be permitted, and that will reduce our workload by about 70%." (Case 3).

The Operations Director, on the other hand, explained his encounter with the attitudes of the engineering department when he first joined the company:

> "..... When I came the quality people reported to the design people, and a week after I came they reported to me (laughing). We just changed the whole thing. .... All the problems ['and manufacturing was blamed?']. Correct! ..... That's why the Director before me left (laughing). I don't know the guy .... I believe the saying was: 'We've designed it, you just 've got to build it! It's your fault - if you don't build it correctly, it's your problem' ['And design was always ... innocent?']. Correct! It doesn't always work that way and we had a few discussions on that point when I arrived and we gradually got it changed. ['It was a challenge, wasn't it?'] Oh, yeah, yeah ! " (Case 3).

Integration projects in the primary cases were led by senior board directors in Cases 1, 2 and 3 and by upper middle managers, who could be described as outstanding technologists in their respective organisations, in Cases 4 and 5. Managers on the engineering side, as opposed to their colleagues in manufacturing, tended to have the final say in decision making processes concerning integration projects. In Cases 1, 2, 3 and 5 integration projects were financed jointly by engineering and manufacturing departments, though the former's contributions were higher. It was evident that design functions were more powerful organisationally. They were conscious that they represented the original source of product information generated within their respective organisations. This was accepted by people in other functions, who called designers the "front-end guys". Manufacturing and other production-related functions depended totally on design for information. Ultimate responsibility for integration projects tended to lie with design rather than manufacturing.

All the primary companies sought to facilitate integration via CE work methods. These were the most popular forms of organisational arrangements. Company 4 changed its structure to a matrix organisation arrangement to facilitate its integration process. Organisational problems continued to be experienced during the transitional period. In Case 1 extremely high costs were incurred for integration due to the wide range of CAD software applications in use. It was found that in Cases 1, 2 and 3, organisational changes in structural and cultural terms were not formally declared major obstacles to integration, as they were in Cases 4 and 5. The largest in the study, Companies 4 and 5 historically had the most rigid mechanical structures and the most centralised cultures. So both companies found themselves in a position where they had to restructure themselves, reorganise their information and work flows, and redesign their employees' jobs in line with integration. This was found to be clearer in Cases 4 and 5. Despite the fact that many employees failed to appreciate the technical significance of such changes, no one was found to be more aware of these changes and their organisational implications than the integration leaders themselves. Such key individuals appreciated, to varying degrees, the essential need for retraining and re-educating their work forces as part of an organisation-wide program aimed at promoting what might be called an "integration-oriented organisational culture".

Such a culture emphasised multi-skilling, flexible specialisation, and innovative organisational structure. According to integration leaders, the targeted cultural context for integration would aim to change conventional values of extremely specialist skilling, narrow division of labour, and rigidly-governed departmentalisation. Integration leaders in Case 4 and 5 were outstanding in this respect. Particularly in Case 4, they exhibited a remarkably encompassing understanding of the magnitude and facets of organisational changes that should be addressed before CADCAM integration (see Chapter 7, section 7.4). They subscribed to the notion that integration was an organisational process in which technology played the role of a tool capable of improving organisational performance.

The integration leaders in Companies 1, 2 and 3, however, continued to conceptualise it as a technical process that imposed organisational changes; such changes would be necessary if the technology involved was to be "operationalised". For example, the understanding in Case 3 was that:

> ".... there's been a change in emphasis ..... the objective [is] to become more effective in the work we do - not just faster but faster and more accurate .... over that period of time we've changed our own structure. ..... We then introduced the team element to the people." (Case 3).

Indeed, integration leaders in Cases 4 and 5 showed that many of the things they wished to see changed about their respective organisations had not been achieved to date because of cultural and power balances that dominated the work place. In other words, they demonstrated clearly that they knew what should be done to facilitate the realisation of their vision of integration but, at the same time, they showed their inability to change organisationally-protected value forces which continued to impede their initiatives. They were clearly aware of themselves as change agents and, more precisely, as representatives of new "left-wing" socio political forces opposed to traditionalist, conservative forces.

In summary, it was found that managing change with integration projects in the primary cases was hindered by several outstanding technical, financial, and organisational obstacles. These will be explained in more detail in the next chapter.

6.3 Summary

This chapter addressed the seven tentative research questions in terms of the case study findings. Presentation of the answers was affected by three factors which overlapped and interfered with each other. These could be summarised in the following points together with the problems that were encountered in addressing the questions:

1) The initial design of the interview schedules, which was influenced by the assumptions reflected in, and theoretically linked to, the research questions (as explained in Chapters 3 and 4). The schedules proved to be very useful in the earlier stages of data-gathering but less so later as gaps were discovered in the data. This therefore required a less structured approach to data-gathering with a view to presenting cohesive and full answers to the seven questions.

2) The manner in which the field investigation progressed, which contributed to the emergence of various substantive theoretical issues and, thus, to restructuring the presentation of the answers accordingly. This produced a need for maintaining a balance between case-specific issues of importance to the analysis and the theoretical themes that emerged from the overall research data.

3) The decision to trace companies' historical experiences of change with CAD and CAM as two separate application areas. This doubled the data-gathering effort as two lines of investigation, corresponding to both areas under consideration, had to be addressed simultaneously for each case. The companies' current experiences of integration were then investigated in the light of the two resultant groups of data with a view to establishing a better understanding of integration as a process of convergence.

The answers established that variation among manufacturing organisations in terms of why and how they acquire, design, introduce, use, maintain, and develop CAD/CAM systems is a crucial element in understanding technical change. Dissimilarities among the ten cases was explained in terms of the factors that were found to influence change. Also, the outcomes of change were discussed and the various aspects of organisational impacts of CAD/CAM systems were explained in the same light. The answers to questions 6 and 7 proved that the status quo of a given company in terms of how work is organised and its production task managed has important implications for addressing the issue of why the company would be, or fail to be, interested in integration. These answers also affected the issue of how an integration project would be managed in integrating companies.

It is clear from the answers to questions 1 to 5 that CAD has inherently different properties than CAM. Although, as mentioned above, this made the task of answering these questions particularly dichotomous in terms of both application areas, it confirmed the finding that CAD and CAM had not only different, but also inherently differentiating properties; each of them has its own characteristics when it comes to the effect they are likely to have on job design and work organisation. Such differentiating properties are a major factor influencing their integration potential. The different values attached to design engineering and manufacturing functions are reflected in how the people associated with CAD and CAM in different role capacities are viewed and socially stratified, how such individuals and functional groups perceive themselves and their role, and how designers' behaviour vis-a-vis manufacturing staff and workers (and vice versa) is affected as a result.

In general, the introduction of CAD systems did not present the companies with a considerably challenging task in terms of work organisation. CAM, on the other hand, did, at least initially. The introduction of CAM systems was found to be more political in nature. However, CADCAM integration presented the primary companies with a much more challenging mission since integration, by definition, threatened to change the existing social and political forces in the status quo. It necessarily involved an element of structural and cultural change between, as well as within, functional boundaries and it was more likely than any previously tried single technology application to provoke reorganisation of work throughout these companies.

The findings showed that, despite deciding upon a particular line of action with regard to how work around CAD and CAM systems should be organised, once such systems had been introduced problems arose which, in most cases, required changes to how systems were used or what particular individuals did vis-a-vis them. Five reasons behind this were identified:

1) Poor planning of the introduction process, particularly lack of training for those involved, which in some cases amounted to incompetence;

2) A realisation that such technologies required greater skill and involvement from their operators, users, programmers and managers than had been envisaged;

3) Opposition to, or lack of co-operation with, the original plans from individuals or groups within the organisation;

4) A desire to increase management control over the systems in use;

5) Unforeseen, unplanned (i.e. beyond management control) changes in the external business environment, creating new operating conditions and constraints[23].

Four significant points emerged from the examination of the overall impacts of CAD and CAM systems on work organisation:

1) The vast majority of "turn-key" CAD systems on the market were predominantly concerned with the automation of individual functional areas of design. In using them for an economic reward user companies were compelled to reorganise in a way that was not necessarily useful or appropriate to the design process itself; in fact, they tended to fragment it because they presupposed a pronounced functional structure. CAD systems developed internally did not necessarily have the same effect.

2) Economic and technical considerations were not always the main reason why changes were made, nor was it the case that the alternatives tried always resulted in improved performance. Indeed, it is not too much to say that issues such as management control and the need to fit with existing structures and practices proved to be more influential in practice than pure economic or technical considerations.

3) Whilst in some cases certain changes were willingly initiated and consciously planned by management, in other cases they were initiated by, or informally organised between, those technical, supervisory or production staff involved with the systems introduced.

4) The divisions between managing, programming, supporting and operating functions were not clear-cut and they could, and did, shift over time as circumstances changed. Attempts made by some of the companies to make clear-cut divisions between these functions were neither practicable nor productive. It would appear to be more useful - if work tasks were to be divided anyway - if those involved in one function had at least a sufficient degree of appreciation of the other functions and the work tasks they performed. This point would be consistent with an integration-oriented philosophy of work organisation, which was characteristic of the primary cases.

In conclusion, it can be seen from the above discussion that CADCAM integration may rightly be viewed as a technical process that involves the interfacing of stand alone technology applications that are capable of being integrated. At the same time, however, it is an organisational process that involves changing deeply-rooted values, practices,

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[23]In Case 9, for example, work around CAD was initially designed for devoted users. However, the company's difficult business circumstances, which eventually resulted in liquidation in 1992, forced work around CAD to be redesigned on a self-service basis for a fewer number of users as the company diminished in size and could not afford to keep devoted CAD users as it had done in the past.

structures, procedures and power relationships. Various factors can either facilitate or impede integration at any given time. It can also be seen that, at present, the interaction of such factors in industry is such that CADCAM integration is either prohibited (e.g. in secondary cases) or pursued (e.g. in primary cases), depending on complex and overlapping economic, technical, and organisational factors. Indeed, even in the primary cases, where integration is pursued, the progress of the integration process is subject to the influence of a number of facilitating and impeding factors.

Therefore, the general proposition that the introduction and use of an integrating technology will be influenced by a wide range of factors, both internal and external to the adopting organisation, was borne out. In particular, the role of prevalent beliefs and practices; financial circumstances; the rigidity, or otherwise, of company structures and practices; the limitations imposed by the type of products being manufactured and production systems used; and, crucially, the values, attitudes, power and self-interest of those involved, emerged, in the cases studied at least, as key factors that influence CADCAM integration. Such factors will be analysed in greater detail in Chapter 7 in the context of the social and organisational processes associated with integration. Hopefully, by exposing what actually happens in organisations a better understanding of integration, as a dual technological and organisational change process, will be developed. The effects of various factors on CADCAM integration, in terms of either stimulating or impeding it, will be discussed in the next chapter in the light of the primary companies' experiences.

CHAPTER SEVEN

Findings, Data Analysis and Discussion - III: A Conceptual Model

7.1 Introduction

This chapter builds on Chapters 5 and 6 in analysing the field findings through a conceptual model especially devised for the purpose. It will begin by introducing the model and outlining it in terms of its constituent components. The model will then be applied to two examples from the cases: a critical incident from a non-integrating company, Case 10; and another from an integrating company, Case 4. By contrasting the two example incidents the present chapter aims to provide an explanation of some of the crucial forces and factors that prohibit and inhibit CADCAM integration on the one hand and those that cause and stimulate it on the other. The emphasis will be on the social processes behind the absence of CADCAM integration in Case 10 and its presence in Case 4.

The analysis in this chapter will focus primarily on the immediate social environment engulfing integration in order to emphasise the significance of the data derived from the grounded theory methodology. This will be done in the context of the experiences of the primary cases in the study.

A number of outstanding obstacles still hinder the process of change in these cases. These will be examined closely in this chapter because of their theoretical relevance to the study and their practical importance to those people who are directly involved in the change process.

7.2 The Model

Research in the area of technological change has been dominated by two major approaches: economists' "diffusion approach" and sociologists' "impact approach" (see Attewell, 1992; Kimble and McLoughlin, 1995; Winch and Twigg, 1993). Diffusion describes the degree to which an innovation has become integrated into an economy. Most technological diffusion models share an assumption that any innovation is progressively adopted by a fixed and homogeneous population of potential users with fixed and similar objectives (see Attewell, 1992). The diffusion approach tends to neglect in its analysis important variations due to organisational specifities because of its preoccupation with issues such as profitability, capital availability, and estimates of risk. The impact approach, because of its sociological - as opposed to economic -

orientation, is more sensitive to such specifities but it tends not to give enough attention to studying the actual unfolding of change.

Both approaches have been criticised in the literature as being incapable of reflecting realistically the challenging nature of technological change (e.g. Pettigrew, 1987; Winch and Twigg, 1993). Although their cohesiveness in consistency terms stands to credit them with theoretical strength, the credibility of their often claimed universal applicability is in question. In particular, they are criticised for failing to illustrate the dynamics of change; the difficult practical challenges it raises for management; and the role a case-specific context plays in a given change process, its management and its outcomes. According to Kimble and McLoughlin (1995), a more "integrationist impact model" is required, one that does not portray an impact as a linear outcome but as "a complex, interactive and ongoing process ... [that] both shapes future outcomes and is shaped itself by what has gone before" (p. 58). As Mahajan and Peterson (1985) point out, in both approaches, research at the macroscopic level often proceeds by attempting to fit a model of the diffusion process to empirical data. Winch and Twigg (1990:1) summarise such criticisms as follows:

> "One weakness that these approaches share is that the false starts, dead ends, postponements, and down right failures associated with technological change tend to be lost from view. Implicitly, the process is seen as rational, linear, and unproblematic from the point of view of the management of the adopting organisation."

Therefore, this study uses an alternative "implementation approach" which concentrates on the "change (or integration) process" itself[1]. Central to this is an emphasis on the social processes that are involved, namely the formal and informal activities that breathe life into a company's organisational (or social) structure (e.g. ".... there will have to be a change in the structure ..... the whole process of moving toward this [i.e. integrated CADCAM] is going to actually change the actual way the organisation looks" [Case 2]). Such activities may, in the process, cause the structure to change through "legitimate" (*de jure*) authority and/or "illegitimate" (*de facto*) power.

Indeed, the need to concentrate on the social processes accompanying integration stems from the most obvious of observations, namely that people, including those initiating and leading an innovation, are social beings and that social life is an inescapable aspect of organisational life[2]. Regardless of their respective positions, individual members of

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[1]This is based on the fundamental assumption that a realistically accurate assessment of the "outcomes" of a change process will be very difficult to realise without researching the actual unfolding of the process itself (see Chapters 3 and 4). Therefore, a processual model is devised here because it is more likely than any other type of model to facilitate the kinds of deduction required to generate theory from the data.

[2]The notion of social processes is relevant to the present model of CADCAM as an essentially organisational process involving "integration between all the disciplines" (Case 4). The kinds of =

an organisation cannot lead a totally self-determining organisational life free from the social context that engulfs them; their experience of it must be influenced by interaction and mutual dependence within their respective organisation as well as with the outside environment. Interaction and mutual dependence are important for understanding how the past, the present and the future are linked together by continuity as well as how they are distinguished by change in the context of a certain case study in the present research[3].

The study's model draws on another fundamental observation, namely that an organisationally-defined division of labour creates socially-differentiated roles for the different individuals and groups who assume different roles and initiate different actions, interactions and reactions. It would be too simplistic to say that the forces for and against change that influence a company's decision regarding whether to adopt or reject an integration strategy are restricted only to market pressures or to some companies' desire to attain state-of-the-art technology. This would have ignored the active social forces that operate inside the organisation at the centre of the change process; or it would have at least underestimated the implications of these forces for the change process in question[4].

= social processes that lead, or otherwise, to integration and/or influence the progress of an integration project tend to manifest themselves through patterns of behaviour motivated by perceived opportunities and threats over an extended period of time.

Since perception plays a major role in how different individuals and groups judge some aspects of integration useful and others harmful, it is important to identify the kinds of threats associated with CADCAM in the minds of those who feel they have more to lose than to gain from it. Perceived opportunities and threats are vital for explaining people's behaviour in the face of change; subsequently, actual gains and losses are crucial for explaining their reaction to its outcomes in their experiences.

Perceived utilities should not be defined solely in technical and economic terms. In addition to these two obvious dimensions, the findings confirm that a careful analysis of such social processes will help a researcher establish how the useful aspects of CADCAM are identified, defined and contested as different individuals and groups within a social form of organisation ascribe different meanings to integration. Indeed, these include different interpretations of the implied technical and economic benefits themselves.

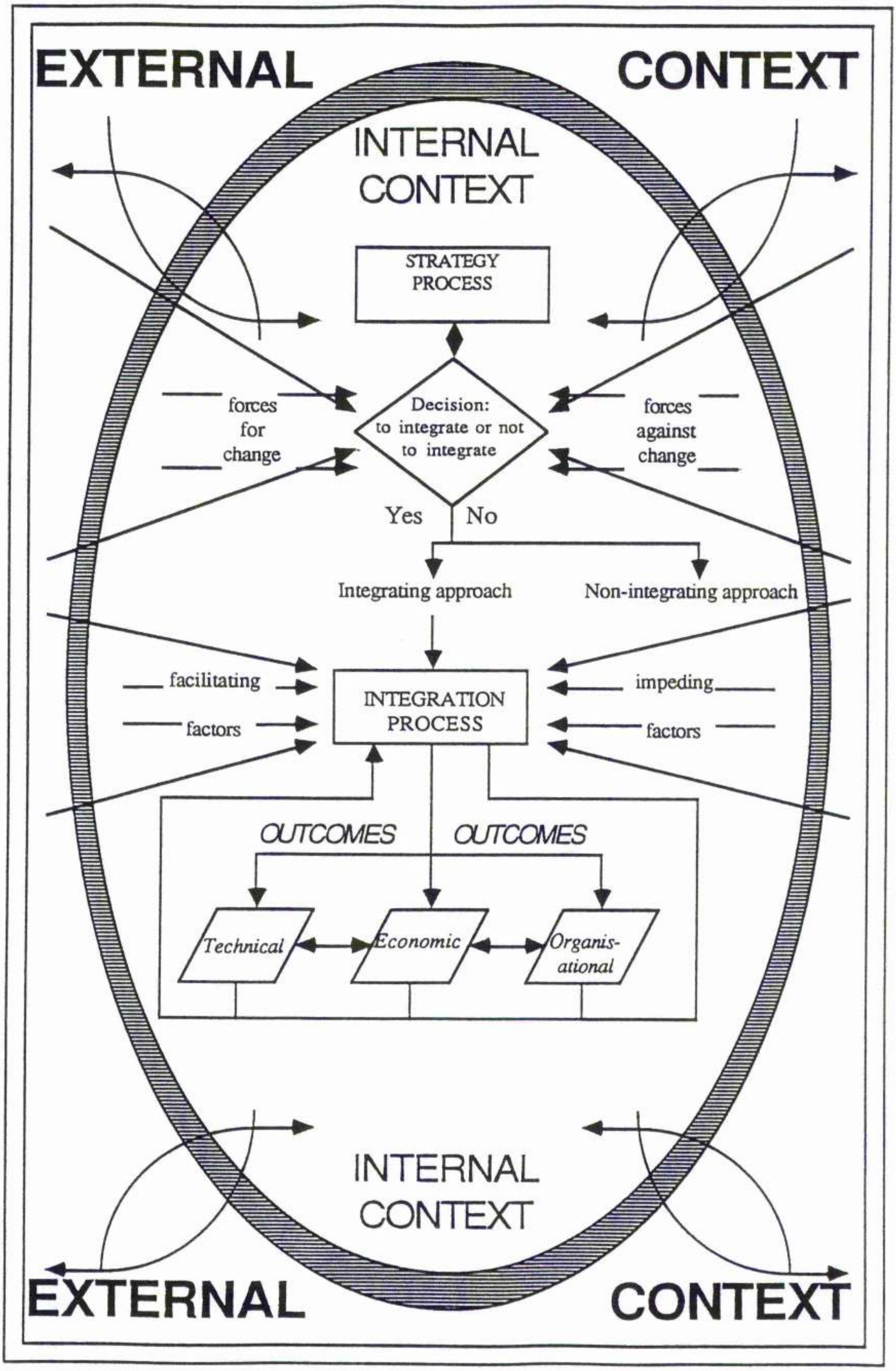
[3]The following example concerning a participant's experience confirms this point:

> ".... The goal of continuous improvement is now in everybody's mind. Everybody expects to do it better all the time. ..... Change has been a way of life: whichever way you do it today, you won't do it that way tomorrow. You'll continuously change it." (Case 5)

[4]The following example from the data on innovation would help illustrate this point:

> ".... it [i.e. innovation] comes in a number of ways: it comes with our R&D people who do know where the technology [is] coming from and what will be our [chances?] to be able to achieve it; it comes from our marketing people who are telling us what our customers are likely to want; but equally [from] inside our organisation .... we do do this and we look very carefully at it because we are coming toward the saturation model!" (Case 1).

Exhibit 7.1
The Conceptual Model



Similarly, the active interaction of this entity with the wider society should not be reduced to one which depicts manufacturing companies as abstract economic agencies dominated by market mechanisms or as inanimate production systems continuously aspiring to technical excellence. Rather, the model takes a wider view of individual and group actions inside a changing organisation and how these are influenced by the various social, cultural and legal characteristics of the wider society.

Exhibit 7.1 illustrates the present study's conceptual model, incorporating the "integration process" as one of its most important components. The model will be explained in what follows in terms of its constituent components, each of which represents a level of conceptualisation.

* ***External Context***

This component of the model represents the outer environment within which a company operates, including, for example, its industrial sector, product market, the educational and cultural context at the national level, and the economic, political and legal conditions both nationally and internationally[5]. The model assumes that the kind of outer environment in which an organisation operates influences, to a considerable extent, the production tasks it undertakes and, in turn, its structural design and choice of personnel[6].

With regard to CADCAM integration specifically, an external environment would influence a company's decision concerning whether to embark on it by virtue of the pressures it exerts on the company to change, say, to match the moves of competitors or standard-setting giants in the same industrial sector, to adjust itself to changing global market conditions, or to respond to new government legislation. Furthermore,

[5]Whilst the emphasis in the consequent analysis will be on the social processes inside the boundaries of the researched companies, it is important to stress here that the role their respective external environments play in internal change should not be underestimated (see Lee, 1989; Miller *et al.*, 1991; Pettigrew, 1985; Stacey, 1993). As Scott (1995: 55) points out, "organisations are penetrated by environments in ways not encompassed by earlier theoretical models". However, this should not be exaggerated by taking it to the extent suggested by the population ecology model (see Aldrich, 1979) which looks at the environment as *the* determining factor in any innovation. This model depicts change as a manifestation of an accident of exploration, occurring as a result of trial and error, chance, luck, and opportunities offered by the environment; the population ecology model therefore ignores the role that can be, and is, played by managers or leaders of change in influencing the direction, magnitude and quality of change through planning and control measures. In addition, it fails to take on board the role and outcomes of internal power dynamics between rival managers. In this regard, the population ecology model can be described in "environmental determinism" terms.

[6]It also assumes that organisations interact with their environments in ways which affect them both positively and negatively. Environments both affect the companies they subsume and can themselves be affected by them; large and powerful companies, for example, may create new conditions leading to changes in their respective external environments whereas smaller and weaker companies are likely to be continuously subject to environmental pressures for change.

an external environment would continue to influence an existing integration process positively or negatively by creating facilitating and/or impeding factors.

* ***Internal Context***

A company's boundaries represent a dividing line between the organisational entity within which CADCAM integration is adopted and the environment that surrounds such an entity. The model conceptualises an internal context as the organisational background against which the process of integration is managed in a manufacturing company. Such background reflects key structural, cultural and political characteristics of the immediate environment through which ideas of change proceed. A thorough understanding of an internal context requires an in-depth appreciation of the set of conditions under which integration has to be managed in a given case. Such conditions are, to a certain extent, structurally-defined but are also shaped by agent actions, interactions and reactions as well as by external environment influences.

By identifying the features of an internal context a researcher can answer important questions pertaining, for example, to the allocation of responsibilities and formal reporting relationships to individuals and departments, the monitoring and assessment of performance for reward and punishment purposes, and the degree of participation in decision making. Having established such background knowledge of an organisation, then the researcher is better positioned to understand the essential dimensions of a given internal context, including, for example, the size of the organisation, its structure, culture, ownership, its dependence or otherwise on a parent organisation, the type of production system in operation, and its current business performance.

The idea is that such fundamental knowledge will enable the researcher to explain how an integration process is influenced by the organised social medium in which it takes place, in the midst of actions and reactions by different individuals, groups and departments pursuing their own chosen paths within a single organisational setting. Such actions and interactions are potentially capable of breaking such a collectivity into smaller parts, following the opposite path to that of integration.

* ***Strategy Process***

The model depicts strategy as an active decision making process reflecting preplanned intended courses of action. Strategy involves long-term planning, typically with certain objectives pertaining to enabling a company to achieve or maintain what is regarded as a proper competitive advantage. Two areas of a strategy process are particularly relevant for the purpose of the present study: (1) a company's specific manufacturing strategy and (2) its overall business strategy. The former is directly associated with CADCAM as a strategic resource potentially capable of improving the performance of a company's

DEM setting through a "strategy-technology alignment" process. The latter is a broader strategy concern which subsumes the former.

