STRATEGIC AND TACTICAL MANAGEMENT OF ADVANCED MANUFACTURING SYSTEMS

A SURVEY OF BRITISH INDUSTRY

Thesis submitted for the Degree of
Doctor of Philosophy

by

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Abstract

British Companies have been slower to automate their manufacturing facilities, and computerise their information systems, than many of their overseas competitors in Europe, North America and Japan. Initially, this research studied advanced manufacturing technology, (AMT), systems theory, the UK economy and investigated the underlying reasons for and against company's decisions to automate.

Automating procedures were studied for a sample of 20 Engineering companies with particular attention paid to their; systemic approach to implementing AMT, inter-business activity communications, individual company strategies, operational tactics, and implications from previous installations. This information was supported by questionnaires targeted at UK design engineers' and equipment suppliers. Interviews with Trade Unions, financial institutions, professional institutions and Government, were also arranged.

The research found that correctly implemented AMT, with the optimum balance of flexibility and complexity, improved businesses' competitiveness, although many operational efficiencies could be attained merely by rationalising existing systems. When a company implements AMT it is critical that they synchronise the equipment with additional complementary systems and manufacturing resources. However, every company has their own unique solutions due to the historical evolution of factory facilities, product ranges and employee skills. The restrictive practices adopted the financial accountants and many of the Trade Union were found to restrain the rate of implementation for AMT and the move towards total integrated businesses.

The research analysis yielded a ten point model for the strategic and tactical management of advanced manufacturing systems. Finally, the work concludes by identifying "accounting systems", and procedures for "designing for manufacture", as areas which deserve further investigation.

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ABBREVIATIONS

Institutions and Bodies

ACARD	Advisory Council for Applied Research and Development.
ACAS	Advisory, Conciliation and Arbitration Service.
AEU	Amalgamated Engineering Union.
BRA	British Robot Association.
BTG	British Technology Group.
CBI	Confederation of British Industry.
DoE	Department of Employment.
DES	Department of Education and Science.
DTI	Department of Trade and Industry.
EEC	European Economic Community.
EETPU	The Electrical Electronic Telecommunications and Plumbing Union.
EITB	Engineering Industries Training Board.
ESRC	Economic and Social Research Council.
HIDB	Highlands and Islands Development Board.
HMSO	Her Majesty's Stationary Office.
ICAS	Institute of Chartered Accountants of Scotland.
IED	Institute of Engineering Designers.
IIASA	International Institute for Applied Systems Analysis.
IMechE	Institute of Mechanical Engineers.
IProdE	Institute of Production Engineers.
LDC	Less Developed Countries.
MORI	Market Opinion Research Institute.
MSFU	Manufacturing, Science and Finance Union.
NEB	National Enterprise Board.
NEC	National Exhibition Centre.
NEDO	National Economic Development Organisation.
NEL	National Engineering Laboratory.
NGA	National Graphical Association.
NRDC	National Research Development Council.
RIA	Robot Institute of America.
SDA	Scottish Development Agency.
SERC	Science and Engineering Research Council.
SPRU	Science Policy Research Unit.
STUC	Scottish Trades Union Congress.
TCC	Technical Change Centre.
TTD	Total Technology Department.
TUC	Trades Union Congress.
UGC	University Grants Committee.
WRU	Work Research Unit.

Technical Terminology

AIS	Accounting Information System.
AMS	Advanced Manufacturing Systems.
AMT	Advanced Manufacturing Technology.
CAD	Computer Aided Draughting / Design.
CAE	Computer Aided Engineering.
CAM	Computer Aided Manufacture.
CIM	Computer Integrated Manufacture.
CNC	Computer Numerical Control.
DCF	Discounted Cash Flow.
DNC	Direct Numerical Control.
EBQ	Economic Batch Quantity.
EDI	Electronic Data Interchange.
EFTPOS	Electronic Funds Transfer at Point Of Sale.
FMS	Flexible Manufacturing System.
GDP	Gross Domestic Product.
GT	Group Technology.
HRM	Human Resource Management.
IBS	Integrated Business System.
IT	Information Technology.
IRR	Internal Rate of Return.
JIT	Just In Time.
LIBOR	London Inter Bank Offer Rate.
MAP	Manufacturing Automation Protocol.
MEI	Management Early Involvement.
MIS	Management Information System.
MRP	Manufacturing Requirement Planning.
NC	Numerical Control.
NPV	Net Present Value.
NRV	Net Realisable Value.
OED	Oxford English Dictionary.
OWC	Order Winning Criteria.
PLC	Product Life Cycle.
QA	Quality Assurance.
QC	Quality Control.
R&D	Research and Development.
ROCE	Return On Capital Employed.
ROI	Return On Investment.
ROT	Return On Turnover.
RPI	Retail Price Index.
SEA	Single European Act.
SPC	Statistical Process Control.
TOP	Technical Office Protocol.
UVI	Unit Value Index.
VDU	Visual Display Unit.
WIP	Work in Progress.
WPI	Wholesale Price Index.