A strategy process, however, is not conceptualised simply as a series of straightforward acts of planning. Rather, it is presented as a problematic process, one that involves empowered actions and reactions often justified on a rational or "bounded rationality" basis whereby top management seeks to exercise strategic choices under changing environmental conditions. Strategic choices are made under different types of pressures exerted upon those agents responsible for strategy formulation and development in an organisation. Such pressures can start from within the internal context of a change process or they can penetrate from the external context[7]. Regardless of the source of such pressures, however, they present strategists with challenging constraints which affect their ability to initiate and/or control a strategy process associated with a long-term integration project.

* ***To Integrate or Not to Integrate? Forces for and Against Change***

Whether or not to embark on an integration project and commit corporate resources to achieve it over a long period of time is essentially an issue of strategy rather than one of an operational consideration. The pressures exerted upon those involved in making the decision of whether or not to integrate are conceptualised as forces acting upon them and thus influencing the outcome of such a decision. Again, such forces can be either internal or external.

The model uses the notion of initiation to conceptualise a company's formal acceptance of CADCAM integration in principle and its embarkation upon it in practice; any force (internal or external) that is identified to be effective in causing or contributing to initiate integration will, therefore, be called a "force for change" (i.e. a force in favour of integration). On the other hand, the model uses the notion of prohibition to visualise the rejection of CADCAM integration formally; any force (internal or external) that is identified to be effective in causing or contributing to initiate prohibition will, therefore, be called a "force against change" (i.e. a force against integration).

Using the above terms for the purpose of data analysis in this chapter, one can say that the forces against change in the secondary cases were dominant; therefore, the question of CADCAM integration did not arise as a viable project, at least not to date. In the

[7]For example, the nature of a company's product and the intensity of environmental pressures have implications for the choices of the strategic pathways followed as well as the relative roles of various players in defining those pathways for the introduction of CADCAM (see Adler, 1989). The question here is not simply related to management practices *per se* inside the company, but rather to senior management's ability to develop a strategic vision to introduce integration whilst adapting to new market conditions.

primary cases, on the other hand, the forces for change were found to prevail over the forces against change; therefore, integration was formally adopted in these cases.

* ***The Integration Process: Facilitating and Impeding Factors***

An integration process is an expression of the total courses of action and interaction whereby CADCAM integration would be implemented in a company. The dynamics of an integration process are attributed to the various actors who participate in the process, subject to various factors which either facilitate or impede the process.

The model uses the notion of promotion to refer to the encouragement and advancement of an already initiated integration effort; any factor, among others, found to be responsible for promotion will therefore be called a "facilitating factor". Similarly, the model uses the notion of inhibition to refer to the discouragement of an integration effort; any factor, among others, found to be responsible for inhibition will therefore be called an "impeding factor".

Without assuming a simplistic relationship between the interaction and possible overlapping of internal and external factors, the model depicts both internal and external factors. Some of these factors can be traced to the internal context and can therefore be described as internally borne whilst others are produced by the environment.

Impeding factors interact with one another and, collectively, against facilitating factors. The outcomes of such interaction at a given time will be reflected in what is found to be the present state of integration in a primary company.

* ***Outcomes of Change***

The model classifies the results of an integration process into three broad categories: (1) technical (i.e. implications for current production methods whose productivity or flexibility, for example, can be improved), (2) economic (i.e. implications for profitability and other intangible business rewards that may result from positive technical outcomes) and (3) organisational outcomes (i.e. implications for job design and work organisation, which will result from the implementation of CADCAM through certain integrating mechanisms).

Variations in strategy process, integration process, internal context, and external context interact differently in different organisations and under changing conditions in an organisation. The specific technical, economic, and organisational results of a certain change process would, therefore, represent the total "resultant" of that process, corresponding to the "sub-totals" of the particulars of the four elements, at a given time.

7.3 Applying the Model - I: A Secondary Company Example

* *CASE STUDY TEN: Company 10*

* ***External Context: Key Relevant Features***

* The national economic recession of the early years of the 1990s affected Company 10's business performance in a negative way.

* Until 1993 the company had been a wholly-owned subsidiary to a Washington-based business group, but it had operated in a different market environment and enjoyed a high degree of autonomy. In 1993 the company was bought out by its British Directors. It is now an independent British company marketing its main product successfully in Europe. Company 10 has become a rather small independent firm, one that is more vulnerable to the dynamics of the free market economies of Western Europe. It has found itself in competition with "quite monopolistic" world leaders in the tachograph industry. This has made management even more careful about controlling expenditure to minimise cost.

* External legal and commercial pressures play a crucial role in maintaining a flexible approach to product design within the company in order to please both industry regulators and customers who happen to be more powerful automobile and heavy vehicle manufacturers.

* ***Internal Context: Key Relevant Features***

* Company 10 is a slow-moving organisation with 370 employees. The history of the company has been one of downsizing. The younger and more adaptable people in particular feel they are a more obvious target for management's redundancy plans. This situation has created tension between senior management and this group of employees who resentfully reject management attitudes and feel threatened by them.

* There is a generation gap between the two groups, one that has been described by the younger group as creating a "cultural gap" and "mental gap" between themselves and the "old fashioned", computer illiterate managers with "1950s type HNDs", who not only happen to exercise a greater *de facto* power but also occupy all the powerful top management positions.

* Learning from previous mistakes is a distinctive feature of the younger, pro-integration group of engineers. This makes many of them eager to use their theoretical knowledge as well as the practical skills they gain from experience in improving how they plan and manage technology. Some of them do not hide a feeling which many of them share, namely that they, in view of the present social atmosphere in the organisation, prefer learning by themselves (even by making mistakes) to having skills offered to them by management (i.e. through formal training).

* Industrial relations have deteriorated as the active blue-collar, "hourly paid" trade union feels that shop floor workers are made to fear for their jobs, and that the threat of redundancy is frequently reinforced.

** **The Strategy Process: A Summary***

The company's strategy process over the last few years has centred around the tachograph product line with a strong orientation towards the European market and away from the Middle and Far Easts where it still markets some of its petroleum measurement products. As explained in Chapter 5, the market demand for tachographs has been stimulated by a European legislation that makes their use a legal requirement as far as trucks and heavy vehicles are concerned.

With regard to the strategy process on integration specifically, the company's most senior manager stated in 1990: "We have devoted the last several years to implementing flexible manufacturing methods - it is now time to optimise customer service through integrated manufacturing and distribution". It should be said, however, that the experience of those middle managers responsible for studying the feasibility of integration has been different. Indeed, it is ironic to find the leading integration enthusiast in the company talk critically about Directors as being "the only obstruction" to integration.

The strategy process in this organisation is influenced considerably by the tension that exists between these two groups. Decision making here is a process in which the pro-integration group is deliberately marginalised by a more powerful anti-integration lobby. This is done in direct and indirect ways. First, directly by preventing them from effective participation in decision making on serious issues relating to integration on the grounds that they are not senior enough to participate in a strategic decision of this type. Second, indirectly by means of advocating an organisational culture that is hostile to integration and in favour of maintaining the company's existing structure and culture, and justifying that in the name of preserving stability and avoiding radical change which is implied by what their opponents advocate.

** **To Integrate or Not to Integrate? Forces for and against Change***

As far as the technical managers of the engineering function are concerned, CADCAM integration would be a positive move: it would be beneficial to the company as a whole because it would improve communications with the other departments of the organisation and eliminate the need for translation software packages. Such software is currently needed to transfer information due to the lack of a common electronic format:

> "We've been having discussions on multi-level set-up ..... you obviously involve sales, manufacturing and engineering as to what .... you can do in parallel rather than in series. ..... If you are producing - for design use - a parts list, for instance, which you have in the design

computer and you want to have that parts list put into the mainframe computer then it would be ridiculous to have to take a print out from the design computer and then go and type it on the mainframe. So, the transfer of information .... [we have] to look at the whole of the systems within the place and look forward to some integration. ..... the reason we didn't go much further than that is because of the type of organisation that we have!"

In 1990 the company's Chief Design Engineer was nominated by senior management for a postgraduate course of study in business administration. He attended the course and studied his company's own experience of computerisation with a particular focus on the element of human resources management. Consequently, he became extremely critical of senior management:

"As a result of doing my MBA .... [I] started to look at the human element of it. ..... It opened up a whole new game .... I became much more critical of some of the decisions that had been made. My MBA dissertation .... I never let anybody see it, because if the MD saw it, it was so critical! ..... The CAD implementation program should never had been carried purely by the manager of the department. The objective overview had to come from top level. ..... Some of the decisions [that] have been taken, none gave thought to company-wide integration."

With middle-class career development ambitions and self actualisation being uppermost in their mind, the pro-integration minority, led by the Chief Design Engineer in this case, believe they have a cause worth struggling for. They are disenchanted with the present attitudes and values that currently dominate the atmosphere of the organisation under its existing power-protected structure. In so doing, however, they are attempting to change an organisational culture that has been solidified over several decades (i.e. since 1948 when Company 10 was established in Dundee) and, if one goes back to the deeper roots of the Dundee subsidiary, by over 150 years of history (i.e. since the corporation's founder started the company). Still, they would like to advocate a cultural change throughout the organisation as far as they can. However, they find it difficult, in effect, to spread their message successfully even within the boundaries of the engineering department which is under their immediate span of control because they are a minority in the organisation as a whole.

Under the leadership of this distinguished individual, some of the key design engineers have turned to their colleagues in the manufacturing and production departments to persuade them to overcome their communication differences so as to pave the way for a corporate decision on adopting a CE-centred integration strategy but so far to no avail:

"... the problems are that their system, their method of breaking down a bill of materials is somewhat different from the way we break down our bills of materials ..... They need the information in a slightly different format to the way it comes out of the engineering set-up of the line. So you've got to put up an interpreter either in the engineering side to put it into their format or in their equipment [, built?] .... and that's what we are working towards, to work out how we can do that most readily."

The manufacturing and production functions are rather traditionalist in their work methods and attitudes. Both of them (production in particular) are strongly associated with the shop floor and widely regarded as being positioned at a lower social level in the organisation and often called the "direct boys downstairs" (i.e. mostly apprenticeship trained, blue-collar employees) as opposed to the "indirect boys upstairs" (i.e. mostly university graduates and professional white-collar office staff).

Many people working in the production and manufacturing functions believe that, if the company is to adopt an integration strategy in the future, they should know more about the integration project and be allowed to participate in making key decisions associated with it. They are particularly concerned that if future training is going to be given to them, which is inevitable, the trainers should not be appointed from the technical department but rather from outside the company (i.e. neutral trainers should be sought). This can be understood in the light of a well-established tradition in the company whereby all in-house training schemes are planned and controlled by the technical (or engineering) department. Since the two main integration enthusiasts, namely the company's Technical Director and the Chief Design Engineer, are also the two persons formally responsible for training, many people in the production and manufacturing functions are not sure that they will receive an objective training. From the point of view of these people, the technical department should not be the "only route" to training because of fears that it will use its superior computer knowledge and discretionary powers to reinforce its advantaged position and deskill them.

To the delight of the traditionalists in manufacturing and production, senior management in this case has decided not to adopt an integrating strategy. Furthermore, it has made rules to maintain the status quo. These include preventing members of the younger group of engineers, who constitute a minority amongst members of staff, from contacting outside suppliers directly; they should do so only through traditionalist sales engineers who have practised as engineers since the 1950s and identify themselves with senior management "due to the politics of it". Senior management remains adamant that an integrating strategy is unlikely to be adopted in the foreseeable future.

In short, the forces for change in this case can be summarised in the following points (see Exhibit 7.2):

* Customers pressing for introducing a greater internal integration to improve the responsive capability of the company as a whole, not just as a design team, so as to improve product quality, shorten production lead-times and increase responsiveness:

> "With certain of our customers, certainly *Scania* and *Volvo*, we are talking about electronic data exchange anyway .... placing orders on a computer-to-computer, doing their scheduling on a computer to-computer so that they can go straight into our system and they can put their order straight into our system. Our system will then take their order and split it down for our

benefit: how many components we need and when we need to make them. This is something the motor industry are getting into .... and will become more and more popular."

* Enthusiasm for integration on the part of a group of young, ambitious and highly qualified design engineers who are proud of their professional standing and are open to external influences: "engineers by and large are aware of state-of-the-art .... go to exhibits, see things [and] get a lot of ideas". These, however, are a small minority in a company which seems to be dominated by a group of older and more senior managers constituting four out of the company's five Directors:

> "We've been trying to work on the principle of integrated manufacture for quite a while. CAD helps in some respects but .... if we are going to integrate manufacture you need the commitment of the people, if that is what they are wanting to do!"

On the other hand, the forces against change in this case can be summarised in the following points (see Exhibit 7.2):

* Resistance to integration on the part of the manufacturing, production and finance functions which are managed by traditionalists who are sensitive to change.

> "It's historical as far as [naming the company] is concerned .... [The founder] was one of those entrepreneurial types .... and from that sort of background the company grew up with this background .... We still, to some extent, have this. If we started from scratch I don't know whether we'd do the same thing again. Obviously, a lot of the company depends on its inheritance - two generations."

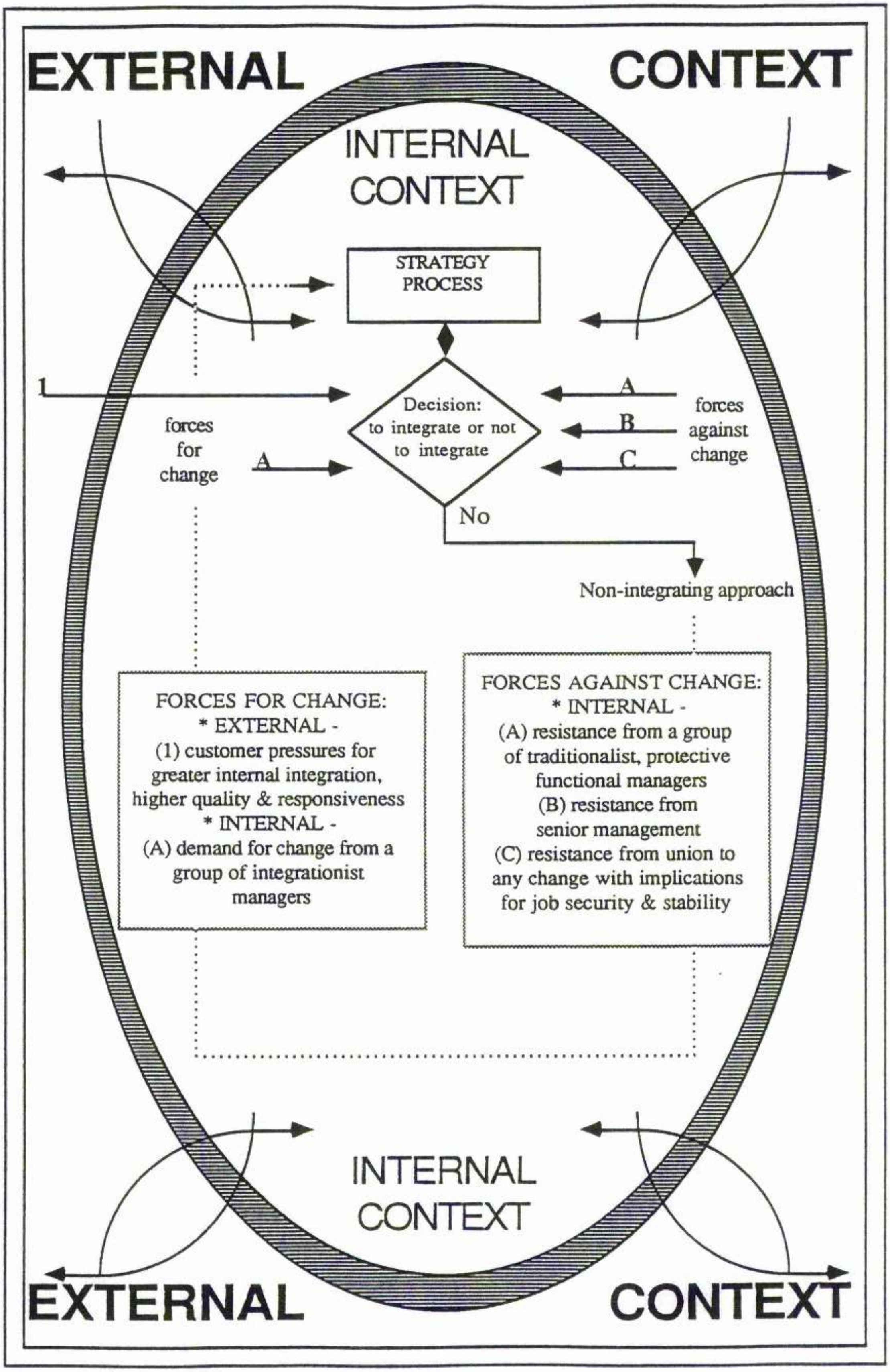
* Lack of interest in integration on the part of the majority of senior managers who hold conservative attitudes and thus happen to side, if only by default, with the production and manufacturing functions in their resistance to integration:

> "The worst possible scenario is if everybody is trying to do their own thing in their own way and it will just get into a state of chaos. .... You've got to be formal in that somebody somewhere has got just to put a list of headings down as to what has been decided, otherwise people go with different ideas. So you've got to have some formality from that point of view."

The Technical Director excluded, senior management lacks a real "paternalistic interest" in integration and justifies that on the grounds that the cost of integration is prohibitive since an integration project would have "to be done at a budget level appropriate to the turnover of the company".

In summary, no decision has yet been made in favour of integration as a future strategic direction. It should be noted that the CAD system which is in use in Company 10, *AutoCAD*, is essentially a drafting package and would not have been readily suitable for integration. To integrate it successfully some extra interfacing software and hardware will be needed at a cost which, according to senior management, cannot be justified under the present circumstances of the company.

Exhibit 7.2
Applying the Model to Case 10: A Non-integrating Strategy



Having applied the model to a critical experience from a secondary company, the next section will apply the model to a critical experience from a primary company.

7.4 Applying the Model - II: A Primary Company Example

* *CASE STUDY FOUR: Company 4*

* *External Context: Key Relevant Features*

* Company 4 is a subsidiary of a logistics systems division of a giant UK defence electronics group which has very strong links with the defence industry in general and the British Government in particular (through the MOD [Ministry of Defence]). These connections have provided the company with important channels for communication with decision making centres of utmost strategic significance in the UK.

* The company's relationship with, and dependency on, its parent organisation is extremely strong; essentially, the former is a sub-contractor to the latter. A comparison with Company 10 (prior to the 1993 management buy-out), for example, would reveal that Company 4 is much more dependent on its parent organisation, although from a legal point of view both of them are wholly-owned subsidiaries. This provides Company 4 with characteristics both of weakness and strength. On the one hand, it limits the company's administrative autonomy to a considerable degree and its potential ability to compete in the global electronic product market for civic commercial applications. On the other, it provides Company 4 with a sense of protection as an otherwise "small fish" in the eyes of its giant competitors in the electronics industry.

* The national economic recession of the early 1990s has had a considerable negative effect on the integration process in this company. This is particularly because it is dependent on the domestic UK market, rather than on export markets[8].

* *Internal Context: Key Relevant Features*

* Company 4 is part of a declining industry which is searching for mere survival under a "new world order".

* Poor industrial relations in the company, which have deteriorated further due to a falling market demand, have created tension between management and the work force[9].

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[8]Ironically, financial justification for integration can be hindered by declining business prospects as much as it can be facilitated by exactly the same factor. The present example of Case 4 shows that where senior management resorts to integration as a means for reviving business prospects in a new market, integration, to the delight of integrationist forces, can been given a boost. Researchers such as Bessant and his colleagues (1985: 285) recognise the plausibility of such a paradox, namely that pressure exerted by recession may "act as the midwife to technological change" in spite of its "general effect of reducing profitability and thus the availability of investment funds".

[9]Passive collective resistance to management plans, which has resulted from the "big gulf" between managers and employees has found expression in the refusal of many shop floor workers to =

* Many of the company's 500 full-time employees (including 230 qualified engineers and technologists as well as scientists of various disciplines) are highly qualified professional people who are affiliated to national and international professional groups. This appears to have increased their awareness of external influences and thus made the company as a whole more sensitive to environmental influences in the context of the wider society, both nationally and internationally. Openness to external influences seems to have enriched the learning experience and improved the personal development prospects of the key integrationist engineers; it thus had a bearing on the quality of leadership of integration internally.

* ***The Strategy Process: A Summary***

Company 4 had always been a strictly defence electronics concern. The parent organisation's orientation towards defence has been subject to reconsideration since the early 1990s. At that time the company's Training Manager said: "..... because a lot of our business is still defence-oriented, we are obviously very sensitive to what is happening in the defence field". Strategic rethinking over the last six years, however, has focused on commercialising some of the company's facilities to supply civilian markets. The first radical change in this direction came into effect in the winter of 1995 as the company won the first contract with a US leisure aircraft manufacturer.

A co-ordinated effort has developed in this company over the last four years to incorporate the integration process into the strategic objectives of the business as a whole. Senior management works closely with the Business Computer Systems Manager in planning an information strategy in the light of the company's overall objectives. CE is introduced as a methodology for implementing organisational change to facilitate integration.

Progress of the integration project in this case has been facilitated by a deliberately planned, frequent selection of compatible computer systems since 1986. An integration champion has been behind this since he joined the company but he also owes a great debt to senior management for his achievements which are deemed important to the strategic performance of the business.

= collaborate in implementing a £3m TQM program which has come to be regarded as a failure by senior management themselves. Low-trust industrial relations can be illustrated further by the case of one technician who

> "..... was sent for a TQM course, a 2-day course, Monday and Tuesday his boss told him: 'you have a secure future ..... you are important to the company'. He had an appointment to discuss his future career on Wednesday. At 9.10 am, just 20 minutes earlier they told him: 'you've been sacked!'"

* ***To Integrate or Not to Integrate? Forces for and Against Change***

Company 4 formally adopted an integration strategy towards the end of 1991 as a Board decision was taken to this effect. Behind the decision were forces (both internal and external to the company) acting for change.

The decision to adopt an integration strategy in this case was inspired by a simple idea, namely making a better use of the many unco-ordinated computer-aided applications in the company:

> "One of the areas that I looked at, that I was very concerned about, was the fact that we had a high degree of computer-based application tools and resources which were not being fully utilised. And what I did was to take an overall picture rather than a narrow view that the people are using these tools [might have]. I wanted to see how they could fit the wider world and then we became interested in concurrent engineering and this really gave the impetus ..... "

Originally, this idea was proposed by some of the company's "best engineers" who saw the potential benefits of integration through their experience of working closely with customers seeking solutions to their equipment testing problems: ".... we write the design specifications for our customers, they often don't have the time or the expertise to do it themselves. Our business is based on our technical ability to solve their problems". A more integrated Company 4 was perceived as being synonymous with a higher quality of service through improved efficiency and responsiveness. Therefore, customer encouragement for this idea strengthened the mentioned engineers' confidence that integration would be rewarding, necessary perhaps, from a business point of view:

> ".... it's all down to business and this is an income - you know. The market is dead, income is very low, not enough funds available .... but it's a fine line because they have to implement it in order to survive in the market place in the future."

Hence, the Business Systems Manager, arguably the company's most respected technologist, presented a case for integration. He emphasised the potential technical advantages of interfacing the company's existing CAD, CAE, CASE and CAM systems in terms of improving efficiency and quality. His case was based on the argument that the anticipated technical gains which would result would translate themselves into a more competitive business performance and higher profitability.

He was supported by a number of professional senior engineers of a high social status in the organisation. Soon after he had started campaigning for integration he found that he was not alone. Another more senior and widely respected manager soon joined him in an informal coalition. This was the Training Manger who occupied a position only one level below the Board of Directors' and was responsible for meeting all the training and education needs of staff and maintaining links with local higher education establishments. This important ally joined Company 4 in 1974 from the army where he had served as a technician in a technical support unit. Since then he has worked in different capacities in the company's engineering, marketing, operations and training departments.

Although the Training Manager entered employment with a technician training, he has earned the respect of his more senior managers over the past 20 years because of his expertise, good conduct and seniority as one of the longest serving managers in the company. More importantly, since 1990 he has become a hero to all workers and line managers who feel threatened by possible future redundancies, particularly those who occupy less senior positions in the hierarchy of the organisation and have a lower social status. This is because he won a legal action he had taken against a senior management decision to make him redundant - with a number of other workers and white-collar staff - as part of a measure to reduce the company's staffing level. Indeed, he was reinstated as a result of winning an unfair dismissal case. By his own admission, he had felt embarrassed, initially, at having to work with management again after that incident, particularly in the face of repetitive references to him by those who argue their respective redundancy cases. Later on, however, he became accustomed to the consequences of this important development; it enabled him to see "the gap between management and the technical staff" and to contend that "one of my tasks is to improve the situation".

It seems that the personal support of this "heavyweight" individual for the Business Systems Manager in his integration campaign has been significant in strengthening an internal force for change. Resistance from within the ranks of the company's managers, however, has existed as a force against change but the internal pressures for integration in this case were so immense that in 1991 senior management decided it would be wisest to integrate despite the organisational difficulties that would lie ahead.

Another major force was behind this, namely that Company 4's parent organisation is always keen to acquire state-of-the-art technology because of its nationally sensitive position in the UK strategic defence electronics sector. Company 4 is regarded as a service company by the parent organisation which has always been prepared to support it by all means so as to guarantee a high quality service in return. Being technology-led, the parent organisation was in a position to initiate another force for change from outside the immediate boundaries of Company 4.

This force was combined with, and exacerbated by, another critical external force, namely the decline of the defence electronics industry under the post cold war world situation. The company responded to the pressures borne out of this decline in a positive manner by reforming its structure in order to be adaptable to the more difficult business circumstances which have existed since the start of the present decade. This move on the part of the company's senior management coincided with the internal pressures for change in favour of integration and, eventually, resulted in adopting an integration strategy:

> "In all aspects of management, I think, management want confidence as .... they need to go on to bid for contracts and win contracts and it makes management want much more confidence in what they can do. If there's a system in place and it's very efficient they can meet the time scales that are there."

In short, the main force against change in this case can be summarised in the following points (see Exhibit 7.3[a]):

* Conservative current from amongst management ranks resisting change and insisting on maintaining the company's "ways of doing things" in the context of the existing structure:

> "It [i.e. the company] is still not a mature environment. ..... People talk about all this integration work but it is still a long way [off]. Maybe in ten years time it will be [achieved] .... but it doesn't just happen .... and there is too much personalised interest .... each [department] has their own personal interest, making their sales, their own profits - you know."

On the other hand, the forces for change can be summarised in the following points (see Exhibit 7.3[a]):

* Turbulent global environment producing challenging conditions under which the company has to operate and prove it can survive as part of a major UK strategic project.

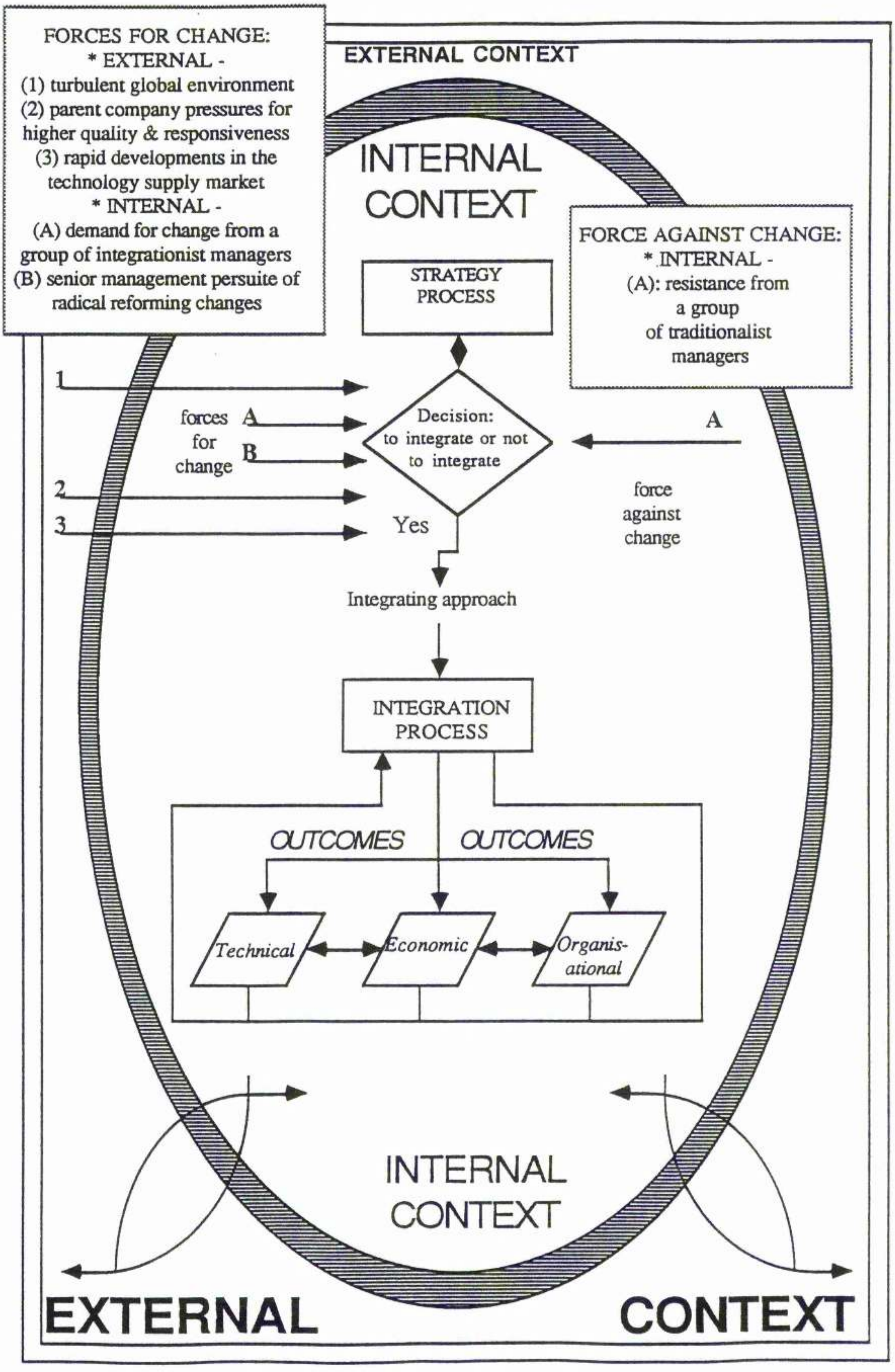
* Parent organisation/customer demands for greater quality and responsiveness pressing the company to take action to adapt to new circumstances in the market place.

* Rapid developments in the technology market where process technology vendors continue to offer up-to-date products and services relevant to enhancing the engineering and production processes of the company as well as to its competitors.

* A section of management, comprising a power alliance and supported by a wide technical knowledge base and a confident leadership, campaigning for integration with radical changes in existing organisational structure and culture.

* Senior management responding to external pressures to reform the company in line with the developments in the environment and to internal forces for change from within management ranks.

Exhibit 7.3 (a)
Applying the Model to Case 4: The Adoption of an Integrating Strategy



* ***The Integration Process: Facilitating and Impeding Factors***

The process of integration in this case can be described in terms of a long-term "evolution rather than a revolution" that aims to establish "the free flow of information between our disciplines" via CE:

> "If the information is made readily available it will make it [i.e. organisation for integration] a lot easier. ..... That's data management: exposure to the right data at the right time, that's concurrent engineering methodology. ..... The designers are 100% involved right from the beginning, not in a linear way but it will be exponential and you get manufacturing involved the other way round. ..... We've brought the area of overlap much greater in here. ..... What concurrent engineering does is not only it brings greater involvement but it also reduced time dramatically."

The company's Business Computer Systems Manager plays a crucial leadership role in the integration process. His instrumental role in "getting the company up and running" has enabled him to become a key individual whose job is to ensure that the systems are adequately supported and that new applications are investigated, selected, introduced and supported. The company's reliance on the technology he masters has made all users dependent on him to a considerable extent in performing their respective jobs. This has enabled him to reinforce his personal authority throughout an organisation where the majority of employees happen to be users as well.

An important feature of his strategy over the last five years is the great emphasis he lays on changing the company's culture to one which will accept integration, and the organisational changes that come with it, more readily:

> ".... that's the nature of human beings ..... We've had engineers who said: 'No, I'm not going to use it !', because they were scared of it or whatever. We've had people who said: 'This is great, this makes my job much easier. I will use it'. So there was a cultural problem and there was a training problem .... so we took in major training programs, we trained everyone that used theses tools. And as a result it's now a company policy that all our designs are done using these tools and it's accepted the culture has changed, but that took .... two years to get it there."

Furthermore, he has led a reformist current in the company, which aims to restructure the organisation along an integrated, project-oriented model. This includes creating "specialist teams", comprising six to eight engineers, and self-sufficient "pools of resources". According to this current, the existing functional structure is outdated and should be scrapped.

On the other hand, the company's Information Systems Manager is leading a conservative wing in the company to resist change:

> "I see certain resistance .... from right next door .... and there will be a conflict in the future .... So you've got this conflict between the engineering systems and the data processing systems ..... I would probably need to take control."

Traditionally, the Information Systems Manager has managed the company's information system[10]. The system has served to support formal communication channels which were set up historically in favour of a bureaucratically-controlled organisation. Therefore, any perceived intervention by one interest in the "territory" of the other will almost certainly provoke a conflict.

In the case of this company it appears clearly that senior management, under an immense pressure to adapt to new market conditions, is more sympathetic to the reformist-integrationist current led by the Business Systems Manager. It has apparently sided with him. He is the undisputed integration champion who aspires, to the detriment of his adversary, to become one day an "IT Manager in the heart of the organisation stretching to the Board". Indeed, he himself admits that:

> ".... senior management are quite serious, they back me up in what I'm doing and they realise they have to implement a system such as that to survive. They realise that if they do not introduce the system, which will increase efficiency in the end, they won't survive because everybody else is, all the big European companies. They all introduce these systems, it makes them so efficient. ..... So the CAE tools and CAD tools were just the first step point solutions to problems .... Now we've got to automate the business, that's what it's all about and management are behind me on that. .... They recognise that it has to happen."

It is no exaggeration to say that the integration champion represents a distinctive feature of Company 4. In fact, he is probably the most skilled, enthusiastic and hard-working change leader in all the ten companies in the study. He also enjoys a close relationship with senior management and is guided by an exceptionally clear, comprehensive, realistic and long-term vision. In addition to his outstanding technical expertise in the area of system interfacing, what strengthens his position is his enlightened appreciation of the far-reaching organisational implications of the project he leads. For example, four positive aspects of such appreciation could be extracted from a single interview with him:

First, his radical but clear-sighted view on the organisational implications of change:

> "I have to change the whole structure of our company, the whole structure of the business. .... I need to .... break up the barriers that are making the problems."

Second, his awareness about organisation-wide structural and cultural transformation requirements of the change process:

> "I have to change the structure .... It's back to the cultural thing again. It's not just a bunch of CAE engineers to change culture, it's everybody to change culture. So that will be the priority. That comes back to organisational change."

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[10]Including a mainframe *VAX* system, MRP, and a network of PC's.

Third, his political and inter-personal management skills. On being asked "how do you handle the different kinds of resistance to change?", he replied quickly and sharply:

> "Diplomatically! That's a day-to-day management reaction. You have to deal with them person by person as they come along. Some people will have to be bulldozed to do a thing, some people need persuasion, some people don't budge and you get power struggle and you get demarcation problems and all these kinds of problems."

Fourth, his appreciation of the need for closer, co-operative relationships with technology suppliers whom he views more as partners in the integration process than as vendors in the conventional sense of the word:

> "My experience from last year has led me to believe that you need very close links with your suppliers .... you need a very, very close relation[ship] and support long after you [have] got it installed."

Indeed, he realises how much power he needs to gain in order to be able to implement his future vision: ".... the only way we can do that is if I'm given power". His instrumental role manifests itself most clearly in his problem-solving skills; not only is he efficient in solving technical problems with the assistance of his teams of engineers but also he uses his outstanding inter-personal skills to settle disputes and find compromises to politically sensitive conflicts arising from the allocation of company resources in the process of integration. These include questions such as where should terminals be installed - together or in clusters throughout the company? How should data base and control systems be designed without sacrificing consensus?

Furthermore, what solidifies his position in the company is the present state of the defence market. From a senior management's point of view, he should be authorised to play the role of a business transformer for adapting to a new environment. Indeed, he regards himself as the individual who holds the key technical knowledge the company needs to "survive the market place in the future". Although his exceptional value to the company should be justified only in this context, he remains proud of that: "Oh, no doubt, I'm the driving force of all the tools and for getting them together".

The significance of the power factor manifests itself clearly in this case; the integration leader has sought power systematically and gained power increasingly to the extent that he has begun to compete with some senior managers (who have empowered him in the first place) on the exercise of a technocratically-justified authority. This is not normal in a bureaucratically-organised company, but has come about in this case largely because this distinguished individual has led a strong current resistant to the company's established authority. As a result, traditional claims of bureaucratic authority seem to have eroded due to persistent pressures from the integrationist current which has worked hard to install a technocratic form of rule.

It can be seen that a process of "power stripping" is unfolding in this case, without necessarily full awareness on the part of senior management. The traditionally bureaucratic but less technically-knowledgeable forces appear to be in the process of loosing power based on formal authority to a new power based on expertise. The newly emerging power alliance is increasing its *de facto* authority to a degree where it is beginning to show (to fellow middle and technical, but not to senior, managers) that it is prepared to lead the company; it represents itself as a saviour from a likely closure due to a declining business demand. This may involve restructuring formal "legitimate" authority relationships within the organisation in its favour and to the detriment of the existing bureaucratic power holders[11].

Indeed, power transformation in Case 4 appears to be in favour of the integration process since those who are emerging as more powerful are themselves the practical leaders and intellectual theorists of integration. However, even when knowledge, sincere intentions and willpower conditions are satisfied, the extent to which integration can be achieved will depend on the interaction of a variety of factors, such as the ones discussed in this chapter.

In conclusion, the integration process in this case is progressing effectively as facilitating factors outweigh impeding ones. The impeding factors in this case can be summarised in the following points (see Exhibit 7.3[b]):

* Multiple systems to be interfaced, including more than a single CAD system, a CAE, a CASE, and a CAM system that are distributed over the company's three sites: "We've got to think about hardware and software. It's happening all the time and managers don't like that". The market for interfacing standards (for data base formats and information exchange between data bases) offers only costly products and services for

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[11]It should be noted, however, that the organisational context of this case is in favour of such power shift. Four points can be mentioned about the conditions under which this phenomenon is emerging in Case 4:

1) The nature of the product development function in this case resembles a technology-intensive R&D (Research and Development) centre; the work place environment for all the company's professional engineers requires them to work closely with each other and this causes them to mix extensively as a social collectivity.

2) The technical knowledge base of the company comprises a larger proportion of the total number of professional engineers than in any of the other companies and, hence, it could be argued that this has helped the cause of technocratic power politics.

3) Because of the reasons outlined above, the integrationist current in this case is empowered, through the integration leader personally, by senior management; such empowerment is central to its success.

4) The economic difficulties encountered by the company in a declining industry appears to have increasingly weakened the credibility of traditional bureaucratic governance which had dominated during the times when business was flourishing, particularly during the "cold war" era. It is likely that the business will be further commercialised to supply the civilian market. This move appears to be favourable to the emerging technocratic alliance which is better positioned to respond to market pressures for higher quality standards and flexibility in the face of changing market demands.

the complex technical requirement of Company 4 (e.g. standards that can handle modelling as well as CAE and CASE information) in a market dominated by giant manufacturers promoting their respective products as standards: "There's no outright standard. Standards that are in the market place need a standard!".

* Financial difficulties justifying integration under the current circumstances of the business and within existing short-term accounting procedures:

> "We have a 4-year depreciation period. .... It's general: any piece of equipment we buy, whether it be a computer or a filing cabinet, they all depreciate. There's a standard form that you fill. ..... Ideally, I would like to replace half of our CAD systems with new ones. ..... I'd like to do that tomorrow, but I know I couldn't cost-justify it."

* Low-trust and unstable industrial relations:

> "We are getting downsized as an organisation, with many lay-offs. .... because of the trauma within the organisation; we've seen three [waves?] of redundancy over the last three years, we've seen the defence industry really bottomed down. Individuals have been concerned or began to conceive that there is a lack of commitment on the part of management."

* The relatively large size of the company as only a subsidiary unit of a larger corporation with a rigid structure and a bureaucratic culture which is resistant to change:

> "Any large organisation is bureaucratic, it has a law of its own, if you step out of it you get hammered to the floor! And unfortunately the [naming Company 4]'s mentality is that ..... There's too much departmentalisation: 'this is my problem, this is your problem' attitude."

On the other hand, the facilitating factors in this case can be summarised in the following points (see Exhibit 7.3[b]):

* A clear vision of integration, guiding a process of strategic planning on the issue to support overall business strategy. The implementation of this vision is being defended fiercely in the face of "totally unavoidable power struggles" to change the existing culture to a more "integration-friendly" one: "It's a cultural change; there's no way you can change a culture without major problems".

* A solid and diversified technical skill base and knowledge at the disposal of the integrationist forces. The emphasis on strengthening existing skills and acquiring new ones is paramount: "We want a very high degree of skills".

* Special attention being paid to the training and staff development requirements of integration and the Training Manager taking a central role in integration alongside the integration leader:

> "We don't just buy in the hardware, that's only the first part and people can recognise that, but we've got to spend a similar sort of money on training, which again people recognise, but on education, 'cause we have to change people's concepts on working in a totally different way under this sort of arrangement."

* Outstanding leadership attributes of the change leader in terms of his technical, organisational, and interpersonal skills and the support and empowerment given to him by senior management.

* A very low-volume type of production system encouraging co-operation among the various groups of engineers and scientists whose common focus is on developing a one-off, complex product item over an extended period of time.

* Close involvement of the parent organisation, which operates on a technological leadership basis, and the company's suppliers in the CADCAM integration process.

* Intensive economic pressures treated as a challenge, rather than a threat, and thus utilised as a facilitating factor in the move towards integration.

* ***Outcomes of Change***

Company 4 is one of the most integrated cases in the study in CADCAM terms. Judging by the present state of the technical, economic and organisational outcomes of its process so far, the integration project in this case seems likely to continue developing at a relatively fast and consistent rate.

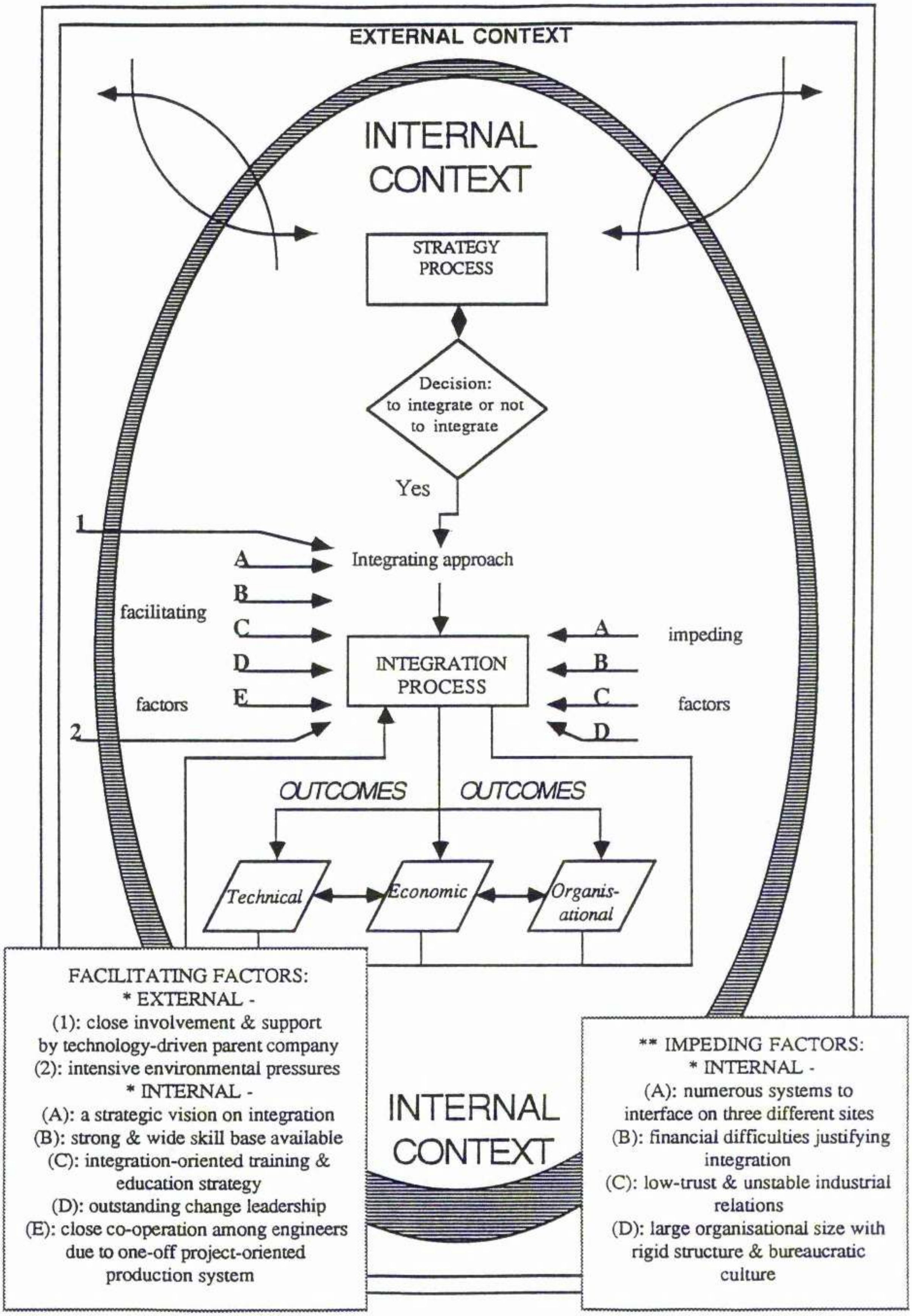
Technically, the company has the largest number of interfaced multi-work-station systems (i.e. CAD, CAE, CASE, CAM) in terms of the cases in the study. Such systems used to exist as independent stand alone applications on three different sites. Despite the difficulties still being faced in trying to increase the degree of interlinkedness, because of the lack of effective affordable standards, the degree of electronic communication among these systems is yet unparalleled in any of the other companies. High interlinkedness has translated itself into a smoother and more efficient information exchange among the different functional departments concerned as well as between the various sections of the company's huge engineering function.

Economically, any achievable financial reward of integration will be rather difficult to measure with accuracy during the period of this study due to three main reasons:

1) A conventional accounting system which was born out of a bureaucratic mode of organisation and has survived over the decades in a manner which is incapable of taking on board integration cost and benefit accounting.

2) Only a few years have passed since an integration strategy was adopted, and a longer time is needed before the true long-term advantages and disadvantages of integration can be appreciated or even expressed in financial terms.

Exhibit 7.3 (b)
Applying the Model to Case 4: Factors in the Implementation of the Change Process



3) Under internal and external pressures, other major changes have been introduced into the organisation as part of a plan to reform it, which makes it particularly difficult to isolate integration as a single factor responsible for the relative improvement in performance since the last quarter of 1995.

Organisationally, the integration process in this company has been synonymous with radical changes in so far as the existing company structure and culture are concerned. Unlike the economic outcomes, the organisational outcomes of integration have already been felt throughout the company. Two polarised streams of opinion can be found: one in favour of and one against change. In view of the depth and width of the organisational changes taking place, it is difficult to find any number of indiviuals or groups who are still disinterested.

CE arrangements have been systematically pursued by the integration champion. The aim here is to operate on a project basis. Regardless of whoever initiates a project idea, the main criterion for acceptance is that the project should be customer-focused. A greater degree of co-operation and information sharing between different groups of design and product development engineers has been brought about. Such groups used to be functionally organised in the old structure which is now being replaced by a CE-oriented one in which new specialist teams are set up for the duration of a project's lifetime and then reorganised flexibly for another project. Each task-oriented team comprises between three to seven members and is led by a team leader selected by the integration champion (with senior management's blessings) who devotes time for each team to co-ordinate their functioning concurrently. Loyalty to the champion, in his formal capacity as the Computer Systems Manager, is important given that team leaders now have to work closely together from the conception of a new project, with the champion as their common reference for technical guidance and "parental" support.

Face-to-face, informal communication is at the centre of this new approach. The idea is to continue removing existing individual offices separated by walls and corridors. Instead, an open-plan office environment is being constructed, in which everyone works in the same physical place and staff move freely to perform their respective project-defined work tasks. Old demarcation lines are being gradually phased out in this environment which resembles a "paperless office" where everybody is required to have access to and use a computer. Of course, staff have not taken to this way of operating overnight or fully accepted it yet but the trend is towards a more transparent kind of corporate culture in which all aspects of the business are known to everybody in this kind of work environment.

This situation contrasts sharply, and is replacing, the older "them and us" corporate culture based on the principle that information should be made available only on a need-to-know basis. Central to the strategic thinking behind this shift is an emphasis on developing people as the key to achieving a competitive edge, through a learning organisation work environment which helps individuals draw ideas from a wide range of sources and adapt them to the company's requirements. From an organisational point of view, therefore, the result of this has been to transform relationships and working practices by replacing the company's traditional structure and culture, though not in everybody's mind, with a team-oriented, company-wide approach.

The concentration of power in the hands of the integration champion stems not only from his position as a controller of such a vast and diverse skill base which the company possesses, but also from the fact that he has offered himself as the only single channel for communication between the company's technical base and the company's highest level of management, despite the resistance he encounters from some senior engineers who are unhappy about the changes. Senior management continues to support the empowered champion as long as he is showing that he can improve performance and thus attain the company's competitive position.

In conclusion, from what one knows about this case, it seems that integration is likely to progress further and bring with it further solidification of the structural changes being implemented. The emphasis on an integration culture to replace the existing culture is also likely to spread further outside the areas of the organisation controlled by the integrationists due to the presence of an integration-enthusiast Training Manager who pays special attention to developing a pro-integration human resource management strategy. The implications are that this important ally of the champion co-ordinates his department's recruitment, training and education plans (which affect the entire company's work force) with those of the integration leader to assist the spread of their vision of culture as the existing one is being gradually phased out.