CHAPTER 1

INTRODUCTION

Chapter 1

Introduction

1.1 Research Overview

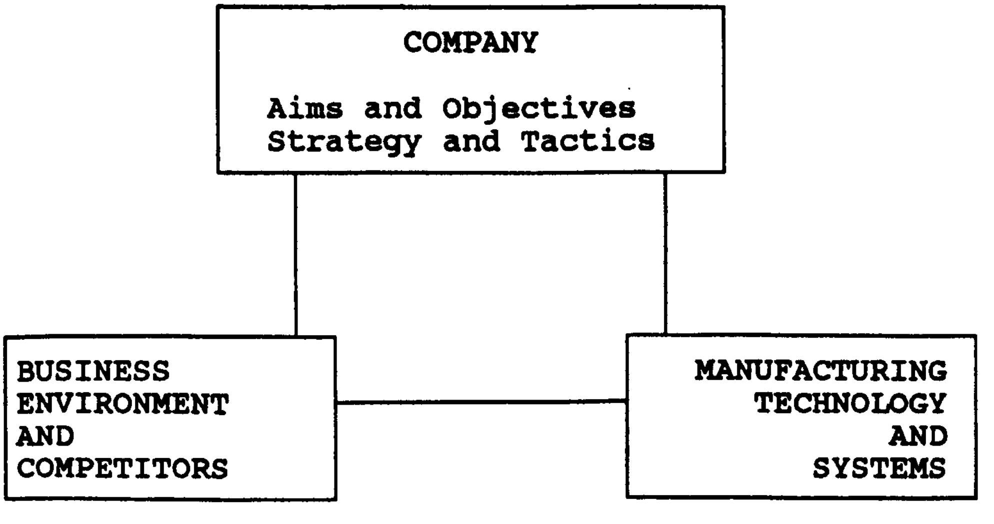
The research has focused on the relationship British based manufacturing companies have had with advanced manufacturing technologies and the business environment, as depicted in figure 1.1. It studies the reasons for and against automation, and considers the diffusion and implementation of AMT, and complementary operating systems. This takes into account the technologies that are available and the state of their evolution.

The work also looks at the environmental constraints and barriers a company has to face when formulating its plans and strategies. Such considerations include the business in which the company operates, the increasing competition within global markets, the raising of finance and the national economy.

The main focus of the research is placed on the strategies and tactics of the individual companies towards automation, and the implications of adopting such technology.

Figure 1.1

Environment of Business Planning for Production



1.2 Technological Development

> "Technology is the disciplined process of using scientific material and human resources to achieve human purpose."
> (Clews and Leonard, 1985)

Derry and Williams, (1973), clearly illustrate the strong relationship between general historical evolution and man's technological progress. They claim that sustained long periods of war and political upheaval have been set backs to technological development, whilst stability results in steady advances in technology. In addition, relatively short wars have also been shown to increase the rate of technological development. The process of technology transfer has also assisted when there is free flow of capital and a lack of trade barriers between countries.

The invention of the silicon transistor in 1954, leading to the integrated circuit, resulted in a new computerised revolution. The power and capability of these inventions has yet to be fully appreciated and understood. However, one consequence has been the miniaturisation of many products, such as radios and computers. In general, the manufacturing companies have been affected in three ways :

1. The products they manufacture.
2. The equipment they use to manufacture the products.
3. The management information and control systems, which computers and technology provide.