The following two sections will look at the primary cases in the study from a wider angle: section 7.5 will summarise the obstacles to integration as experienced in the cases and section 7.6 will discuss the organisational aspects of the obstacles in terms of the internal contexts in which they are identified.

7.5 An Overview of the Primary Cases: Obstacles to Integration

According to the study's model, a company's decision to adopt an integration strategy is likely to be made as a result of the dynamics of the various internal and external forces for and forces against change acting within the company's strategic decision-making sphere. Similarly, the progress of an integration process is dependent on the factors acting upon it from within and outside the company. From the point of view of those managers who are associated with integration in the primary cases, the process is unfolding but very slowly and problematically. Why is that so? As far as they are concerned, there are "obstacles" on the way to full integration, which are responsible for the this situation.

The model's conceptualisation of the facilitating and impeding factors influencing an integration process and thus its outcomes can be used to explain the identified obstacles. In other words, the theoretical groundwork of the model can be used to illustrate how the conceptualised facilitating and impeding factors may help trace the internal and external roots of the obstacles. In the context of the present model, these obstacles can be an expression of the relative prevalence of the magnitude of the impeding, over the facilitating, factors[12].

The identified obstacles can be classified and codified into three groups: 1) "**E**": economic, 2) "**T**": technical[13] and 3) "**O**": organisational (Exhibits 7.4 and 7.5). The emphasis in this and the consequent sections will be on analysing the organisational obstacles[14] which are "probably the most difficult to overcome" because integration "challenges the accepted way in which organisations work on a day-to-day basis" (Bessant, 1991: 305).

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[12] This reference to the "magnitude" of the factors involved means that the impact of such factors on an integration process is not assessed in terms of the number of individual factors acting upon it in either direction, but rather in terms of the criticality and force of each factor.

[13]The technical obstacles identified include incompatibilities of data structures and programs because independent data processing systems were developed separately throughout the 1970s, 80s and early 90s. The use of translation programs to match up different island programs and data systems and then combine them is technically possible but rather complicated. It causes a serious barrier to further integration by linking existing integrated modules with others.

The market situation in product-related information processing is not supportive of systems integration (see, for example, Boubekri *et al., 1995*); numerous software houses with outstanding knowledge of technology are in a good position to supply customised integration modules to small and medium sized enterprises but these companies' systems are supplied by larger manufacturers, each of whom has their own comprehensive package standards. From the point of view of small and medium sized companies, therefore, integration is difficult because they have to construct their own systems gradually, depending on various technology vendors due to their constraining investment and product diversity levels.

[14]As explained in Chapter 1, a detailed analysis of the technical and economic factors is outside the scope of the present study.

Exhibit 7.4
Coded Obstacles to Integration in the Primary Cases

CODED MAIN OBSTACLES TO CADCAM INTEGRATION
FOUND IN PRIMARY CASES

TECHNICAL

- *T1 System interfacing difficulties due to incompatibilities
- *T2 Difficulties incorporating new CAE package
- *T3 Diffculties replacing existing CAD system for integration purposes
- *T4 Too many isolated "islands of automation"
- *T5 Lack of standardisation in the CADCAM supply market
- *T6 Lack of technical co-operation within manufacturing industry and among companies and educational institutions and research establishments

ECONOMIC

- *E1 Financial justification difficulties

ORGAISATIONAL

- *O1 Lack of senior management support
- *O2 Protective functional managers
- *O3 Changing organisational structure
- *O4 Changing organisational culture
- *O5 Lack of customer involvement
- *O6 Lack of supplier involvement
- *O7 Inadequate incentive and reward policies
- *O8 Employee resistance behaviuor

MAIN OBSTACLE as found in a Primary Company	Distinguishing Characteristics					OBSTACLE FREQUENCY
	Case 1	*Case 2*	*Case 3*	*Case 4*	*Case 5*	
TECHNICAL						
T1	✓	✓	✓			III
T2		✓				I
T3			✓		✓	II
T4				✓	✓	II
T5	✓		✓	✓	✓	IV
T6						
ECONOMIC						
E1				✓		I
ORGANISATIONAL						
O1	✓	✓				II
O2	✓	✓	✓	✓	✓	V
O3				✓	✓	II
O4			✓	✓	✓	III
O5		✓	✓			II
O6		✓	✓	✓	✓	IV
O7		✓	✓	✓	✓	IV
O8		✓		✓	✓	III

*T1 System interfacing difficulties due to incompatibilities
*T2 Difficulties incorporating new CAE package
*T3 Diffculties replacing existing CAD system for integration purposes
*T4 Too many isolated "islands of automation"
*T5 Lack of standardisation in the CADCAM supply market
*T6 Lack of technical co-operation within manufacturing industry and among companies and educational institutions and research establishments

*E1 Financial justification diffculties

*O1 Lack of senior management support
*O2 Protective functional managers
*O3 Changing organisational structure
*O4 Changing organisational culture
*O5 Lack of customer involvement
*O6 Lack of supplier involvement
*O7 Inadequate incentive and reward policies
*O8 Employee resistance behaviuor

KEY TO CODED OBSTACLES USED IN TABLE BELOW

Exhibit 7.5: Main Coded Obstacles as Found in the Primay Companies

7.6 Organisational Obstacles: An Internal Context Perspective

Building on the social processes perspective of the present model, one can extend the basic argument about the need to take a closer look at the social structure of an internal context of change with a view to identifying the reasons why the integration process in the studied primary cases does not seem to progress as speedily as it might do[15]. No attempt is made here to reduce the obstacles that integration encounter into social relations *per se*. By the same token, however, it cannot be said that such obstacles are restricted to technical and economic limitations alone.

Socially-explainable "centrifugal tendencies" (see Child, 1977) that may be found in any organisation (due to the various and conflicting paths chosen by the many different individuals and groups who are affiliated to it in different capacities) are an important factor in explaining the nature of such obstacles. This is because such tendencies not only point directly to straightforward organisational obstacles but they can also help one explain possible organisational causes to what appear to be obstacles of a purely technical or economic nature. For example, one can argue that system interfacing difficulties due to incompatibility (i.e. "**T1**" in Exhibit 7.5) is, partly, a result of excessive departmentalisation in the first place, with each department going its own way in computerising its operations without co-ordination with other departments through a common corporate vision of integration. Also, financial justification difficulties (i.e. "**E1**" in Exhibit 7.5) can be traced, in part, to accounting systems that reflect an organisational culture dominated by short-term financial gain values and a highly bureaucratic structure.

In examining obstacles to integration in the five primary case studies in the light of the evidence from Chapters 5 and 6, a number of points can be made. First, it is obvious that the design, engineering, and manufacturing tasks carried out in each company are dependent on the company's product attributes[16] and production system attributes[17].

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[15]This study's emphasis on the internal social processes affecting integration does not mean that external influences are, or should be, ignored. On the contrary, as the two case examples (sections 7.3 and 7.4) clearly show, these play a significant role in causing and directing change; it is the present study's orientation, objectives, and design that lend themselves to an internal focus since a detailed analysis of external factors is beyond the study's scope.

[16]Such as the number of levels of product structure, the number of components and subcomponents in a typical product, the percentage of standard versus special parts, the degree of customisation versus design freedom, raw materials lead-times and product life cycles.

[17]Such as type of production system (e.g. jobbing, batch or process); whether capital or labour intensive; whether low, medium or high level of operations; type of layout (e.g. functional or CM); availability of labour and machinery; degree of on-site assembly; level of skills; percentage of cost on design, manufacturing, assembly and commissioning; and inventory and stock control system data structure, MRP scheduling, CAPP and JIT practices.

They also depend on product range[18]. Given that each company in the study has its distinctive production system which is reflected in the structure and processual dynamics of the work tasks of its DEM functions, each CADCAM integration project draws directly on the nature of the technical core of its host manufacturing company.

Second, key individual "champions of change" in the companies studied appear clearly to have influenced both the process of change and its outcomes through their power, values, interests, tacit knowledge and relations with external constituencies of technology suppliers and capital providers (see Greiner and Schein, 1988; Howell and Higgins, 1990; Scarborough and Corbett, 1992). Transformational leadership behaviour (e.g. in Cases 4 and, to a lesser extent, 5) manifests itself in terms of intellectual stimulation to integration team members (see Nadler and Tushman, 1990). Although communication skills of the more successful leaders are an important factor in winning the involvement of many employees, a leader's ability to "turn words into actions" (Case 2) is even more important from the followers' point of view.

The "socio-political context of change" (Lee, 1989) in an organisation is of a central importance in understanding how the integration process unfolds, where more powerful individuals and groups are likely to influence decision making considerably[19]. Integration leaders in the researched organisations tend to belong to technically-oriented middle management ranks. Some of them remain restricted by, and content with, their existing share of power. Their power positions are protected by their immediate senior managers who, in most cases, occupy positions at a Board level. Under the leadership of such powerful individual "sponsors", integration leaders concern themselves mainly with the technical aspects of change in the majority of cases (e.g. in Cases 1, 2 and 3). Others, however, are not content at all and seek to support their manoeuvres by reinforcing their "individual power bases" via increasing, among other things, their information, expertise, professional credibility, reputation, and staff support[20] (see Greiner and Schein, 1988).

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[18]In Cases 2 and 3, for example, the variety of wide-ranging design projects commissioned is identified as a significant barrier to further development of the original CAD systems and their integration within a CADCAM arrangement.

[19]As Clegg (1994: 164) puts it, "the experience of power is inescapable whenever there is effective organisation, binding independent agents together, yoking them to the pursuit of a purpose made common". Power - in its various forms or "dimensions" (derived from resources, processes and meanings [see Frost and Egri, 1991; Lukes 1974]) - is therefore sought by change agents in order to drive CADCAM in a desired direction (see Greiner and Schein, 1988; Hardy, 1994).

[20]Whatever power share integration leaders may be able to earn, it should be stressed, nonetheless, that their role should not be exaggerated to the extent that organisational change is viewed as solely the product of far-sighted action by champions willing to take risky decisions. The context within which transformational leadership is exercised, the extent to which personal leadership attributes match the logistical requirements of a situation, and the hierarchical position of the leader within the formal =

Third, an organisation's size[21] is a significant factor in integration (see Arcelus and Wright, 1994; Thong and Yap, 1995). Smaller size is associated with more flexible organisational structure, more efficient communications, less social stratification, and less formal working relations. Such characteristics are potentially capable of facilitating integration in smaller companies, provided that it is economically feasible and technically advantageous in the first place. These two conditions, however, could rarely be found in the smaller companies studied.

On the other hand, larger companies tend to have more formal procedures, more specialists, better qualified staff, wider horizontal and longer vertical spans of control, and decentralisation of operational, but not strategic, decisions. Due to more standardised procedures, decision making on CADCAM integration tends to take longer in larger and more bureaucratic organisations. Vertical and horizontal communications are slower: "even in a larger company the opportunities and difficulties in getting CADCAM in operation are extremely difficult" (Case 2). However, the most expensive and advanced integrating technology is to be found in these companies. This confirms the proposition that larger, more resourced companies are more likely to take the lead in new technology investment because of their greater enabling resources whereas smaller ones tend to observe the change process and then follow suit (see Arcelus and Wright, 1994; Currie's, 1989; Truman and Keating, 1988).

> "We are not in the business like *IBM* where we throw a couple of million dollars and say: 'Well, that was a good idea but it didn't work!' .... when we do things they have to work!" (Case 3).

Fourth, the findings suggest that an organisation's size and structure[22] are closely interlinked. The larger an organisation, the more likely that its informal mechanisms for the direction, co-ordination and control of activities will break down as the number of linkages multiplies beyond the limits manageable by individuals. Bureaucratic processes are then introduced to control increasingly decentralised operational decisions. This phenomenon is clear in larger companies (e.g. Cases 4 and 5) where

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= organisational structure (i.e. *de jure* authority predicament) and actual (i.e. *de facto*) power position are crucial factors that constrain a leader's ability to change.

[21]Variations in size can be reflected in several organisational attributes, such as the number of levels of management in a hierarchical organisation and the number of employees reporting to a specific manager. In this regard, the findings support the proposition that size is closely associated with bureaucracy (see Weber, 1947). The findings also support those of subsequent studies in the *Aston* tradition, proposing that an organisation's size is a major determinant of structure (Child, 1973; Pugh and Hickson, 1976; Pugh and Hinings, 1976).

[22]An organisation's structure represents the background or relative constancy against which a CADCAM integration process has to be managed (see Pettigrew, 1985). Therefore, key properties of such background (e.g. communication patterns, networks and roles) influence, positively or negatively, the progress of integration and its outcomes in any case.

more formalised, standardised, and lengthy procedures are the norm. Case study evidence supports the proposition that organisational size correlates with the formality of organisational structure (see Burns and Waterhouse, 1975)[23]. It is evident from the findings that formal decision making based on departmental budgetary systems in some cases can become a ritualistic management activity which does not serve the cause of integration.

As far as size is concerned, larger organisations tend to have more mechanic structures, whilst organic types of structures are associated with smaller organisations (see Burns and Stalker, 1968)[24]. Given that larger organisations tend to use more complex process technology, it is tempting initially to deduct on such grounds that they will have greater chances of integrating their CAD and CAM systems. However, the findings do not support such a proposition. Organically-structured companies, by definition, are prone to integration. Mechanistic types of organisation, on the other hand, are so rigidly fragmented that any form of organisational change will be resisted by many individuals and groups whose social identities have been shaped over the years around a strong departmentalised division of labour: ".... they [i.e. managers] always see they are going to [i.e. protecting the interests of] their [own] departments" (Case 5)[25].

It can be argued that such a situation represents a dichotomy. On the one hand, smaller companies with less complex technology enjoy a more organic structure which may

[23]The characteristics of an organisation's budgetary control system represent a function of the general level of bureaucracy (see Burns and Waterhouse, 1975). Management in more bureaucratic companies might be expected to have developed reliance on formal budgeting systems which are perceived to be a necessary part of the procedures by which decentralised operations are planned and controlled. When viewed from another point of view, however, budgeting systems increase the degree of bureaucracy as a strategy for control by adding to the number of formal documents and procedures, to the number of qualified specialists, and to the spans of control in certain parts of the organisation. Indeed, more bureaucratic organisations are more likely to introduce budgeting and, in doing so, they are likely to become even more bureaucratic. Financial justification documents also serve a legitimising function in larger bureaucracies where various competing rationalities are defended by various groups - formal and informal alike.

[24]The main characteristics of mechanic organisations are: (1) specialised differentiation of functional tasks, (2) tightly and precisely defined functional roles, (3) control via the hierarchy, (4) a hierarchical structure which protects secrecy about what happens on the top of the pyramid, (5) interaction tending to be between superior and subordinate, (6) operations and working behaviour governed by supervisors, (7) loyalty and obedience highly valued, and (8) greater importance attached to knowledge of the company's ways of working rather than general knowledge, experience and skill. On the other hand, the main characteristics of organic organisations include: (1) the contributing nature of special knowledge to the common task, (2) the adjustment of individual tasks through interaction with others, (3) the spread of commitment to the concern beyond the technical definition, (4) a network structure of control, authority and communication, (5) a lateral rather than vertical pattern of communication, (6) a content of communication consisting of advice and information, rather than instructions, (7) importance attached to affiliations and expertise which had validity outside the narrow environment of the firm.

[25]Informal interest and alliance groups, which are invisible on a formal organisation chart, are also likely to stand against organisational change if they feel it will diminish their influence.

potentially facilitate integration. Yet, integration is not likely to be as feasible economically nor is it likely to be supported as well technically in smaller companies. On the other hand, the technical conditions for integration are reasonably satisfied in the majority of the larger companies. Yet, integration experiences in such organisations are a massive challenge because existing structures were not only initially designed for a fragmented and highly differentiated approach to technological development, but also have protected individual, departmental, and group distinctions that have accumulated over a long period of time. If one was to imagine an ideal situation with optimal conditions for integration, it would be one that combined the organisational strengths of smaller companies and the technical and economic advantages of the larger ones.

Fifth, the findings show that an organisation's culture[26] has implications for either stimulating or discouraging CADCAM integration. This corresponds to the general point discussed in the innovation literature, concerning the role of culture in terms of how supportive it is of change (e.g. Currie, 1989; Kanter, 1983; Robey and Azevedo, 1995). Culture can either facilitate or hinder an integration process because it establishes a degree of order in social life above and beyond that order suggested by a formal structure; it influences individuals' behaviours, especially at those times of uncertainty which will surround any significant change. This explains, in part, why the most instrumental integration leaders in the researched companies regard organisational culture as something that is more difficult to manage than the integrating technology itself. In Case 4, for example, culture is presented as the number one obstacle.

It is important to stress, however, that several sub-cultures can, and do, coexist within an organisation, particularly in larger organisations (see Gregory, 1983). Therefore, any notion of "company culture" (see, for example, Adler, 1989) should not be taken for granted as implying a necessarily homogeneous culture throughout an organisation. Intra-organisational cultural variations tend to be based on functional, professional and occupational divisions. A typical example of cultural differences among different functions within a company are those found between design and manufacturing; such differences contribute to a high degree of differentiation along formal departmental lines.

[26]The earliest explicit reference to the concept of "organisational culture" is attributed to Pettigrew (Robey and Azevedo, 1995). Pettigrew (1979: 574) defines an organisational culture as a system of "..... publicly and collectively accepted meanings operating for a given group at a given time". Thus, it represents shared subjective interpretations of shared experience. The role a collective experience plays in forming a culture is illustrated in its ability to mould learning, validation, sharing and transmission of such meanings into a set of recognisable explanations related to an organisation's on-going attempts to maintain itself (Schein, 1990).

The presence of more than a single sub-culture gives rise to the question of dominance and its implications for an integration process; in most of the researched companies design or engineering departments' tend to dominate. The professional influence of so-called "front-end" designers, responsible for providing the rest of the organisation with the information needed for the manufacturing operations, is apparent in most cases. This is so even in those companies where designers are a minority (e.g. Cases 1 and 3). Senior management often sides with white-collar, professionally-oriented design sub-cultures at the expense of the manufacturing and production sub-cultures[27]. This helps one explain why the leaders of integration projects were invariably from the design department, even though the computerised manufacturing technology involved in integration is invariably a more expensive investment than CAD. It is not surprising, therefore, to find that integration is conceptualised and directed from a design culture point of view. Most of the members of staff who are demanding more integration, and thus representing a progressive force for change inside their respective organisations are from engineering or design rather than manufacturing or production (as shown, for example, in the critical incident case examples in sections 7.3 and 7.4).

Sixth, the lack of CADCAM knowledge by many executive managers, partly due to their underestimation of the magnitude of moving to full integration, represents a serious problem in some cases (e.g. Cases 1 and 2). Training for CADCAM involves substantial expenditures that are not always anticipated beforehand. Senior managers tend to expect fast and effective results without paying too much attention to the quantity and quality of training given to users, operators, programmers, and managers. The thinking is that, given time, these people will learn on the job. However, this situation often amounts to an "incomplete organisational learning" process (see Kim, 1993; March and Olsen, 1975). This occurs when a learning cycle fails to develop properly as a result of flaws such as learning under ambiguity, situational learning, and fragmented learning. There is, seemingly, an implicit belief that hardware will fix things and that one does not have to worry overtly about the human element: "We created problems for ourselves .... and those are the things that are not gonna happen again" (Case 5).

[27]It can be said that this reflects the social reality of the two functional areas as it is perceived by many members of the studied organisations, including people from production and manufacturing themselves. A greater degree of prestige is attached to engineering positions, most of whose occupants tend to be university graduates who are aware about their professional and, thus, social standing; they also tend to earn higher salaries. This applies to draughtsmen as well, who are also classified as white-collar staff with office-based jobs, although to a lesser degree. On the other hand, the majority of manufacturing and production staff, excluding a top few managerial and technical positions, tend to be blue-collar, hourly-waged employees who entered employment through apprenticeship schemes.

It is evident that senior management's reluctance to invest in training is a major barrier to a more effective utilisation of CADCAM. Not surprisingly, middle technical managers, who are always held responsible for integration in terms of operational gearing, tend to be much more concerned about training; they tend to have a more realistic understanding of the challenges of integration and the training issues it raises[28]. Their demands for broader and better formal training arrangements can be seen as a way of expressing their concern about the performance of newly introduced technology. Training is a politically sensitive issues; it is often used in self-defence if and when senior management accuses them of failing to accomplish set objectives.

Seventh, protective behaviour by many functional managers is a common denominator amongst the five cases, particularly in larger companies with a more dynamic power politics context. It manifests itself most clearly in the strict control which functional managers exercise with regard to releasing and sharing what they regard as "departmental information": ".... it's the departmental manager that causes the problem" (Case 2). The traditional separation of responsibilities (particularly in larger, more structured bureaucratic organisations) has created extremely differentiated conditions which work against integration at the procedural, structural, and cultural levels: "We've always done it like that" (Case 5). It is difficult to see how integration can be brought about without developing sufficient training, education and social support capacities to facilitate a greater emphasis on openness, knowledge distribution, communication, participative decision making, and discipline (see Fossum, 1986).

Eighth, the findings on the budgetary process show that many engineering managers are unhappy about traditional approaches to capital budgeting for integration, because of their short-termism[29]. Although they believe that senior management should still be

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[28]For example, leading technical managers find that CADCAM integration requires a shift from a situation where employees have a single skill tied to a single function, towards multi-skilling and flexible disposition of these skills. They also find that a greater attention should be given to senior management's training and development to stimulate their commitment to, and participation in, integration as a strategic process (see Bessant, 1991).

[29]Whereas in the past stand alone systems could be more easily justified on the basis of quantifiable operational gains, CADCAM now requires a justification mechanism capable of calculating its potential strategic benefits (see Gunson and Boddy, 1989). Short-term financial justification practices might have supported isolated stand alone applications such as CAD or CAM; however, they represent a serious obstacle to integration projects.

Financial justification of CADCAM is particularly difficult because it involves an initial commitment of very high capital and subsequent amounts for further integration. The groundwork to prepare human and infrastructural resources to establish acceptability of CADCAM must also be paid for (see Mohanty, 1993).

Parker and Lettes (1991) suggest that companies should develop new techniques which would require a surge in outlays that accounting conventions treated as a current expense on the basis of the primary cost elements in CIM. Such elements should be driven by decisions concerning: (1) capital equipment, (2) product technology, (3) computer software, (4) production operations, and (5) factory overheads.

in control of capital expenditure, they are helpless to change the procedures whereby a great degree of control is exercised by accountants. Technical managers find themselves stuck between senior managers who hold them responsible for achieving the promised benefits of technology and financial controllers whose short-termism often prevents a comprehensive illustration of the strategic benefits that cannot be based on a straightforward payback evaluation (see Currie, 1989; Dodgson, 1988). CADCAM in particular is not suited to short-term approaches because of the long gestation period required to make the system fully operational and the high uncertainty and risk associated with estimation of expected monetary returns over a long period of time[30].

> "Main Board Directors of any PLC are driven by the share price .... by the shareholders wanting return on their investment .... by the pension funds, the big institutions wanting the money for their people either in share growth or in profit. So it's all take, take, take - all the time. ..... You get these guys sitting on the Board, if they don't perform somebody takes them over. They will pressure the company to get the maximum output in financial terms and tend not to take the risk on the longer term lane .... they have certain financial constraints in front of them to meet the wishes of the City." (Case 3).

In the face of their unhappiniess about existing accounting rules, integration leaders in some cases (e.g. Cases 3, 4 and 5) are tempted to ally with other high-ranking managers, particularly those with a technical background, who happen to be sympathetic to the cause of integration. Through such alliances, they aim to work out how to make integration investment proposals more presentable. Besides forming political alliances to increase pressure on the finance department, they also attempt to take the cost of training out of the technical budget and add it onto other budgets to make the proposed integration project look more appealing.

7.7 Summary

This chapter has presented the third and concluding part of the analysis and discussion of the findings from the field research. It has introduced the conceptual model used to depict the crucial elements of CADCAM integration as a technology-induced organisational change. Two examples have been given of how the model could be used to explain a critical experience in a non-integrating company (i.e. the "cultural or mental gap" example in Case 10) and another in an integrating company (i.e. the "power-stripping" example in Case 4).

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[30]As Primrose and Leonard (1986: 27) point out, "despite the condemnation in accountancy literature of non-discounting techniques, such as payback or accounting rate return (ARR), many UK companies still use these techniques ..... because they are easier to apply". By comparison,

> ".... they take a longer term, industry-wide view in Japan. .... If you look at the motorbike industry and the ship-building industry .... where they came with 50 cc and stripped the industry totally off this country. They didn't crucify the British motorbike industry overnight; .... they took a long-term view of where they wanted to go and dominated the market .... and somebody had to finance all that. It's the same in electronics, they dominate it, but they were prepared to do it." (Case 3).

In spite of the high accumulative integration costs incurred in Case 4 (due to intricate system interfacing requirements), these were justified because of the support the company received from its parent organisation. As explained earlier, the situation in Case 10 was different; unless stronger external pressures were to be exerted on the company (e.g. from customers, industry regulators and/or government) senior management in Case 10 would seem unlikely to change its current position and adopt an integrating strategy as demanded by a group of the company's technical middle managers. In Case 4 internal and external forces acted collectively and simultaneously upon management and pressed it to adopt an integration strategy in a manner which had not happened to the same degree of intensity in Case 10. In Case 4 senior management's support for integration as a likely ingredient of a formula to reform the company had led to it develop a sympathetic attitude to the pro-integration group within the organisation. This group, in turn, made the best possible use of the favourable environmental conditions to campaign for, and empower, the cause of integration.

In general, it can be said that when a business is in decline the issue of technological progress becomes less of a priority. However, in some cases (e.g. Case 4) management's reaction to immense external pressures may take the form of revising organisational practices to attain maximum efficiency. To the integrationists (most of whom are "anti-establishment"), this is a long-awaited opportunity to seize in order to transform the company, as far as they can, into a more integrated organisation.

It can be said therefore that a flourishing business performance may encourage management to think more seriously about CADCAM integration but it is not sufficient, on its own, to make managers take practical steps towards its implementation, unless there are also strong pressures for change from within the organisation. By the same token, integration may be sought as a way out of decline if management thinks that the technical advantages inherent in it will help save the company as a viable business; evidence from Case 4 supports this proposition.

As argued in Chapters 2 and 3, a technical rationality approach would not have encompassed the effect social processes have on the progress and outcomes of integration, since it would have represented CADCAM as a universally desirable profit-maximisation technology whose implementation would have been simply a matter of investment justification and straightforward, rational managerial decision making. This chapter has shown that by using an implementation model a researcher can focus on the social processes that emerge in organisational life (in whose context integration takes, or fails to take, place), and thus develop a picture of change which is grounded in its true social environment. The resulting picture is therefore much more likely to reflect the active social and political forces that make this environment a dynamic one.

By focusing on the internal context of change the foregoing grounded analysis aimed to stress the importance of the dynamics of an organisation's social processes for understanding the link between the internal and external forces and factors that influence integration. To neglect the dynamic nature of this link means to give way to more deterministic tendencies in explaining technological change in terms of a straight-line progressive pursuit of technological advancement, a pursuit that is motivated only by profit maximisation or other desirable financial objectives. Whilst such obvious influences should be sufficiently accounted for, due attention should also be given to the internal context of the adopting organisation, where the existing and potential energies of social processes are capable of making a difference to the process of change and its outcomes.

At any rate, just as the argument for environmental determinism is rejected because it exaggerates the role of environment in in-company technological change, the suggestion that mere scientific knowledge is the only prerequisite for a successful innovative process cannot be accepted. This is because, in order for an innovation to work effectively, more is required than the mere production of technology that improves or replaces, for example, an existing work method on a factory floor and therefore yields economic advantages. Essentially, it should also (1) fit the social context in which it is supposed to function and (2) be enlightened by knowledge of the social processes that the innovative process is likely to induce. Without satisfying these two conditions an innovation would not be likely to realise its full potential.

This chapter has focused predominantly on the integration process in the primary cases, summarised the impeding and facilitating factors, and analysed the problematic areas which had been identified during the field research as being outstanding obstacles. It is not sufficient merely to understand what factors influence the integration process. It is also necessary to understand how this process can be improved for the sake of developing a balanced socio-technical organisational system, both from the view point of management and those in the organisation who have to live with the outcomes of change.

Planning and commitment are needed in order to optimise the organisation of work around integrated CADCAM through a comprehensive consideration of the human, organisational, technical, and financial resources that are available. This can be facilitated by involving different functional groups during agenda formation and technology selection when important decisions are made. It is of paramount importance to pay special attention to the internal context of change and the social processes that are likely to influence its progress and thus its outcomes.

CHAPTER EIGHT

Theoretical Propositions and Hypotheses

8.1 Introduction

Chapters 5, 6 and 7 provided a framework for theory development in the context of the study's theoretical and methodological approaches explained in Chapters 3 and 4. The aim of this chapter is to present the theory resulting from the study; it summarise the research's substantive and formal theoretical propositions and hypotheses which follow from the three phases of data analysis and discussion presented in the previous three chapters

The substantive propositions draw on the conceptual framework developed in Chapter 7 and are based on concrete conceptual elements derived from the substantive cases studied. The formal theoretical propositions include abstract conceptual elements which are derived from, and correspond to, the substantive propositions, as explained in Chapter 3. Finally, the chapter presents the research's formal hypotheses which are, in turn, derived from the formal propositions.

8.2 Underlying Conceptual Assumptions

Before presenting the theoretical conclusions of the study it is important to clarify the basic conceptual assumptions underlying them. These can be summarised in five points which are crucial to the derivation of the propositions and hypotheses in terms of defining what constitutes a constant, an independent, and an dependent variable:

1) The content of change - as a process under investigation - is held constant for the purpose of the present study: it is CAD/CAM and integration. In another study, however, a different technical or organisational change process can be the subject of investigation. The content of change may vary therefore according to other studies' specifities relating to subject matter, research design and/or objectives.

2) The technical, economic, and organisational outcomes of the process are considered variables dependent on the unfolding of the process.

3) The process is itself deemed a variable, one that is dependent on the internal and external contexts or environments of change.

4) An internal context of change is deemed a variable also, one that is dependent on its external context. It is highly likely for a process in any of the studied companies to influence its internal context in a direct and considerable manner in the long run, but it is less likely for such an influence to impact its external context in the type of

companies studied. Therefore, to avoid a dialectical argument over the different possible conceptualisations of the relationship between an organisation and its environment, it is assumed that, for the purpose of the cases in the study, the former is dependent on the latter.

5) Facilitating and impeding factors - as illustrated in the conceptual model (Chapter 7) - are subsumed, each within its respective variable category. These can be internal or external. The idea that each of these factors, within a variable, interacts with other factors and also across variable boundaries, is central to the model. Nonetheless, to avoid another dialectical interpretation of what is a complex and dynamic network of relationships between such factors, which could oversimplify such relationships, it is assumed that each factor is subsumed into its respective variable category and addressed as a point of emphasis within it.

8.3 Substantive Theoretical Propositions

The decision to present the substantive theory resulting from the study in a separate, concise chapter was a matter of choosing the most appropriate layout from amongst other alternatives that had also been tried. The question of presentation is important for any thesis; it should be addressed in terms of the specific objectives and methods adopted. In a multiple case study research such as this certain theoretical inferences concerning particular concepts, categories, and properties of categories are likely to be grounded in more than a single case. Indeed, they are likely, in terms of their theoretical linkages, to be derived from more than a single case.

In the context of a research carried out in a grounded theory frame of reference, as a researcher attempts to ground the substantive theory resulting from his/her analysis exactly where the theory's categories and properties occur in the data (across the cases), he/she is bound to face the challenging task relating to how the theory as a whole can best be presented. The question that arises then is: how to lay out the theory such that it relates to the different points of interpretation of the cases without sacrificing the comparative element of the analysis, which requires theoretical inferences to be contextualised in terms of the individual distinctive characteristics of each case. This question was encountered in this thesis. Alternative ways of laying out the substantive theory had been tried before the decision to present it in a separate, concise chapter was made.

Therefore, this subsection summarises the substantive theoretical propositions arising from the substantive case findings. These propositions represent the overall theoretical conclusions derived from the data analyses and discussions presented in Chapters 5, 6 and 7, using the analytical techniques explained in Chapters 3 and 4. This subsection brings together, in what follows, the substantive propositioms from where they are, respectively, contextualised in the thesis.

PROPOSITION (1): On the Conditions for Optimisation of CADCAM Integration

- *Maximisation of the technical and economic benefits of CAD and CAM systems is facilitated by a vision for integration which incorporates customisation of the technology and development of the organisation so that mutual conformance is achievable by design.*

  (see p. 150 [paras. 3-4]; p. 154 [paras. 3-6]; p. 187 [paras. 2-3]; p. 201 [para. 5]; p. 234 [para. 3]; p. 238 [para. 2]; p. 239 [paras. 4-8] - p. 240 [paras. 1-2]; and p. 242 [paras. 11-12]).

PROPOSITION (2): On Managerial Learning

- *Managers learn from past experiences of failure and success in introducing and managing stand alone systems and may use learned lessons in managing CAD/CAM and/or integration.*

  (see p. 149 [paras. 6-7]; p. 154 [paras. 3-6]; p. 163 [paras. 6-7] - p. 164 [pars. 1-3]; p. 170 [para. 8] - p. 171 [paras. 1-2]; p. 172 [paras. 6-7]; p. 183 [paras. 5-6]; p.239 [para. 4]; and p. 255 [para. 2]).

PROPOSITION (3): On Inhibition of Optimum Technical Practice

- *Technically achievable optimum engineering practice is difficult to attain in CAD/CAM and/or integration because of economic, legal, commercial and organisational constraints.*

  (see p. 140 [paras. 2-3]; p.143 [para. 5-6]; p. 146 [para. 5]; and p. 188 [paras. 3-4]).

PROPOSITION (4): On Formal Management Justification

- *Formal management justifications of CAD/CAM and/or integration highlight desired potential technical and economic advantages of the technology over traditional work methods.*

  (see p. 138 [para. 4]; p. 150 [paras. 3-4]; p. 153 [para. 9]; p. 171 [paras. 3-4]; p. 177 [para. 1]; p. 179; and p. 202).

PROPOSITION (5): On Technical and Senior Management View on Justification

- *Technical management justifies CAD/CAM based primarily on its operational performance benefits, whereas more senior management justifies it in terms of supporting overall business goals.*

(see p. 137 [paras. 3-4]; p. 139 [para. 1]; p. 153 [para. 3]; p. 162 [para. 2]; p. 163 [para. 4]; p. 176 [para. 6-7] - p. 177 [para. 1]; and p. 239 [para. 3]).

PROPOSITION (6): On the Individuality of Companies' Experiences in Designing and Using CADCAM

- *Different organisations design and use CAD/CAM and/or intergation differently depending on their respective technical, economic and organisational specifities.*

(see p. 135 [paras. 5-6]; p. 157 [paras. 1-2]; and p. 181 [paras. 3-4]).

PROPOSITION (7): On the Individuality of Companies' Experiences in Organisational Adaptation to CADCAM

- *In implementing CAD/CAM and/or integration different organisations devise different methods for work reorganisation and job redesign depending on their respective technical, economic and organisational specifities.*

(see p. 135 [para. 7] - p. 136 [paras. 1-2]; p. 156 [paras. 6-7] - p. 158 [paras. 1-2; and p. 190 [paras. 3-4]).

PROPOSITION (8): On the Scope of CADCAM Integration as a Change Process

- *CADCAM integration involves a complex and lengthy process of change whose effects are highly likely to be felt at the technical, economic, and organisational levels of a manufacturing company's functioning. This includes the introduction of the technology; investment of resources in anticipation for economic reward; and reorganisation of structure to accommodate the technology being introduced.*

(see p. 144 [paras. 1-2]; p. 192 [paras. 2 & 4-6]; p. 211 [paras. 4-5]; and p. 238 [paras. 2 & 4-6]).

PROPOSITION (9): On the Technology Base Background to CADCAM Integration

- *The state of existing intigrateable CAD and CAM systems affects the speed, magnitude, duration, scope and depth of the technical, economic, and organisational sub-processes and outcomes of CADCAM integration (or lack of it).*

(see p. 144 [paras. 6-7]; p. 152 [paras. 5-6]; p. 158 [paras. 8-10]; and p. 170 [paras. 1-5]).

PROPOSITION (10): On Duration of CADCAM Integration Process

- *Long-term technical and economic benefits of CADCAM integration can be expected to materialise only after an integration process commences and becomes well established over a number of years.*

(see p. 140 [paras. 4-5]; p. 141 [para. 3]; p. 183 [para. 6]; p. 203 [paras. 7-8]; and p. 236 [para. 5]).

PROPOSITION (11): On Managerial Control Over CADCAM Integration Process

- *The technical and economic outcomes of CAD/CAM and/or integration are influenced by a mixture of management design/utilisation decisions and uncontrollable environmental elements.*

(see p. 146 [paras. 4-5]; p. 157 [paras. 1-3]; p. 165 [paras. 5-9] - p. 166 [paras. 1-5]; p. 168 [paras. 6-7]; and p. 186 [paras. 3-4]).

PROPOSITION (12): On the complexity of Internal and External Environment Influences

- *Technical, economic, and organisational sub-processes associated with CAD/CAM and/or integration and their outcomes, are influenced by a complex interaction of factors from within and outside the organisational boundaries of the manufacturing company accommodating the integration process.*

(see p. 163 [para. 4]; p. 230 [paras. 2-3]; and p. 239 [paras. 2-8] - p. 241 [paras. 1-2]).

PROPOSITION (13): On the Partial Dependency of the Outcomes of CADCAM Integration on the Process of Change

- *A CADCAM integration project and its outcomes are influenced by how supportive or impeding are the factors associated with the process of change itself.*

(see p. 141 [para. 4-5] ; p. 192 [paras. 1-2]; p. 203 [paras. 7-8]; and p. 239 [paras. 2-8] - p. 241 [paras. 1-2]).

PROPOSITION (14): On the Partial Dependency of the Outcomes of CADCAM Integration on Internal Organisational Context

- *A CADCAM integration process and its outcomes are influenced by how supportive* or impeding are the factors associated with the internal organisational context of the *manufacturing company in which it is managed.*

(see p. 140 [paras. 2-3]; p. 144 [paras. 6-7]; p. 152 [paras. 5-6]; and p. 165 [para. 9] - p. 166 [paras. 1-4]).

PROPOSITION (15): On the Partial Dependency of the Outcomes of CADCAM Integration on External Environment

- *A CADCAM integration process and its outcomes will be influenced by how supportive or impeding are the factors associated with the external environment of the manufacturing company in which it is managed.*

(see p. 140 [paras. 4-5]; p. 229 [paras. 5-6] - p. 230 [para. 1]; p. 233 [para. 2]; and p.257 [para. 2]).

PROPOSITION (16): On Managerial Perceptions of CADCAM

- *Different managers attach different values to CADCAM integration by virtue of differences in personality, ideology, interests, power, social status, functional background, and formal position and responsibilities.*

(see p. 149 [paras. 6-7]; p. 191 [paras. 5-6]; p. 199 [para. 2] - p. 200 [paras. 1-2]; p. 236 [para. 5]; and p. 238 [paras. 7-8] - p. 239 [para. 1]).

PROPOSITION (17): On Functional Differences in Responding to CADCAM Integration

- *Different functional departments respond differently to cross-functional CADCAM integration depending on functional specifities and perceived gains and losses arising from change.*

(see p. 140 [paras. 6-8]; p. 141 [paras. 2-5]; p. 145 [paras. 4-5]; p. 154 [paras. 2-6]; p.165 [para. 9] - p. 166 [paras. 1-4]; p. 197 [para. 3] - p. 201 [paras. 1-3]; p. 212 [paras. 1-4]; p. 236 [para. 5]; p. 238 [paras. 7-8] - p. 239 [para. 1]; and p. 256 [para. 2]).

PROPOSITION (18): On the Minimisation of Obstacles to CADCAM Integration

- *Organisational obstacles to CADCAM integration are minimised if and when a CADCAM system is customised to support a manufacturing company's technical task in line with a managed process of organisational change based on consensus, participation and learning.*

(see p. 149 [paras. 4-7]; p. 152 [paras. 2-4]; p. 172 [paras. 6-7]; p. 192 [paras. 4-6]; and p. 198 [para. 2]).

PROPOSITION (19): On the Role of Size in CADCAM Integration

- *A manufacturing company's size plays a dual and dichotomous role in CAD/CAM and/or integration by simultaneously offering a set of facilitating and another of impeding organisational properties. A larger company size is likely to facilitate integration by making available greater resources and a larger skill base; a smaller* *size is likely to be associated with work procedures, structure and culture which are much more supportive of CADCAM integration.*

(see p. 140 [para. 3]; p. 157 [paras. 1-2]; p. 159 [paras. 1-2]; p. 189 [para. 4]; and p. 242 [paras. 6-7]).

PROPOSITION (20): On the Relationship Between Environmental Pressures, Business Continuity, and CADCAM Integration

- *Under intensive environmental pressures the question of survival overshadows technical advancement, unless CAD/CAM and/or integration is pursued as a means for survival within a strategic adaptation vision.*

  (see p. 163 [paras. 3-4]; p. 165 [paras. 5-8]; p. 234 [paras. 4-5]; p. 235 [para. 4] - p. 236 [paras. 1-2]; p. 239 [paras. 2-3]; and p. 252 [paras. 1-3]).

8.4 Formal Theoretical Propositions

Substantive theory is grounded in research in a specific substantive area - CAD/CAM and integration in the case of this research. Thus, its relevance remains limited to this specific area unless it is developed further into a formal theory[1], as was explained in Chapter 3. This subsection presents, in what follows, the formal theoretical propositions derived from the above substantive theoretical propositions.

PROPOSITION (1): On the Need for a Vision for change

- *An encompassing, long-term vision for change is very important as a middle ground for resolving competition between differently biased conceptions and conflicting partial courses of action.*

PROPOSITION (2): On Change as a Learning Process

- *Change agents are likely to recall their past learning experiences and act upon them in managing future change.*

PROPOSITION (3): On Inhibition of Technical Excellence

- *The incorporation of technical excellence standards into a technological change process may be inhibited by non-technical constraints*

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[1]In this respect, Glaser and Strauss (1967: 79) state:

> "..... substantive theory is a strategic link in the formulation and generation of grounded formal theory. ..... although formal theory can be generated directly from data, it is most desirable, and usually necessary, to start the formal theory from a substantive one. The latter not only provides a stimulus to 'good' idea, but it also gives an initial direction in developing relevant categories and properties and in choosing possible modes of integration. Indeed, it is difficult to find a grounded formal theory that was not in some way stimulated by a substantive theory."

PROPOSITION (4): On Formal Justification of A Change Project

- *To appear credibly justifiable, an organisational change tends to be presented publicly on rational grounds that emphasise a potential result more advantageous than maintaining the status quo.*

PROPOSITION (5): On the Contingency of Change Viewing upon Formal Positional Role

- *The level of an individual's or group's position in an organisation's formal hierarchical structure affects their perception of, reaction to, and role in an organisational change.*

PROPOSITION (6): On the Uniqueness of a Generic Change Content in Substantive Organisations

- *The generic content of an organisational change varies from one substantive situation to another and takes a specific form in any substantive organisational setting depending on contextual specifities.*

PROPOSITION (7): On the Situational Uniqueness of Organisational Adaptation to Change

- *An organisational setting's response to change is highly influenced by its own properties and contextual specifities.*

PROPOSITION (8): On the Nature of Technology-Induced Integration as a Change Process

- *Technology-induced integration involves a process of change whose effects are to be felt technically, economically, and organisationally: introduction of an integrating technology; investment of resources in anticipation for economic reward; and adaptation of organisation to accommodate the technology being introduced.*

PROPOSITION (9): On the Impact of A Change Content Background on the Process of Change and its Results

- *The content of a change affects the specific properties of the process whereby it unfolds and its end results.*

PROPOSITION (10): On the Duration of a Strategic Change Process

- *Measurable and verifiable results of a strategic change are likely to appear only over the medium and long term.*

PROPOSITION (11): On the Manageability of a Change Process

- *The results of a change process are open to the influence of both planned and controllable action as well as to unplanned and uncontrollable environmental elements.*

PROPOSITION (12): On the complexity of Internal and External Environment Influences

- *Desirable results of a change process are likely to materialise if and when it is supported by a facilitating internal context, and the latter supported by a facilitating external environment.*

PROPOSITION (13): On the Partial Contingency of the Outcomes of a Change on the Unfolding of the Process

- *A change process and its end results are influenced by how supportive or impeding are the set of factors associated with the unfolding of the process itself.*

PROPOSITION (14): On the Partial Contingency of the Results of a Change Process on Internal Organisational Context

- *A change process and its end results are influenced by how supportive or impeding are the set of factors associated with the immediate or inner environment.*

PROPOSITION (15): On the Partial Contingency of the Outcomes of a Change Process on External Environment

- *A change process and its end results are influenced by how supportive or impeding are the set of factors associated with the outer or external environment.*

PROPOSITION (16): On a Change Agent's Perception of a Change Process

- *Different agents ascribe different subjective and objective meanings to an organisational change because of natural and acquired differences amongst them.*

PROPOSITION (17): On Subjective and Objective Differences in Responding to a Change Process

- *The speciality of an individual's or group's position in an organisation's functional division of labour affects their perception of, reaction to, and role in an organisational change.*

PROPOSITION (18): On the Minimisation of Barriers to a Change Process

- *Challenging barriers to integration are likely to be minimised via customisation of an integrating technology to support a clear set of consensual objectives in line with a process of change managed on the basis of consensus, participation and learning.*

PROPOSITION (19): On the Role of Organisational Size in Change

- *Organisational size plays a dual and dichotomous role in change by offering both facilitating and impeding organisational properties.*

PROPOSITION (20): On the Relationship Between Environmental Pressures, Survival, and Change

- *Organisational change is subject to environmental pressures which have a potentially detrimental inhibiting impact on it but can be turned effectively in its favour.*

8.5 Formal Hypotheses

The term "hypothesis" has a somehow specific significance when used in the context of a grounded theory research. It is conceptualised differently from other logico-deductive approaches aimed at the formulation of theory for testing purposes. The fundamental philosophy underlying hypothesis formulation in a grounded theory research can be summarised as follows (Glaser and Strauss, 1967: 39-40):

> "The comparison of differences and similarities among groups not only generates categories, but also .... generates generalised relations among them ...... multiple hypotheses .... are pursued over long periods of time because their generation and verification are linked with developing social events. ..... Generating hypotheses requires evidence enough only to establish a suggestion - not an excessive piling up of evidence to establish a proof, and the consequent hindering of the generation of new hypotheses. In field work, however, general relations are often discovered in vivo; that is, the field worker literally sees them occur. This aspect of the 'real life' character of field work .... is an important dividend in generating theory. ...... In the beginning, one's hypotheses may seem unrelated, but as categories and properties emerge, develop in abstraction, and become related, their accumulating interrelationships form an integrated central theoretical framework - *the core of the emerging theory*. The core becomes a theoretical guide to further collection and analysis of data."

This subsection builds on the previous one by formalising some of the key substantive theoretical propositions in a hypothesis form, as explained in Chapter 3. This study's formal hypotheses are as follows:

HYPOTHESIS (1):

A) *The more integrating and pervasive a technology is, the wider and deeper are its organisational implications.*

B) *The less integrating and pervasive a technology is, the narrower and shallower are its organisational implications.*

HYPOTHESIS (2):

A) *The more an organisational change is presented on rational grounds emphasising a potential result that is more advantageous than the status quo, the more likely it is to appear credibly justifiable in public.*

B) *The less an organisational change is presented on rational grounds emphasising a potential result that is more advantageous than the status quo, the less likely it is to appear credibly justifiable in public.*

HYPOTHESIS (3):

A) *The greater the non-technical constraints surrounding a technological change, the smaller the chances for possible technical excellence to be achieved.*

B) *The lesser the non-technical constraints surrounding a change process, the greater the chances for possible technical excellence to be achieved.*

HYPOTHESIS (4):

A) *The more an organisational change process is tailored to support technically sound and organisationally manageable consensual objectives, the less challenging its implementation is likely to be.*

B) *The less an organisational change process is tailored to support technically sound and organisationally manageable consensual objectives, the more challenging its implementation is likely to be.*

HYPOTHESIS (5):

A) *The greater the degree of achievable control and planning of a change process is, the greater the chances for its intended results to be attained.*

B) *The lesser the degree of achievable control and planning of a change process is, the smaller the chances for its intended results to be attained.*

HYPOTHESIS (6):

A) *The longer the time passing after a strategic change, the more likely that the change's positive or negative results will become verifiable and measurable.*

B) *The shorter the time passing after a strategic change, the less likely that the change's positive or negative results will become verifiable and measurable.*

HYPOTHESIS (7):

A) *The more favourable to change an immediate organisational change's environment is, the more likely that the unfolding of the process will be facilitated.*

B) *The less favourable to change an immediate organisational change's environment is, the less likely that the unfolding of the process will be facilitated.*

HYPOTHESIS (8):

A) *The more favourable to change an outer organisational change's environment is, the more likely that the unfolding of the process will be facilitated.*

B) *The less favourable to change an outer organisational change's environment is, the less likely that the unfolding of the process will be facilitated.*

HYPOTHESIS (9):

A) *The more supportive internal and external contexts of change are and the more an organisational change process is tailored to support consensual targeted and* *managed objectives, the less challenging its implementation and the more desirable its end results are likely to be.*

B) *The more inhibiting internal and external contexts of change are and the less an organisational change process is tailored to support consensual targeted and managed objectives, the more challenging its implementation and the less desirable its end results are likely to be.*

<u>HYPOTHESIS (10):</u>

A) *The more consistent the unfolding of a change process with its consensual planned and managed objectives, the more likely that such objectives will be met efficiently.*

B) *The less consistent the unfolding of a change process with its consensual planned and managed objectives, the less likely that such objectives will be met efficiently.*

<u>HYPOTHESIS (11):</u>

A) *The more a change agent is capable of learning from practical experience and drawing on learned lessons, the more successful he/she is likely to be in managing future change encounters and avoiding repetition of past mistakes.*

B) *The less a change agent is capable of learning from practical experience and drawing on learned lessons, the less successful he/she is likely to be in managing future change encounters and avoiding repetition of past mistakes.*

<u>HYPOTHESIS (12):</u>

A) The greater the natural and acquired differences among different agents, the greater the differences among the meanings they respectively ascribe to change.

B) The lesser the natural and acquired differences among different agents, the lesser the differences among the meanings they respectively ascribe to change.

<u>HYPOTHESIS (13):</u>

A) The larger an organisation's size, the more likely it is to facilitate change technically at an affordable cost but impede it in terms of organisational adaptation .

B) The smaller an organisation's size, the more likely it is to impede change technically at an affordable cost but facilitate it in terms of organisational adaptation.

<u>HYPOTHESIS (14):</u>

A) *The greater the environmental pressures, the more threatening and likely to demand action they are.*

B) *The lesser the environmental pressures, the less threatening and likely to demand action they are.*

8.6 Summary

This chapter has presented the theoretical conclusions of the study on the basis of the theoretical concepts, components, categories, and properties resulting from the open, selective, and axial coding of the research data. The analysis and discussion of the findings in Chapters 5, 6 and 7 have been used as the basis for presenting the study's substantive and formal propositions. The chapter's concluding part has summarised the study's formal hypotheses on a theoretical integration basis. It can be said that the hypotheses represent the climax of the refining and integration of the theoretical revelations resulting from the research.

Hopefully, this chapter, in line with the purpose of the study outlined in Chapter 1 and the theoretical and methodological assumptions explained in Chapters 3 and 4, has succeeded in contributing to the development of theory substantive to CAD/CAM and integration and in formalising the substantive theoretical propositions so as to help develop a better understanding of technology-induced organisational change specifically and organisational change in general.

The next chapter is the final and concluding chapter of the thesis. Therefore, it provides an overall concluding summary of the study and the lessons learned from it.

CHAPTER NINE

Concluding Summary and Implications

9.1 The Nature of CADCAM Integration as a Change Process

It is apparent that what may be initially viewed as a purely technical change related to the introduction of a CAD or CAM system may have implications for job design and work organisation. Such implications, though, are likely to be felt locally at a departmental level under a strictly compartmentalised functional structure. The more differentiated a company's structure is, the more likely it is that islands of automation or computerisation will prevail. Under dominant Tayloristic/Fordistic organisational cultures isolated computerised applications are a normal practice. As Lee (1989) rightly argues, "direct control" strategies are likely to result in selective training and a traditional work organisation, whereas "responsible autonomy" is likely to result in general training leading to flexibility in work organisation.

Any functional department will be tempted to maximise its own operational performance. Such a practice is likely to be detrimental to the functioning of the entire company as an organised socio-technical system with presumably uniform objectives. From a strategy point of view, this means that different departments' operational objectives are likely to be, at best, incompatible with one other and, at worst, conflicting and competing at the expense of corporate strategic performance. Indeed, conflicts due to a differentiated formal organisational structure are not the only thing that affects strategy formulation and implementation; informal organisation's conflicts and contests are likely be as impeding, if not more so, to the instrumentality of strategic plans.

One relevant point to make regarding the subject matter of this study is that under a divisive organisational structure and culture the introduction of a stand alone CAD or CAM system is likely to be a low-key, departmental issue. It is unlikely to have organisation-wide implications, particularly when each functional department sets out to computerise its work without paying enough attention to the implications of this for other individuals' or functions' work outsides its boundaries. In this respect, a strictly functional, Tayloristic organisational structure, and a parallel organisational culture which strongly promotes its worth, can be viewed as a context that helps reinforce compartmentalisation of technological progress along departmental lines. In fact, under such circumstances technology in general, and stand alone CAD and CAM specifically, is likely to become both a cause and effect for strengthening compartmentalisation.

With CAD or CAM alone, manufacturing companies did not have to be particularly concerned about organisational adaptation to accommodate such systems. This was the case with many manufacturing companies during the 1970s and 80s. With the advent of integrating technologies such as CADCAM, however, some leading companies have begun to feel the need for interfacing the isolated islands of automation that had developed during the past two or three decades. However, any move towards interfacing isolated systems requires such islands to be physically connected with one another, common or compatible data structures to be developed and data base management systems to be designed so as to facilitate communication among various information architectures and software systems. These can be challenging because this covers a wide and multi-disciplined area of technical expertise; multiple vendors, consultants and subcontractors may, indeed, be needed in the process. Yet, this remains a technically achievable mission. The more serious challenges lie in how to manage this change process in an organisational setting.

As competitive performance becomes more critical and the need for a more effective use of technology (as a strategic resource) in the current competition age increases, integrated CADCAM is likely to be a serious issue for the 1990s and beyond. This thesis showed that the barriers to achieving CADCAM lay not so much in technical difficulties but more in organisational and managerial obstacles.

Of course, technical expertise is needed but good knowledge of organisations and how they function is no less important for the management of a successful CADCAM project. CIM should be seen broadly mainly as a business concept and as a methodology for work organisation rather than as a mere system of technology. It is accepted that the success of an integration project depends "on understanding this and having the necessary strategy to relate it to the needs of the business" (Bessant, 1991: 294). However, it should be borne in mind that to rely exclusively on an adopted "strategic perspective" on CIM by management change agents would be an unnecessarily restrictive and almost dogmatic stance. Other plausible perspectives (such as the sociological, organisational development and technical perspectives), should not be ignored, at least theoretically, nor ruled out in the formation of a "composite" vision on CADCAM as a technology-induced organisational change (see Forrester *et al.*, 1995).

In order to introduce CADCAM and make it work effectively as a cross-functional system, work tasks need to be redesigned at the individual level and the organisation of work as whole needs to be reviewed and changed at the corporate level. Compatibility between CADCAM and work organisation is important. This means that organisational change is inevitable, regardless of how minimum, unplanned, or problematic it turns out to be. In this respect, CADCAM is both a technical change and an organisational change too, two processes of change that should have important implications for the company in concern as a profit-making enterprise.

9.2 The Tentative Questions of the Research

This thesis answered the seven tentative research questions in terms of the case study findings. It established that variation among manufacturing organisations in terms of why and how they acquire, design, introduce, use, maintain, and develop CAD/CAM systems is a crucial element in understanding technical change. Dissimilarities between organisations were explained in terms of the factors that were found to influence change in the substantive cases researched. The outcomes of change in technical and financial terms were also discussed and the various aspects of organisational impacts of CAD/CAM systems were explained in the same light. The organisational background to an integration project would have serious implications for a CADCAM integration process. Therefore, the last two tentative questions addressed the issue of why a manufacturing company would be, or would fail to be, interested in integration and the issue of how an integration project would be managed in adopting companies.

It compared the ten case studies and highlighted, through theoretical sampling, the issues that emerged from the field investigation. It is clear from the foregoing attempt to answer questions 1 to 5 that CAD has different properties than CAM, and that such inherently different properties made the task of answering these questions particularly dichotomous in terms of both application areas. The specific content of an application (i.e. either CAD or CAM) set up a specific context for answering each of the questions; the difficulty arose when two contexts were maintained simultaneously within the framework used for answering the questions. However, it has to be noted that the differentiating characteristics of CAD and CAM are a major factor influencing their integration potential in terms of the values attached to each of them. This is because of organisationally-explainable differences between design engineering and manufacturing functions.

Such differences can be presented in terms of six criteria (see Winch, Voss and Twigg, 1991):

1) Functional input and output: the nature of work carried out in design/engineering tends to be "one-offs" despite redesign and modification tasks that are carried out from time to time, whereas manufacturing work tends to be inherently repetitive, particularly in mass production situations.

2) Nature of skills: the former requires mainly elective intellectual skills, whereas the latter requires more action-oriented skills.

3) Level of task uncertainty: the former is associated with inherently unspecified work tasks, whereas the latter is dependent on the former and cannot start production until the tasks involved have been specified in the form of drawings and other design information.

4) Capital intensity: labour cost is by far larger in the former, whereas the latter tends to be more capital-intensive.

5) Organisational structuring: the former tends to be professionally-oriented through member affiliations to various professional bodies whereas the latter's organisation depends more on practical apprenticeship training.

6) Labour market: the growth of specialisation in the engineering labour market contrasts with a decline in mass production and trade union power.

It is important to further explain such differentiating characteristics in terms of innovation theory which has attracted the interest of many researchers in the area of organisational studies (Frost and Egri, 1991). This is necessary for developing a better understanding of the effect of such differentiating characteristics on the adoption, and subsequent integration, of CAD and CAM. Five criteria can be used for this purpose (see Rogers, 1983):

1) Relative advantage: the degree to which the innovation is perceived to be better than that which it is to replace. Both CAD and CAM are perceived to be better from a techno-economic rationality point of view.

2) Complexity: the degree to which the innovation is understandable to the user. CAM is by far more complex than CAD in the majority of the cases.

3) Observeability: the degree to which the improvements can be seen or demonstrated. This is clearer in CAD cases prior to implementation. Invariably, CAM systems have to be made to order and user companies have to rely on the manufacturers' promise that their particular requirements will be met whereas CAD vendors tend to be prepared to approach potential customers and offer them a demonstration on their own data. After a successful implementation, however, CAM may, arguably, demonstrate a greater observeability.

4) Triability: the degree to which the potential user can try out the innovation before making a full commitment to it. This is much easier in CAD cases.

5) Compatibility: the degree to which the innovation fits with the context in which it has to operate. This criterion is perhaps the least considered in both CAD and CAM cases due to the types of structures, cultures and work organisation philosophies which dominate the organisations in the study. Apart from Cases 4 and 5, most of the other companies did not seriously consider compatibility as a constraining factor when selecting CAD and CAM systems alike.

Under an integrated CADCAM arrangement, information flows both within and between human, physical and technological resource areas. An electronic exchange of information is involved[1]. Employees of different functional disciplines and at different levels of authority will communicate more efficiently throughout the organisation. Integration means that departmental information systems are likely to be linked to a common source of information in order to capture information and act upon it. By reaching out to end users, information processing systems are likely to become a repository of current and historical information to support the operation and management of the business as a whole.

It can be seen from the above discussion that CADCAM integration may, rightly, be viewed as a technical process involving the interfacing of integrateable stand alone technology applications but it is, at the same time, an organisational process which also involves changing deeply-rooted values, practices, structures, procedures and power relationships. Various influences can either facilitate or impede integration at any given time. It can also be seen that, at present, the interaction of such factors in industry is such that CADCAM integration is either prohibited (e.g. in secondary cases) or pursued (e.g. in primary cases), depending on a set of complex and overlapping economic, technical, and organisational factors. To use Lewin's (1952) three-stage model of change ("unfreezing, "moving" and "freezing"), the situation in the secondary companies can be described as one that has not yet been unfrozen and moved in the direction of integration. Indeed, even in the primary cases, where integration is pursued, the progress of the integration process is subject to the influence of a number of facilitating and impeding factors.

[1]Creating open system environments has become increasingly achievable in response to pressing user demands. The European unity, the rise of standards bodies, and the foresight of leading vendors have combined to make open systems a feasible concept (Tapscott and Catson, 1993). Yet, achieving an open system remains a difficult challenge due to insufficient software "portability" and system "interoperatability" across the entire spectrum of the IT market for the CADCAM and CIM requirements at present. This relates, for example, to common operating environments, cross-systems communications, shared and distributed databases, common user interfaces, and cross-system development environments. Further development and availability of standards is vital for the cause of integration in areas such as: operating systems, communication services, database, user interface, software development tools, and systems management services.

Therefore, the general proposition that the introduction and use of an integrating technology will be influenced by a wide range of factors, both internal and external to the adopting organisation, was borne out. In particular, the role of prevalent beliefs and practices, financial circumstances, the rigidity, or otherwise, of company structures and practices, the limitations imposed by the type of products being manufactured and production systems used, and, crucially, the values, attitudes, power and self-interest of those involved, emerged as key factors that influence integration as an organisational process. Such factors were analysed in Chapters 5, 6 and 7.

This research demonstrated that only by creating jobs which embodied skill, variety, and autonomy and, thus, establishing a stable and well-motivated work force, could organisations obtain the full technical and economic benefits of new technology. Without developing flexible job design and work organisation structures that truly support a company-wide integration project, it is difficult to see how the organisational adjustments required to accommodate integration could be implemented.

Hopefully, by exposing what actually happens in organisations a better understanding of integration, as a dual technological and organisational change process, can be developed. This is an alternative to relying blindly on some of the existing literature where assumptions of linearity and rationality often deform the reality of change processes (Pettigrew, 1985). The effects of various factors on CADCAM integration, in terms of either stimulating or impeding it, were discussed in this thesis in the light of the primary companies' experiences. Hopefully, the result of such an analysis will be beneficial to the practical management of the integration process.

9.3 Modelling Change: Theoretical and Methodological Conclusions

It is clear that one of the theoretical difficulties facing researchers of organisational change is the lack of a consistent terminology to define, for example, a change, the degree of change, the pace and shape of change and the process by which the change unfolds (Nutley, 1991). This makes any attempt to model organisational change prone to conceptual vagueness unless due attention is given to defining clearly the terms used in any attempt as they are intended by the modeller.

Van de Ven and Poole (1995) carried out a study aimed at explaining processes of change in organisations. Four basic ideal type theories were identified as the "building blocks" for their explanation: life cycle (symbolising organic growth), teleology (symbolising purposeful co-operation) dialectics (symbolising conflict and opposition), and evolution (symbolising competitive survival). These represented various schools of thought modelled from about 20 different process theories that varied in substance across disciplines. However, research into real complex change processes in an organisation, such as the present one and those associated with integration through CIM, could not, and arguably should not, confine itself to a single theoretical perspective since, as the authors themselves confess, "observed change and development processes in organisations often are more complex than any one of these theories suggests because conditions may exist to trigger inter-play among several change motors and produce interdependent cycles of change" (p. 534). Even at a purely theoretical level of analysis, most specific theories of organisational change are more complicated than ideal types of theory.

In terms of the methodological approach used in the present research, this confirms the role intervening conditions play in influencing action, reaction and interaction of actors in the specific context of a researched reality. It also supports the argument that a qualitative, longitudinal understanding of change is needed to account for the "processual dynamics of changing", without claiming universal conclusions from studying one or few isolated "change episodes" (Pettigrew, 1985: 10). In this research, therefore, a greater emphasis was given to discovering how embedded change was in its natural context in order to take account of the intervening conditions in line with the researcher's ontological, epistemological and axiological assumptions outlined in Chapter 3. The chosen methodology and theoretical approaches were consistent with the study's ultimate objective of developing a better understanding of CADCAM integration as a technology-induced organisational process.

The findings demonstrated that CADCAM integration could be equally described as an evolutionary and revolutionary kind of change. On the one hand, it is evolutionary because it involves long-term, continuous development and improvement of implemented technology. On the other, it is evolutionary in that it requires a radical change of deeply-rooted organisational practices, structure, and culture.

> "Evolutionary change means keeping the existing process in place, looking for flaws, difficulties and inefficiencies, and fixing the problems one at a time as they are discovered. This approach is called by a variety of names, including *continuous process improvement*. ..... Revolutionary change means a complete redesign of a business process from the ground up. It means discarding all your previous notions about what things should be done, how they should be done, and who should do them. .... it is difficult, expensive and disruptive. ..... Evolution is always easier, less expensive, and more pleasant than revolution. If evolution will do what you need done, use it. If not, revolution may be your only choice....." (Hoffman, 1994: 87-88).

Of course, the degree to which a change process could be managed depends on the degree to which management could exercise its planning, control, monitoring and directing functions over change by shaping its direction and influencing its outcomes (Plant, 1995). The thesis did not develop a deterministic view on change as a completely controllable process, neither did it deny the role of external environmental pressures and internal power factors in constraining management's ability to control change. The role of contextual contingencies, which the research design aimed specifically to take on board, is again implicated.

9.4 The Conceptual Model of The Research

A conceptual model was developed for the purpose of the current research and presented in Chapter 7. Central to this process were simultaneous developments at four levels of conceptualisation:

1) pursuing "system-building" at the level of interfacing various hardware components;
2) solving software and communication problems among various systems;
3) solving database and architecture problems related to the electronic format for information;
4) preparing the organisation for a radical but piecemeal change of formal structure and culture for integration;
5) changing a financial system's practices, procedures and underlying values so as to be more sympathetic to the cause of integration.

The model developed in this study incorporated the outcomes of a change process and assumed that these would be interacting cyclically with the process itself as well as with its internal and external contexts. The term "change process" was used in this thesis to refere specifically to a CADCAM integration process or project which would proceed once the forces for change outweighed the forces against change in a given company.

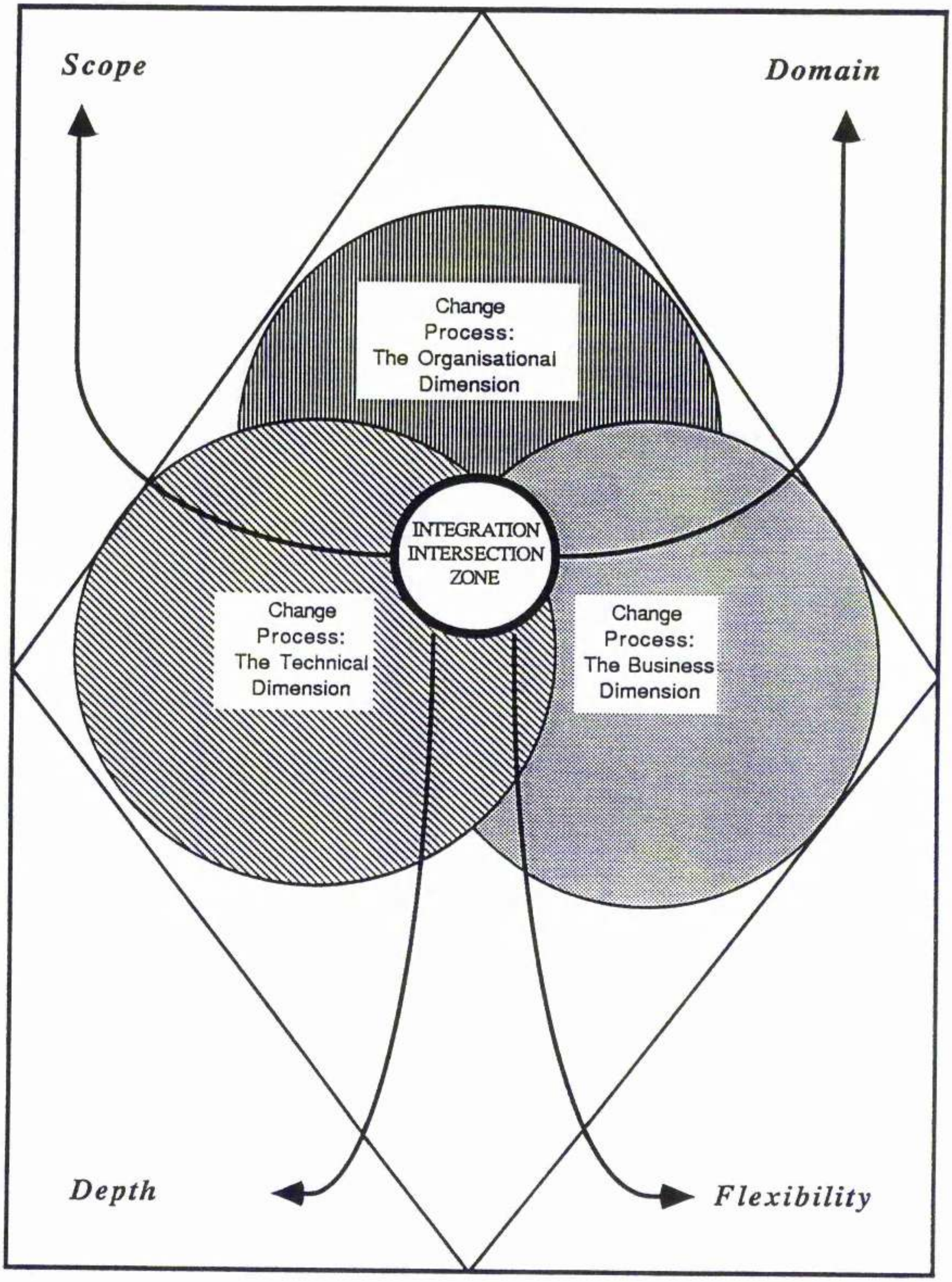
Furthermore, the change process itself was conceptualised, in relation to its outcomes, in terms of technical, economic and organisational sub-processes. The findings of the study demonstrated that these sub-processes and their respective outcomes at any given time during a lengthy integration project would be influenced by a complex interaction of impeding and facilitating factors from within and outside the organisational boundaries of the manufacturing company at the centre of change.

The results of a CADCAM integration project are likely to be evaluated on the basis of some key attributes of the change process itself - technically, economically, and organisationally. Four major criteria for evaluation can be used (see Exhibit 9.1):

1) <u>Scope</u>: the geographic extent of an integrated CADCAM system and the total number of people who have access to it and depend on it as a vital source of information for their respective job tasks.

2) <u>Domain</u>: The extent to which the information produced by an integrated CADCAM system is shared across other DEM, AMT and IT systems across hierarchical levels and also across the organisational boundaries of the host business unit or company.

Exhibit 9.1
Main Attributes Influencing the Quality of an Integration Process



3) Depth: the extent to which information penetrates various business activities and processes, not just in design and manufacturing but throughout the organisation.

4) Flexibility: the ability of an integrated CADCAM system to respond to environmental challenges requiring changes in business plans and development of the technology and work methods in current use.

9.5 The Need for an Appropriate Strategic Vision for Integration

It is clear that integration requires a new way of thinking about how to do business based on a strategic vision in the context of a manufacturing enterprise. Indeed, strategy can be defined in the context of a vision as "a coherent or consistent stream of actions which an organisation takes to move towards its vision" (Burnes, 1996: 328). To manage a business in an integrated context, management needs to change its traditional point solution approach where it introduces a CAD system solely to solve the problem of mechanical drawing as a functional concern or CAE to solve the problem of circuit diagram design calculations or a simulator to simulate an object.

A change towards CADCAM involves a new way of universal thinking in which these stand alone tools or point solutions could still be used in this limited sense to solve particular local problems, but they should be designed and developed in such a way that they contribute, within a planned organisation-wide program, to addressing the business's entire mission. Far-reaching organisational implications are therefore inescapable since this is no longer a purely technical issue of local functional significance, as was the case with CAD or CAM only, but rather a universal matter that affects the entire organisation.

Under integration, numerous individuals and departments will have access to product and design information made available to them by the design office. This situation was not possible before under point solution approaches. This will depend, though, to a considerable extent, on how an integrated CADCAM or CIM system is designed and used by virtue of the ideology, values, interests and power of those who are responsible for making key decisions associated with planning, implementing and steering such a major project. Another significant factor is their ability to learn from experience and develop better strategic practices in the future, both as individuals and as facilitators of collective organisational learning.

In this respect, strategy can be viewed as a "learning process" (Starkey, 1996) in the context of a "knowledge-creating company" (Nonaka, 1996). Planning, in general, can also be viewed as "learning" (De Geus, 1966). Indeed, CADCAM strategy formulation and implementation is conceptualised, in the light of the present study's assumptions and results, in a broader and less linear, and thus less positivistic and deterministic, frame of reference than would have been the case had a "purely" rational perspective (typically associated with classic strategy paradigms) been adopted. In this regard, the present study's view of strategy is consistent with Peters and Waterman's (1996) "beyond the rational model" perspective; it shares the proposition that "though it may seem to drive the engine of business today, the conventional business rationality simply does not explain most of what makes the excellent companies work" (p. 37).

Therefore, due attention should be given to non-rational and non-linear subjective practices associated with managerial decision making behaviours which are inevitably constrained by virtue of human limitations[2].

As shown in Exhibit 9.2, a CADCAM strategy can be viewed as part of a wider business strategy, in which a more generic IT strategy occupies a central position in a manufacturing company's strategic thinking. It is important for management to evaluate the implementation of a CADCAM strategy from time to time during its different stages of progress in order to influence its direction, and also hopefully, its outcome, as much as possible. Where necessary, integration leaders would need to take corrective action, within existing constraints, in their capacity as managers responsible for the results of change. In this respect, the importance of senior managers in promoting integration should be emphasised. However, as Beatty and Lee (1992) rightly argue, this should not be done in a manner that underestimates in any way the crucial role played by middle technical managers in implementing technological change and, thus, influencing its outcome.

9.6 Managing Resistance and Organisational Change with CADCAM

The diffusion of new technology has received increased attention in the literature over the past two decades and has been studied from different perspectives and for different purposes. The organisational perspective is concerned with the interaction between technical change and organisation. The socio-technical approach to the organisational design, which was developed in the 1960's by Emery and Trist (1960), Rice (1963) and Kast and Rosenzweig (1970) at the *Tavistock Human Relations Institute*, was a distinguished milestone in the history of the organisational perspective.

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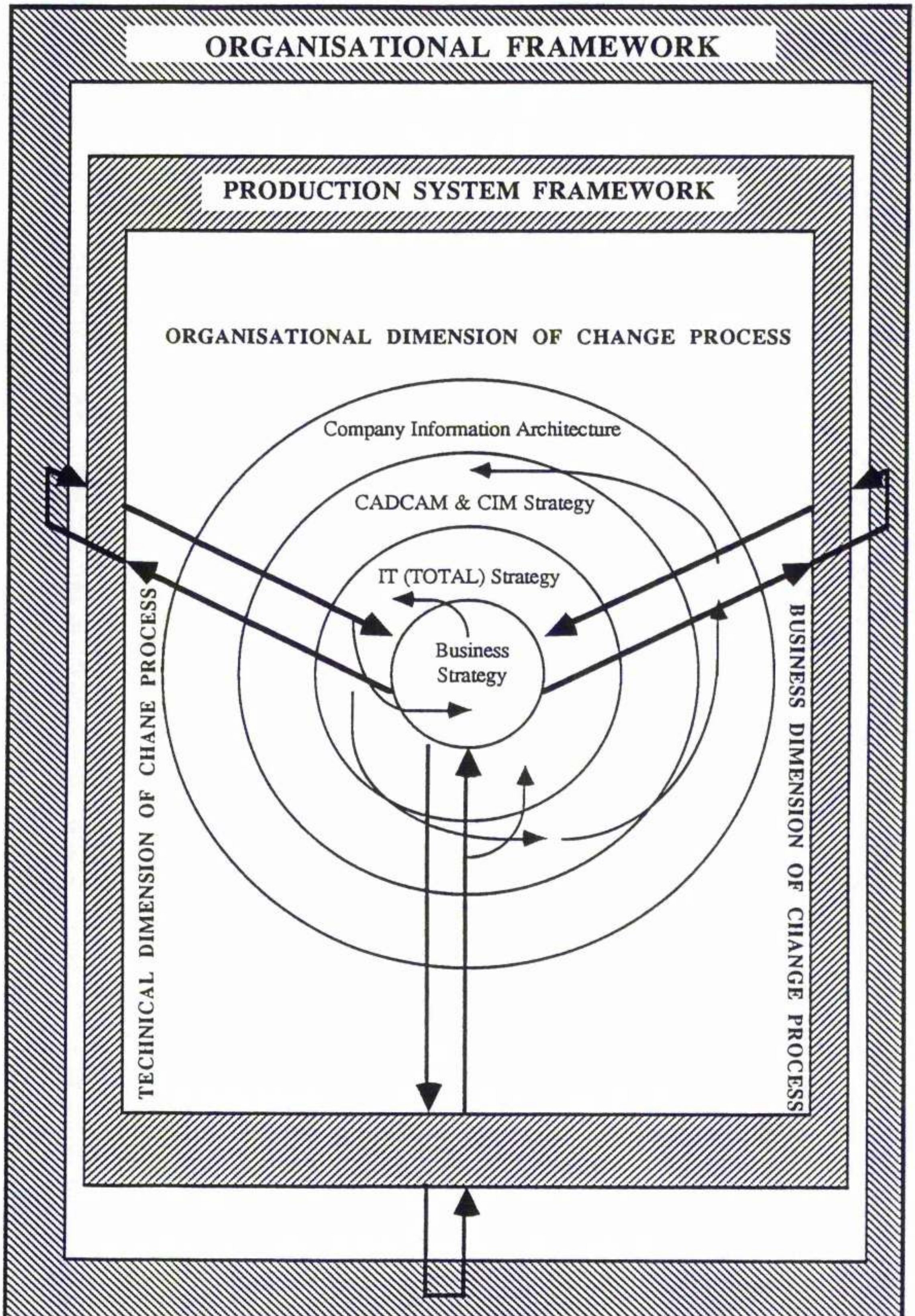
[2]For example, numerous contingency factors can make strategy formulation and implementation a mixture of a rational and irrational process but still continue to support the continuity of a business concern as a soci-economic enterprise operating within a societal framework. These factors can be traced to personal contingencies (e.g. personality, emotional sensitivity, moral values, family up-bringing and social institutionalisation); situational contingencies (e.g. formal position in hierarchy, skills, and qualifications); intentional contingencies (e.g. interests and power ambitions) and environmental contingencies (e.g. intervening conditions as well as culture, customs and traditions, law and order and social acceptability).

Exhibit 9.2
Integrating CIM Strategy with Business Strategy



It appears that interest in the interaction between technology and organisation will grow and become more important as more sophisticated, pervasive and integrating technology is introduced into the work place in the future. The introduction of a new technology demands a dynamic process of mutual adaptation between the technology and the organisation, because a "turn-key" technology almost never fits into the specific organisational context of a user company. Integration requires even more customisation of the integrating technology in concern so as to fit into the accommodating organisation and vice versa. Misalignments may be corrected or adjusted by altering the technology or the changing organisation or both, by means of "cycles of adaptation" (Susman and Chase, 1986).

Reactions to a technological change, and whether a new technology is perceived by end users as an improvement or deterioration in their work environment, depends on the individual's background and also on the way the change process is managed. A major factor in success with implementing new technology is when managers consider carefully the organisational and social structure of the workplace. That way it would be more likely to achieve its intended objectives (Ettlie, 1988; Majchrzak, 1988). According to the socio-technical perspective, the outcome of a technical or organisational change process corresponds to the shaping of the process itself (Chern, 1976).

This study confirmed Adler's (1989: 215) argument that "the challenge of CAD/CAM goes to the core of our conception of the firm". It also proved the truth of the suggestion that CADCAM integration would call for "a subtle change in the whole fabric of the organisation, away from a conception of the organisation as a production system and toward a new conception of the organisation as a system with a dual objective of both production and learning" (p. 214). At the same time, it argued, in line with one of Lee's study's (1991) main findings, that the change process would be highly influenced by the specific societal and organisational cultural contexts surrounding it and so too would be its outcome.

Given the magnitude of change involved in CADCAM integration, it would be reasonable to expect resistance to it by some individuals and groups who feel that they would loose more than they would gain from change. Resistance has to be addressed seriously and skilfully. Human beings tend to resist change either because of "systemic" factors which operate in the cognitive domain or/and "behavioural" factors which operate in the emotional domain (Plant, 1995). Systemic factors (e.g. lack of information, skills, support, reward) can be identified and addressed relatively easily. Behavioural factors (e.g. anxiety, threats to status, threats to power, fear of failure, reluctance to experiment, lack of trust, and culture and norms), on the other hand, are more difficult to identify and deal with. Therefore, careful attention has to be paid to diagnosing and treating behavioural resistance factors through a greater emphasis on better communication, employee participation, wider and multi-skilling training, encouraging collective problem-solving, and adopting a learning organisation philosophy: "organisations as learning systems" (Nevis, 1995; Nevis *et al.*, 1995).

Central to the notion of organisations as learning systems is a sustained and systematic effort to change organisational culture such that it is made more sympathetic to integration as a common goal. A company's "learning style" or "orientation" (as influenced by its history, culture and core competencies) should be adjusted towards a learning-oriented organisation. A few key questions should be asked (e.g. What promotes learning? Are there best practices that should be adopted? What are the common processes or structures that will support learning?). A number of appropriate measures should be taken, evaluated, and assessed periodically to support a longitudinal and challenging transformation process.

9.7 Change Leaders' Role

Integration leaders should seek to promote effective communication between the different functions involved in CADCAM integration, across professional disciplines both horizontally and vertically, and, most importantly, between technical and senior managers. As explained in Chapter 7, the integration leader in Case 4 provided a good example in this respect. It is clear from this study that the more "envisioning", "enabling" and "energising" an integration leader, the more likely that his/her leadership of integration will be effective (Nadler and Tushman, 1990).

IT professionals in general and integration leaders in particular have to be as instrumental as possible by assuming new roles not only in designing systems but also in getting more involved in the business process. They need to know how best to support it and develop a greater awareness about the organisational context in which the acquired technology is supposed to meet its set objectives. Without interpersonal skills to support his/her technical skills, an integration leader is likely to be technically efficient but incapable of much of the social manoeuvring required in managing the politics of change. Knowledge and vision are necessary but insufficient; in order to be a "driving force" he/she need to: (1) be highly empowered or occupy a formal position of power, (2) maintain and increase his/her share of power, (3) use this power as diplomatically as possible to facilitate change. An integration leader has also to play a leading role in envisioning, enabling and energising employees in general and his/her management team in particular with regard to participating in change as a learning process (Senge, 1996).

If a change leader happens to occupy the position of a senior manager, then the chances for a rapid and effective progress on integration will be given an upward thrust. If not, then it is vital that he/she is empowered such that he/she is able of assuming a challenging leadership role.

Strategic, organisation-wide initiatives, such as a TQM program, can be utilised not only as a measure for improving competitiveness in the market place but also as a gradual approach to developing better communications among change leaders themselves, on the one hand, and between them and the rest of the organisation, on the other. Change leaders can utilise improved communications in favour of the change process in concern. This is particularly important in larger organisations which may be well resourced in financial and technical terms but less capable, as a collectivity, of responding to a change leader's invitation to participate in a culture-shaking change. This is supported by the proposition that larger companies are more likely to be competitive in terms of their respective competitive resources whereas smaller firms are more likely to be in a position to transform themselves more readily from inside in adapting to environmental changes. In doing so, however, smaller firms' response to the need for change is likely to be influenced by what Lee and Oakes (1996) term "templates of change" (e.g. "world-class manufacturing", "TQM", and "business process re-engineering"), which originate in giant corporations' cultural symbolism. (Such templates are both produced and consumed, principally, in larger firms).

This thesis identified size as one of the most significant factors in technological change (Chapters 6 and 7). In this respect, the research's conclusions are consistent with Lee and Oakes's (1995) recent study of the implementation of TQM in the experiences of selected smaller firms. That is, small company environments can be propitious for introducing many of the major tenets of TQM relating to human resources. The success of these principles depends on change leaders' ability to effectively manipulate human resources, motivate employees to communicate better for the sake of a purpose made common to all of them, and involve the work force in building a new quality culture or, in the case of CADCAM, a new integration culture. In short, it can be said that a change leader's role in envisioning, enabling and energising a change process is of critical importance but, at the same time, it should be understood in the light of the contextual specifities of the organisation in which it is assumed.

9.8 Senior Managers' Role

Given the strategic nature of CADCAM, the role of senior management in facilitating change towards integration is crucial. The thesis showed that the lack of support for integration at a Board of Directors level could be a major barrier to integration. Worse still is when key senior managers resist integration in principle and fail to see its relevance. Therefore, the extent of what Ferlie and Pettigrew (1996) termed "headquarters level change" or "transformation" should not be ignored as a crucial factor in facilitating, or delaying, organisation-wide change action because of the power invariably inherent "in and around the board room" (Pettigrew and McNutly, 1995).

Moral or symbolic senior management's support is vital but insufficient on its own. It is important for senior managers to be personally involved in implementing a strategic vision of integration and not delegate that completely to middle managers. Strategic business objectives should match operational and control objectives and strategic performance should be assessed and managed vis-a-vis operational performance and vice versa. Senior management's direct involvement in implementing a strategic CADCAM vision will hopefully fill any gaps that are otherwise likely to develop between these sets of objectives.

9.9 Middle Managers' Role

Change may start at the top but it cannot progress if it is sustained only at the top; top executives can only run organisations with the permission of those they think they control. Middle managers are unlikely to be preoccupied with their technical role to the extent that they abandon their legitimatory role which incorporates administrative powers and sociological vision. They can assume both roles to facilitate or hinder change. Middle management are not powerless; they can change things in their own departments and, hence develop an influence throughout the organisation (Block, 1988).

As Beatty and Lee (1992) rightly argue, the role of middle level technical managers in implementing a technological change is vital. The impact, positive or negative, of leadership by technical managers on the technical, business and organisational outcomes of a technology-induced change, such as CADCAM integration, should not be underestimated. This study demonstrated that the role of middle managers in promoting and facilitating CADCAM integration should be given due attention. It also showed that some middle managers could resist it strongly if they perceived it to be a threat to their privileged status and, in so doing, they would become yet another barrier to integration (Chapters 6 and 7).

When middle managers run their respective departments as if these were independent business units, thus creating semi-independent organisations of their own choosing, their local shares of power may become a source of fragmentation and reinforcement of multiple power centres under a Taylorist mode of organisation. By insisting on doing things their own way, middle managers are likely to carry out a political act, an example of powerfulness to influence the whole organisation. Subject to the level of power they have reached, they can potentially act against outside constraints; they can be influential without formal authority (Kotter, 1985). For example, a middle manager can manage his/her boss by creating good working relations, by knowing his goals, pressures, strengths, weaknesses and working style and matching these to his own.

Middle technical managers in particular are supposed to assume a key role in technological change. Therefore, it is important that their role in change is clarified and that they are empowered and motivated enough to play it effectively in favour of set integration objectives. It is essential that their commitment is such that it may work as a facilitating rather than an impeding factor.

9.10 Supervisors' Role

In order to encourage integration, a more positive view of supervision has to be propagated whereby the role of a supervisor is redefined as one of assisting subordinates to trust their own instincts and take their own responsibility for success. Power should be used in a non-coercive manner such that they feel empowered themselves (Block, 1988). Somehow, a balance should be struck whereby this could be achieved within the framework of a strategic vision of integration. It is important that people's creative energies, potential for hard work, and willpower are stimulated in such a way that serves to facilitate change as much as possible or else it would be likely to manifest itself in behaviour which resists change.

> ".... while machines, materials, and vehicles have change imposed upon them, they will not answer back. They are passive recipients of change. But people do and will answer back, and none of the changes brought about in relation to things and materials can happen without people playing their part." (Wille and Hodgson 1991, 82-83).

At any rate, a responsible autonomy approach is much more likely to stimulate interest in training and flexibility than a Taylorist-oriented direct control approach which emphasises selective training and a traditional highly compartmentalised work organisation (see Currie, 1989).

9.11 Integration as a Learning Process

CADCAM integration may well be described as a process of development when viewed from a technical point of view. Arguably, it can be viewed as a process of organisational development, too. Integrating organisations would need to move beyond their traditional models of learning towards newer, more encompassing ones which encourage members to challenge norms and values that have dominated the workplace for a long time. The higher degree of uncertainty and the demand for greater participation, which characterise the emerging work environment in manufacturing, necessitate new "continuous improvement" approaches to organisational learning. This approach should encourage participants to detect and correct an error when it occurs in ways which involve the modification of an organisation's underlying norms (see Argyris and Schon, 1970). The negative aspects of bureaucracy, which may indeed hinder learning, must be addressed since errors in a bureaucratic organisation are extremely difficult to correct in a manner which involves a corrective action on behaviour (Crozier, 1964). This is because relative long-term stability is an underlying assumption of bureaucracy through its "variable tendencies" such as hierarchisation, stratification, formalisation, standardisation, centralisation, legitimisation, officialisation, and impersonalisation (Clegg, 1990: 33-40). To solidify to any considerable extent, and thus become an established norm, these tendencies require time but are, at the same time, reinforced by becoming long-standing traditions.

A "learning organisation"[3] would facilitate the transition towards CADCAM integration through knowledge acquisition, sharing and utilisation, which concentrate on the development of core competencies, the promotion of an attitude that supports continuous improvement, and the encouragement of the ability to continuously revitalise itself.

An organisation can be viewed, therefore, as a "learning system" (Nevis *et al.*, 1995). Self-development and action learning play a role of crucial importance in managing a learning system (Jones and Hendry, 1994).

> "The 'learning organisation' is a metaphor, with its roots in the vision of and the search for a strategy to promote individual self-development within a continuously self-transforming organisation. Learning is associated with the capacity for continuous transformation, based upon individual and organisational development. The subject of individual learning has received much attention in psychology but organisational learning, which draws upon the integration of the sum of individuals' learning to create a whole that is greater than the sum of its parts, is far less understood. In the learning organisation human resource development strategy is central to strategic management. Excellent organisations, we increasingly realise, depend upon the commitment of their people in a context where constraints require that the human resource is utilised to its fullest capacity." (Starkey, 1996: 2).

To reiterate what was said in section 9.5, even strategy can be viewed as a fluidity and learning process when practised within a learning organisation philosophy. It may

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[3]The concept of a "learning organisation" has become increasingly used in the literature by many researchers (e.g. Jones and Hendry, 1994; Senge, 1996; Starkey, 1996; Wille and Hodgson, 1991).
Wille and Hodgson (1991) define learning organisations as:

> "..... networks of cooperatioon and idea-sharing, and they buy into other external networks to enhance the learning process. ..... Learning organisations are inspired by a vision, a sense of purpose and meaning . They have role models and mentors from whom they may learn. They are not status conscious. All can learn from each. All are colleagues and fellow-learners." (p.172-173).

> "The essence of a learning organisation lies in the doing of things. It learns as it proceeds, as the teams comprising it act, in the practical carrying out of the purposes for which they have come together." (p. 166).

potentially lead to a source of competitive advantage in the long run (Mintzberg, 1979; Starkey, 1996). As Bessant *et al.* (1996) argue technological innovation itself offers an opportunity for "learning to learn", whose accumulative utilisation over time provides a solid base for strategic technology management. The 1988 OECD report stresses the need for such a shift:

> "..... the effective implementation of technological change requires a strong commitment by management to deepen the involvement of those affected by new products, processes and systems. ..... this means ..... a shift from "Talyloristic" patterns of organisation, with their fragmentation of work tasks and layers of supervising management, towards multi-skilling and the devolution of responsibility. Such change will require the retraining both of managers and workers. It also means a trend towards the "horizontal" integration of departmental functions within the enterprise, and the interchange of information throughout the enterprise, from the earliest stages. ..... We believe that the more radical the nature of technological change the more profound and complex the social interaction it generates, and the more innovative institutional changes it necessitates." (OECD, 1988: Introduction).

As Bessant (1991: 345) put it, the proposed learning organisation vision is a new "way of looking at organisations ... as a living system, interacting with their environment and trying to survive and develop". This would place greater pressures on a manufacturing company to constantly adapt or close down.

> "..... any failure to appreciate the emerging realities of the highly competitive and turbulent environment may lead to a loss of competitiveness and possible death of the enterprise - as other leaner, fitter and more agile competitors adapt better. ..... there is a need to build in a system of continuous improvement, of constant responsiveness to the environment coupled with sufficient internal stability to maintain the organisation. ..... This highlights the point about the total organisation. If - as many now argue - we are moving from an era of capital intensity to one in which knowledge and problem-solving ability becomes as important a feature as fixed capital equipment, then the ability to become a learning organisation, constantly developing and improving this knowledge, becomes critical." (Bessant, 1991: 346).

Apart from formal training, a learning organisation will facilitate the learning of all its members and continuously transform itself by creating a climate where all the individuals are encouraged to learn and develop their full potential beyond mere competence (Jones and Hendry, 1994; Kim, 1993). Learning also extends to all stakeholders. An appropriate human resource development strategy is central to the management of CADCAM integration, one that promotes positive employee relations, trust and respect. A greater emphasis is laid on skills of understanding with a view to discovering and solving problems, rather than on "fact-oriented" knowledge (Lowstedt, 1988).

This research demonstrated that successful management is as much about the utilisation of resources as it is about the mobilisation of relationships. People should not be dealt with like any other "static" resource to be managed, because they are not powerless. As one of the participants in the study put it, "people are naturally resistant to change" (Case 2); a different participant commented: "if people aren't committed they'll beat the system; they will not let a machine beat them" (Case 4); and yet another participant explained: "if we are going to integrate manufacture you need the commitment of the people, if that is what they are wanting to do!" (Case 10). Hence, the management of human resources requires special communication skills on the part of change leaders:

> "..... It's the need to actually keep people informed of what actually you are doing, why you're doing it, where they figure in this, what part do they have to play in it, how it's going to change the way they do their jobs, the rewards for the job, the way they're expected to participate in the whole organisation." (Case 2).

Apart from formal working communications, people acquire informal and social relationships in the workplace. A successful manager should mobilise such relationships to develop a process of learning out of the implementation of CADCAM. The importance of such vision lies in treating an organisation like a learning being who receives the formal training offered to him/her whilst looking for satisfying his/her psychological and social needs through work relationships; "it is the subtlety of these relationships which is the cement that binds people together into an organisation, rather than them being just a crowd (Wille and Hodgson, 1991, 164).

People can potentially learn both from experiences of failure and success in a harmonious group working atmosphere in such a balanced manner that maintains the individual creativity and the entrepreneurial spirit without an excessive reliance on system and bureaucratic methods of control. The introduction of such controls however may become necessary for avoiding descent into anarchy in certain situations where interrelationships become impossible to link otherwise. As Wille and Hodgson (1991) contend:

> "There is something about a collective organisation of people which has an existence analogous to that of the individual. So real is this that we speak of the heart of the organisation, the spirit of the organisation, its soul, its values, its vision, its mission, its thought , its actions. When we do this we are not just talking of the spirit, heart, actions of the chief executive or any one member of the organisation, but we are envisaging it as a whole, in which the whole is greater than the parts. We use the word 'synergy' to describe this power of the whole." (p. 166).

> "The individual is a learning organism. When individuals get together to act in concert, they become a learning organisation. The way in which they operate is a kind of expansion of the individual learning organism. ..... It is this something bigger than we mean when we refer to the 'learning organisation'. Yes, the individual learns, but the team learns more on the basis of its synergy, where 1+1=3 or more."(pp. 163-166).

In short, it is clear that the notion of organisational integration is consistent with CADCAM interfacing. It is also consistent with the emphasis placed on the collective personality of an integrating or learning organisation. Indeed, one way of conceptualising an integrating organisation is in terms of the wealth of learning opportunities and experiences which will have accumulated during the course of a lengthy integration project. In particular, the central learning role that may be assumed by an integration leader personally is important, as well as his/her part in advocating organisational learning as a means for developing work team identity and improving collective problem-solving for integration purposes. Lessons resulting from individual and organisational learning can therefore be incorporated into future strategy formulation and implementation to improve the management of the overall project technically, organisationally and, hopefully, economically too. Hence, it can be said that a successfully led integrating organisation should have learning as one of its key characteristics.

Indeed, the likelihood is that a "holistic"[4] approach to organisational design and development will be favourable to the progress of CADCAM integration, because "it acknowledges and takes advantage of the fact that the whole of a business process is more than merely the sum of its parts" (Hoffman, 1994: 94).

9.12 Implications of the Study

In addition to the theoretical and practical importance of the study, which was explained in Chapter 1 (section 1.7), the thesis has several implications for managers, consultants, trade union leaders, and researchers. First, the conclusions of the study should help guide future practical management of CADCAM integration in general and technological change in particular. The same forces that require managers to make radical changes to production methods and business processes require them to make radical changes in the way work is organised around newly introduced techniques and systems. Where an integrating technology is introduced organisation-wide changes are inescapable and, thus need to be managed as carefully as possible. This may start with the basic ideas and tools of earlier technology and business planning methods, but it should make important additions and modifications in the way an investment is justified and implementation is carried out in line with the distinctive nature of an integrating technology. For example, this may mean that the proposed approach:

1) Recognises the concept of breaking a production process into component parts, but rejects the idea that every process must be divided into the most elementary possible operations.

2) Recognises the work flow diagrams as tools that are useful for work analysis purposes, but makes use of other important analysis criteria pertaining to, for example, information and material flows, informal organisation, and *de facto* power distribution.

3) Recognises the idea of technological advancement being driven by business needs, but defines those needs in terms external to the business (e.g. serving customers) rather than in terms internal to the organisation (e.g. accounting rules).

[4]According to Hoffman (1994: 94), "holism is the name of a philosophic viewpoint that asserts that every entity, animate or inanimate, has reality of its own in addition to the realities of its components."

4) Recognises the important role of regulatory systems, methods and rules of organisational control but takes account of the more important role dominant organisational cultures and managerial philosophies and traditions play in shaping and maintaining them.
5) Recognises that the introduction of a new technology necessarily involves a kind of technical change at the level of the adopting organisation, but rejects the idea that every technical change is necessarily an innovation process and draws on other organisations' experiences of change with a tried technology.
6) Recognises the important role of rational techno-economic thinking in the acquisition and utilisation of a new technology but rejects the proposition that technological change is governed solely by objective, value-free rules of behaviour.

Second, the conclusions of the study should be of interest to senior mangers and strategists in general. It can be argued that the desired success of a corporate strategy depends, among other things, on a sound technology strategy which supports business objectives and takes account of the organisational modifications needed to facilitate its implementation. A clear and dynamic strategic vision on CADCAM and other technology-led integration projects (including mission, valued outcomes, valued conditions and mid-point goals) is vital to the instrumentality of the overall strategic vision. This should be done in a strategy formulation framework which links integration strategy to manufacturing strategy to corporate business strategy. Senior management's direct involvement in the implementation of these interlinked strategies is crucial.

Third, management practitioners who are made responsible for leading change, and consultants who may support them in decision making, should find the study's conclusion useful in several ways:
1) Despite the highly influential potential advantages of computerisation/automation, human resources are in fact the key element in organisational design and development. Encouraging human beings to use their own knowledge and judgement about how the business should operate is likely to contribute to creating the conditions for a successful organisational change, provided that :

a) what is deemed a successful change is sufficiently publicised;

b) they are made aware of the pressure for change;

c) their legitimate fears and concerns are carefully understood and addressed;

d) they are given sufficient information about business objectives and current performance; and

e) they have the information necessary to assess the consequences of their actions in a learning organisation frame of reference which encourages communication and employee involvement in change.

2) The needs of users should not be the only requirements taken into account during a process/technology phase of implementation, all stakeholders' needs should be addressed;

3) The technical, organisational and business considerations of a proposed technology should be assessed simultaneously right from the outset by assessing the need for change, clarifying the problem or opportunity, investigating alternative solutions, gaining feedback, and recommending the best possible course of action. This may involve prototyping (using computer simulation techniques whenever possible) an integrated organisational system on the basis of a customised CIM reference architecture which addresses the identified problems. This may be done in order to assist participation in decision making in the light of a specific integration strategy suitable to the requirements of the company in question. Such assessments should be reviewed regularly thereafter to take account of changing circumstances; and

5) The right culture for change should be created and top management's commitment should be stimulated. Newcomers in particular should be "initiated" and encouraged to adopt such culture so as to sustain the momentum.

Fourth, the analysis and discussion of case study findings should be of interest to trade union leaders who are required to play a more positive role in technological change. Trade unions should not expect management "invite" them to take part in change without them changing themselves from inside. By reviewing their traditional concerns about pay and conditions and adopting a more proactive point of view on the technological change they are likely to make themselves more presentable as a collective source of power and influence. By seeking to assume new roles which make them appear more as partners in change rather than victims of it, they are likely to allay their members' fears about what they perceive to be threatening effects of new technology. The more they develop expert knowledge of new technology and promote it among their members, the more likely that trade unions will be able to negotiate participation in managerial decision making and, thus be more successful in assuming new roles.

Fifth, commentators on the societal impacts of technology would find the conclusions of interest in that they demonstrate the important roles human intention, change agent action and contextual contingencies play in shaping the outcomes of a technological change. The universality of both technological determinism and labour process theory perspectives could be rightly questioned

Finally, the thesis introduced innovative features into the research design, which, hopefully, may enhance future research in this increasingly important area of academic concern. The implications of the study for researchers can be summarised in the following points:

1) Integrating technologies have wider and more serious organisational implications than stand alone new technology applications and, thus, research in this area requires new approaches in order to establish the present and potential extent of such implications. Further research could also identify the issues of relevance, develop suitable methodologies to study them best, address their practical significance to the individuals and different groups concerned, and propose remedies to help managers overcome obstacles to integration.

2) The theoretical and methodological frameworks (including the conceptual model) developed for the purpose of this research could be applied, with slight modifications perhaps, to studies concerning other integrating technologies (e.g. MRP - II).

3) A greater emphasis should be placed in future research on the dynamics of change rather than on investigating the results of change under the assumption that these are static and will easily fall under the researcher's control.

4) Combining a grounded theory methodology with longitudinality in a research based on case study approach will help the researcher not only answer the research's initial questions but also develop substantive theory on the phenomenon under investigation, which can then be formalised and presented in a more theoretically abstract form.

APPENDIX A

First Correspondence

UNIVERSITY OF ST. ANDREWS

DEPARTMENT OF MANAGEMENT
KINNESSBURN
KENNEDY GARDENS
ST. ANDREWS
FIFE KY16 9DJ
SCOTLAND U.K.

Telephone: St. Andrews (0334) 76161 ext: 8102
Telex: 76213

Donald Hardie, Esq,
Institute of Directors,
13 Great Stuart Street,
EDINBURGH, EH3 7TP

17th January 1990

Dear Donald,

I wonder if you could be of assistance to me in my membership capacity? I have a very able Ph.D. student in Management, Mr Tarek Tantoush, who has a manufacturing management background. Currently he is researching a doctorate in "The Management of Technological Change" under the joint supervision of myself and Fiona Wilson.

In particular, he is interested in Robotics and CAD (Computer Aided Design). Do you have any member firms whose activities include such change, where he might visit the company and gain some insight, (and offer some, I hope) into the issues involved? Perhaps you might have some contacts he could approach?

He is a very bright and charming young man, whom one would have no hesitation in introducing to senior executives.

Yours sincerely,

Gill Gillespie

pp Professor Stewart R. Clegg
Chairman of Department

c.c. Dr. Fiona Wilson
Mr Tarek Tantoush

IOD
Institute of Directors

SCOTTISH DIVISION
Chairman
Sir Gerald Elliot
Director
Donald Hardie, OBE

Professor Stewart R. Clegg,
Chairman,
Department of Management
University of St. Andrews,
Kinnessburn
Kennedy Gardens,
ST. ANDREWS KY16 9DJ

12 February, 1991

Dear Stewart,

I have not overlooked your letter of 17 January about Tarek Tantoush. I am waiting for replies from one or two members who might have suggestions to make. I, myself, do not know of any relevant companies but as soon as I hear of any I will write you again.

Yours sincerely,

Donald

J.D.M. HARDIE, Director

Institute of Directors 13 Great Stuart Street, Edinburgh EH3 7TP
Telephone (031) 225 3101. **Fax** (031) 226 4552

IOD
Institute of Directors

SCOTTISH DIVISION
Chairman
Sir Gerald Elliot
Director
Donald Hardie, OBE

Professor Stewart R. Clegg,
Chairman of Department,
Department of Management,
University of St. Andrews
Kinnessburn
Kennedy Gardens,
ST. ANDREWS KY16 9DJ

12 March, 1991

Dear Stewart,

I have not had much luck in fixing Tarek Tantoush. I am sure you will appreciate how difficult it is for me trying to help members with enquiries such as yours when I do not really know what all our members do.

No one has told me of any Brazilian trade connections. I suggest you try to contact to contact Colin Carnie who is some sort of South American contact for a variety of companies. You can find him care of the Scottish Council (Development and Industry), 23 Chester Street, Edinburgh although he works in Glasgow. You might also contact Hamish Morrison, Chief Executive of the Scottish Council. One of his roles is to encourage overseas initiatives.

As far as Tantoush is concerned, you might try Findlay Mackenzie at Hewlett Packard Ltd., South Queensferry or Keiichi Shimakura of NEC, Livingston or Alan Simmons, Digital or Derek Bumpsteed at Exacta Circuits in Selkirk.

Sorry not to be more helpful.

— Donald.

J.D.M. HARDIE, Director

Institute of Directors 13 Great Stuart Street, Edinburgh EH3 7TP
Telephone (031) 225 3101 Fax (031) 226 4552

APPENDIX B

Company Invitation Questionnaire & Covering Letter

UNIVERSITY OF ST. ANDREWS

DEPARTMENT OF MANAGEMENT
KINNESSBURN
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ST. ANDREWS
FIFE KY16 9DJ
SCOTLAND U.K.

Telephone: St. Andrews (0334) 76161 ext: 8102
Telex: 76213

To whom it may concern

I am writing on behalf of Mr. Tarek Tantoush, a graduate student in Management at the University of St. Andrews. Mr. Tantoush is researching the implications of new technology as part of his doctoral degree in management at the University. I would be grateful if you were able to facilitate his study, by offering him whatever assistance you are able to give. In the future, Mr. Tantoush would be only too willing to discuss with your Organization any relevant findings from the overall research project.

Sound research in Management depends upon cooperation between management in industry, management in both public and private sector organizations and departments of the universities such as ours. I do hope that you are able to use this opportunity to facilitate the further development of management as a soundly researched enterprise.

....

Professor Stewart R Clegg
Chairman of Department

UNIVERSITY OF ST. ANDREWS

DEPARTMENT OF MANAGEMENT
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ST. ANDREWS
FIFE KY16 9DJ
SCOTLAND U.K.

Telephone: St. Andrews (0334) 76161 ext: 8102
Telex: 76213

20th. March 1991

Dear

I would like to introduce myself: My name is Tarek Tantoush and I am a postgraduate student in the Department of Management at the University of St Andrews. I am researching different organizations' experiences of technological change in manufacturing industry for my PhD.

The project is being jointly supervised by Professor Stewart Clegg and Dr Fiona Wilson. Under their supervision I am seeking to establish some basic information which you can help me by providing. If it is not too much trouble, I would be grateful if you could complete and return the accompanying form,

Yours sincerely

T. TANTOUSH

Tarek Tantoush

THE IMPACT OF MICROELECTRONICS TECHNOLOGY ON JOB DESIGN AND ORGANIZATION

Has your company recently (during the last 3-5 years) been involved in projects to implement forms of microelectronics- based technology, for example CAD/CAM, Robotics, MRP?

☐ Yes
☐ No

If yes which of the above technologies has been introduced?

....

....

....

Yes I would like to have the opportunity to discuss the experience of my organization in introducing and implementing technological change.

☐ Yes
☐ No

Name and position of respondent:..

Name and address of company:..

....

Is your company a subsidiary or parent company?

☐ Subsidiary
☐ Parent

If a subsidiary, what is the name of the parent company?

....

Approximate number of employees on your site:................................

Nature of the business:..

THANK YOU FOR YOUR COOPERATION.

APPENDIX C

Interview Schedule (I)

INTERVIEW SCHEDULE (I)

SECTION (I): BASIC BACKGROUND INFORMATION

Personal Interviewee Details

01) Name:

02) Job title:

03) Tasks and responsibilities vis-a-vis everyday work:

04) Tasks and responsibilities in relation to technological change project(s):

05) Approximate Age (?):

06) Length of employment in the company:

07) Previous work history and experience :

Company Details

01) Name:

02) Address and telephone number:

03) Ownership:

04) Legal status of the organisation (please tick as applicable):

Independent .... ☐
Subsidiary of another company .... ☐
Division of another company .... ☐
Company branch .... ☐
Company head office .... ☐
Only company site .... ☐

05) History:

06) Structure:

07) Employees on your site:
07.1) Approximate number ?
07.2) Composition in terms of categories of functional specialisations (with approximate numbers of employees in each functional area/department)?
07.3) Approximate blue collar employees / direct labour to white collar employees/indirect labour ratio?
07.4) Approximate overall gender ratio and distribution in terms of company structure?

08) Nature of business, products and markets:

09) Main manufacturing / production process(es) and structure of production system:

10) Production planning / scheduling, management and control system:

****

SECTION (II): IDENTIFYING A TECHNOLOGY APPLICATION FOR RESEARCH DESIGN

11) Has your company recently (over the last few years) been involved in projects to implement forms of micro-electronics based technology?

Yes .... ☐

No .... ☐

11.1) If yes, in which area(s) of the following have they been? [please tick opposite the applicable area(s) and specify application(s)]:

* Production planning and control [e.g. material requirements planning (MRP) system, just in time (JIT) stock control system, etc.]·················· ☐

* Design / engineering / R & D [e.g. Computer aided design (CAD),etc.]···· ☐

* Shop floor equipment / processes / systems :

** Manufacturing ·· ☐

** Assembly .... ☐

** Quality control / inspection ·· ☐

** Materials handing·· ☐

* Any other area(s) [please specify] ··· ☐

11.2) If No, is the company planning to do so in the near future ?

12.1) Has the company been involved in projects to plan the integration of specific computerised systems or the implementation of integrated advanced manufacturing technology systems [e.g. CAD / CAM integration, flexible manufacturing systems (FMS), computer integrated manufacturing (CIM), etc.]? [please specify and explain]

Yes·· ☐

No·· ☐

13) Would you say that the company at the moment is more concerned with
*implementing various forms of new technology in various areas / departments improve performance [e.g. CAD in design and engineering, CNC in manufacturing, etc.], ... ☐

* <u>or</u> interfacing already existing computerised systems / equipment [e.g. by integrating CAD with CAM, etc.] .... ☐

* <u>or</u> planning / implementing integrated technologies [e.g. CAD / CAM, FMS, CIM, etc.] .... ☐

14) With regard to the current technological changes happening now in the organisation, for how long has the implementation project been going on, considering the start of the planning phase as its starting day ?

****

SECTION (III): IDENTIFYING THE ISSUES ENCOUNTERED IN COMPANIES' EXPERIENCES OF TECHNOLOGICAL CHANGE FOR RESEARCH DESIGN

15) What have been the company's objectives in implementing the technology ?

16) In your company's experience of technological change what kinds of technical issues/challenges/obstacles have been encountered [e.g. system selection, specifications, etc.]?
- 16.1) To what extent have they been overcome ?
- 16.2) Any plans / measures to overcome them and facilitate a smoother change process?

17) In your company's experience of technological change what kinds of organisational / managerial issues / challenges / obstacles have been encountered [e.g. job redesign, new co-ordination requirements, industrial relations difficulties, etc.] ?
- 17.1) To what extent have they been overcome ?
- 17.2) Any plans / measures to overcome them and facilitate a smoother change process?

18) In your company's experience of technological change what kinds of financial/ accounting/investment management issues/challenges/obstacles have been encountered [e.g. investment appraisal, strategic/ financial justification of project, etc.]?
- 18.1) To what extent have they been overcome ?
- 18.1) Any plans / measures to overcome them and facilitate a smoother change process?

19) What has the impact of technological change been on jobs :
- 19.1) Employment level ?
- 19.2) Design of jobs associated with the new technology ?
- 19.3) Nature of other jobs not directly associated with the new technology ?

20) What has the impact of technological change been on the existing company structure? and what restructuring arrangements have been necessary ?

21) Is there any organised trade unions in the company?

21.1) Have they participated in the change process and how? and what has there response been to the process ?

21.2) What has been the impact of technological change on industrial relations ?

22) How has the management / co-ordination of the technological change process been organised in relation with the existing company management structure? and has it been handled entirely internally or with the assistance of external consultants?

- Delegation
- Teamwork
- Participation and involvement: by whom and how
- Sense of belonging / ownership of new systems / new technology.

23) What has been the effect of the economic recession in the UK upon the business ?

24) From your / the company's point of view are there any other issues of importance and concern to the company, which the interview has not addressed ? What are such issues which you feel the company would be more interested to discuss than others, possibly with various departments / people ?

****
****

APPENDIX D
Interview Schedule (II)

INTERVIEW SCHEDULE (II)

SECTION (I): CAD/CAM AS AN INVESTMENT PROJECT

01) When was the initial purchase of CAD/CAM made?

02) There are various CAD/CAM systems on the market. Which CAD/CAM systems did you choose in this company?
Regarding this system, can you tell me something about:
02.1) Hardware (e.g. make, supplier, how many workstations, etc.)
02.2) Software (e.g. package capabilities: drafting, drawing, modelling, or / and analysis)
02.3) System capacity.

03) Approximately, how much did it cost as an overall investment package?
*Less than £10,000
*Between £10,000 and £20,000
*Between £21,000 and £50,000
*Over £51,000
Cost element details : (hardware, software, training, consultation, others):
Total: £ ....

****

SECTION (II): CAD/CAM MANAGERIAL AND ORGANISATIONAL IMPLICATIONS

04) In general terms, how would you describe the process of product design and manufacture in the company?

05. In the year prior to the introduction of CAD/CAM how many people on average had worked in the design/manufacturing functions / departments?

06) What had been their functional specialisations?

07) Approximately, how many people had been associated with each of these specialisations?

08) Has the introduction of CAD/CAM affected the work and organisation situation in your company?
*Yes
*No *If No, go to question 09 or else*
Can you tell me how?

****

SECTION (III): THE PROCESS OF TECHNOLOGICAL CHANGE: METHODS OF IMPLEMENTATION

09) What has been your involvement with CAD/CAM?
09.1) Prior to implementation?
09.2) During implementation?
09.3) After implementation?

10) How did the original idea to use CAD/CAM come about in the company?

11) Was there a consensus?

12) Once the adoption of CAD/CAM had been decided what process of assessment / recommendation was followed?

13) How was the decision to purchase CAD/CAM made in the organisation?

14) Were there any areas of resistance in the company? Please comment.
*Yes
*No *If No, go to Question 15 or else*
14.1) From within management?
14.2) From within other white collar staff groups?
14.3) From non-unionised workers in the design/manufacturing functions / departments?
14.4) From non-unionised workers in other departments than design?

15) What do you think were the main objectives in deciding to purchase a CAD/CAM system at first ?

16) How were these objectives formulated in the organisation? (e.g. task force / committee formation, meetings, seminars, informal discussions, vendor demonstrations, etc.- please explain)

17) Have these objectives changed with time?
17.1) Prior to implementation :
*Yes
*No *If No, go to 17.2 or else*
Can you explain how?
17.2) During implementation:
*Yes
*No *If No, go to 17.3 or else*
Can you explain how?
17.3) After implementation :
*Yes
*No *If No, go to question 18 or else*
Can you explain how?

18) Was a formal justification of purchase carried out?
*Yes
*No *If No, go to question 19 or else*
Is it possible to review the justification document(s)?

19) Have all the initial problems in running the system been resolved?
*Yes
*No *If No, go to question 20 or else*
Approximately, how long did it take to bring the system under full operational control ?
* .... days
* .... weeks
* .... months
* .... years.

20) What do you think were the main issues that arose in the implementation phase? Can you tell me about them in terms of the following areas:
20.1) Technical issues?
20.2) Financial issues?
20.3) Personnel issues?
20.4) Organisational / social issues?

21) Did any problems arise subsequently in operating the system?
*Yes
*No *If No, go to question 22 or else*
Can you tell me about them?

22) Has the original system ever been changed (e.g. expanded, upgraded, or / and replaced) subsequently after it had been first installed?
*Yes
*No *If No, go to question 25 or else*
21.1) How many times did changes take place?
21.2) What kinds of changes were these (each time)?
21.3) How was / were the decision(s) to carry out theses changes made in the organisation?

23) Approximately, how long did it take for subsequent changes to the system to be brought under full operational control ?
*.......... days
*.......... weeks
*.......... months
*.......... years

24) Did any problems arise when implementing subsequent additions / changes, workstations, or packages ?
*Yes
*No *If No, go to question 25 or else*
Can you tell me about them?

****

SECTION (IV)
THE IMPACT OF CAD/CAM ON WORK ORGANISATION, EMPLOYMENT, RECRUITMENT AND TRAINING

25) Did the introduction of CAD/CAM present the company with a need to change the number of employees in design, drafting, or engineering / manufacturing?
*Yes
*No *If No, go to question 26 or else*
25.1) Did it lead to hiring extra people to cope with the new system's requirements?
*Yes
*No *If No, go to 25.2*
25.1.1) How many of them had to be hired?
25.1.2) For what positions were they hired vis-a-vis CAD/CAM (e.g. managers, supervisors, operators, support staff, etc.) ?
25.1.3) What was the impact of this on operating costs?
25.2) Did it lead to laying off some of the existing staff?
*Yes
*No *If No, go to question 26 or else*
25.2.1) How many of them had to be laid off?
25.2.2) Which worker groups did the lay offs affect (e.g. draughtsmen, designers, engineers, etc.) ?
25.2.3) What was the impact of this on operating costs?

26) How was work organised around CAD/CAM when it was introduced at first in terms of arranging the CAD/CAM-associated jobs?
26.1) System managers' / supervisors' work?
26.2) System operators' work? *(Question continued next page)*

26.3) System services / support / maintenance staff's work?

27) Have these work organisation arrangements changed with time?
*Yes
*No *If No, go to question 28 or else*
27.1) What have been the reasons for change?
27.2) How is work organised around CAD/CAM at present?

28) What kind of effect has CAD/CAM had on other areas / departments in the company?

29) How were staff selected for CAD/CAM work?
29.1) From within the organisation?
29.2) From outside the organisation?

30) Did the company have to employ new people to operate, supervise, or support CAD/CAM?
*Yes
*No *If No, go to question 32 or else*
How many of them and for what positions vis-a-vis CAD/CAM?

31) How did the company recruit them?

32) Have there been any staff changes among those involved with CAD/CAM since it was first introduced in terms of:
32.1) staffing levels?
*Yes
*No *If No, go to 32.2 or else*
Please explain?
32.2) Turnover rate?
*Yes
*No *If No, go to question 33 or else*
Please explain?

33) Generally speaking, what expectations did staff have of the CAD/CAM system?

34) What effect has CAD/CAM had on employee morale so far?

35) Did staff who worked on CAD/CAM receive any training for the system?
*Yes
*No *If No, go to question 36 or else*
35.1) What kind of training did they receive?
35.2) How useful was the training for them vis-a-vis everyday work?

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SECTION (V)
THE IMPACT OF CAD/CAM ON JOB DESIGN

36) How has the introduction of CAD/CAM affected your job?
For instance, do you find that CAD/CAM has :
36.1) Made your job generally easier or harder ?
- Very much easier
- Somewhat easier
- No significant change
- Somewhat harder
- Very much harder

In what ways? *(Question continued next page)*

36.2) Increased or decreased your control over your job?
- Highly increased
- Somewhat increased
- No significant change
- Somewhat decreased
- Highly decreased

In what ways?

36.3) Made your job more or less demanding due to new technical knowledge requirements?
- Much more demanding
- Somewhat more demanding
- No significant change
- Somewhat less demanding
- Much less demanding

In what ways?

36.4) Increased or decreased the need for a broader understanding of the entire design function?
- Highly increased
- Somewhat increased
- No significant change
- Somewhat decreased
- Highly decreased

In what ways?

36.5) Increased or decreased the requirements for people management skills ?
- Highly increased
- Somewhat increased
- No significant change
- Somewhat decreased
- Highly decreased

In what ways?

36.6) Made the experience of your job more interesting or boring?
- Much more interesting
- Somewhat more interesting
- No significant change
- Somewhat more boring
- Much more boring

In what ways ?

36.7) Increased or decreased the level of your overall job satisfaction?
- Highly increased
- Somewhat increased
- No significant difference
- Somewhat decreased
- Highly decreased

In what ways ?

37) Do you find that the introduction of CAD/CAM has changed your relations with fellow managers?

*Yes

*No *If No, go to question 38 or else*

Can you explain in what ways have they changed ?

****

SECTION (VI)
THE IMPACT OF CAD/CAM ON INDUSTRIAL RELATIONS: TRADE UNION AND EMPLOYEE RESPONSES TO CAD/CAM

38) Do you have trade unions in the company?
*Yes
*No *If No, go to question 41 or else*
38.1) What trade unions are active in the company?
38.2) Which sections of the work force do they organise?

39) What has been the formal union attitude to CAD/CAM?

40) To what extent has the union been involved with CAD/CAM?

41) Has CAD/CAM affected management-worker relations ?
*Yes
*No *If No, go to question 42 or else*
In what ways has it affected them?

****

SECTION (VII)
EVALUATION OF CAD/CAM INVESTMENT PROJECTS

42) To what extent have the original objectives in buying CAD/CAM been met?

43) Have any unanticipated advantages or disadvantages emerged?
*Yes
*No *If No, go to question 44 or else*
Please explain ?

44) Do you think the company is getting the full potential of the CAD/CAM system?
*Yes
*No
Please explain ? (e.g. to what extent does the system meet the criteria laid down prior to implementation in terms of cost, deadline, performance, and productivity and quality gains ?)

45) To what extent have you personally been convinced about the need to buy CAD/CAM?

46) Have your views about the usefulness of CAD/CAM changed with time?
*Yes
*No
Please explain ?

47) Do you believe CAD/CAM has been a success?
*Yes
*No
If No, what do you think have been the main reasons for the lack of success?
or else
What do you think have been the main achievements of CAD/CAM?

****

SECTION (VIII)
CADCAM INTEGRATION AND INTEGRATEABILITY

48) It is widely believed that system compatibility is a factor which would help achieve interdepartmental computer integration, as for example the case of design computers being able to communicate with those of the manufacturing department.
Was system compatibility taken into account in selecting the system that was purchased?
*Yes
*No *If No,* why was it not considered ? **or else**
Why was it considered?

49) When considering CAD/CAM did the company have in mind any specific areas of integration such as CAD/CAE, CAD/CAM, CIM or MRP-II for example?
*Yes
*No *If No, go to question 51 or else*
Can you explain about what the company had in mind?

50) How have these integration plans changed with time?

51) What is the company's position regarding future integration planning at present?

52) Are the current systems suitable for interfacing with other systems in the company?
*Yes
*No *If No, go to question 53 or else*
Which other functions / departments can it communicate with?

53) How has your experience of CAD/CAM implementation affected your view of integration?

54) Do you as a company have any forms of inter-functional computer integration at present?
*Yes
*No *If No, go to question 56 or else*
In which areas is integration operational and is CADCAM included?

55) The literature on computer integration identifies a number of major difficulties firms encounter in their efforts to implement interdepartmental integration in, for instance, the technical, financial and organisational areas.
Did you encounter any problems in implementing integration?
*Yes
*No *If No, go to question 56 or else*
Can you tell me what these major areas of difficulty have been, illustrating with examples as much as possible?

56) Does the company have any plans for future integration:
56.1) in the immediate future?
*Yes
*No *If No, go to 56.2 or else*
What are they?
56.2) over the intermediate term (up to 5 years ahead)?
*Yes
*No *If No, go to 56.3 or else*
What are they ?
56.3) over the long term (over 5 years ahead) ?
*Yes
*No *If No, go to question 58 or else* *(Question continued next page)*

What are they ?

57) Do you foresee any likely obstacles towards achieving greater progress on future computer integration?
*Yes
*No *If No, go to question 59 or else*
What are these obstacles?

58) Personally, how convinced are you about the need for integration by expanding onto CAD/CAM?

59) How optimistic or pessimistic are you that the obstacles to integration can be overcome? Please comment and give reasons and examples as much as possible.

60) What would be the best possible scenario you could think of in terms of future computerised integration in this organisation?

61) What would be the worst possible scenario you could think of in terms of future computerised integration in this organisation?

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SECTION (IX)
PERSONAL INTERVIEWEE DETAILS

62) Just for the convenience of keeping correct records can you confirm the following personal details?
Name:
Approximate age (?):
Tasks and responsibilities:
Length of employment in the company:
Previous work experience:

****
****
*****
*

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