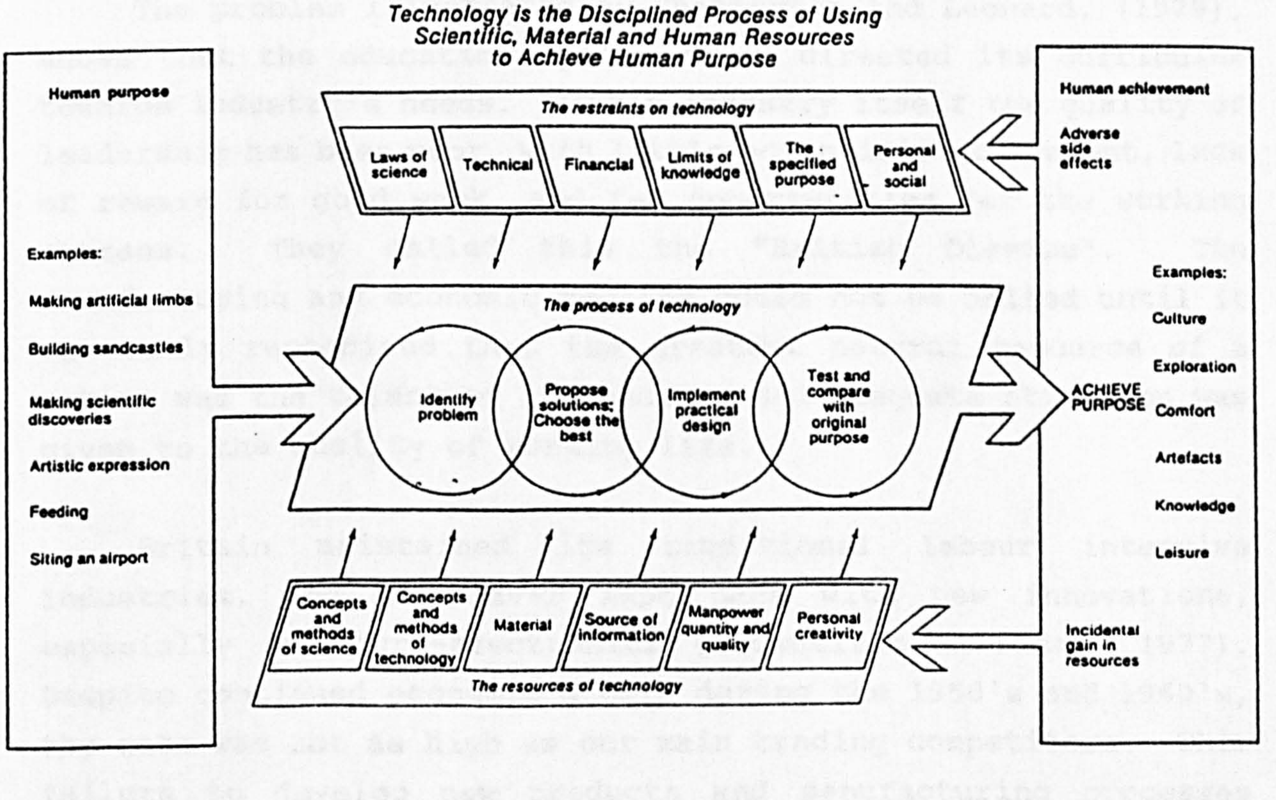
These three factors, which together form the "process of technology", are summarised in Clews and Leonard, (1985). This highlights how the physical technology is simply a resource which has to be managed effectively to manufacture a product.

Technological innovation is perceived as being an imperative for national economic development. However, manufacturing investment can be associated with employment loss. Rothwell and Soets, (1983), suggest that the key factor is whether the investment is intended for expansion or rationalisation. Therefore, it is important to judge whether investments into AMT and other manufacturing systems are primarily to increase production, or efficiency. In addition, the diffusion of the new technologies, the impact on the company, and the barriers to its development also need to be studied.

The equipment and all the affected variables have to be identified and managed. No longer can major pieces of technology be implemented in isolation. To be successful many different aspects have to be analyzed, some of which are outlined by Boody and Buchanan, (1986) :

> "Impact of new technology is determined by managerial decisions on why and how it is used as well as the capability of the equipment."

Figure 1.2 **The Process of Technology**



Source : Clews & Leonard, "Technology and Production", (1985), p10. After Schools Project, January 1970.

1.3 British Industry

Since the middle of the nineteenth century Britain has faced growing competition with the US, Japan and other European countries. In addition, many of Britain's traditional overseas markets, and particularly those of the Commonwealth, were developing their own industrial capability, and purchasing from other countries.

Despite the development of new technology in the industrial revolution, there have been some legacies which have persisted. Initially, a "class system" evolved, which discriminated against the working class. Organisations were built on a structure of authority and control, which was rejected by the workers. The education system epitomised the class structure, since the upper class had access to better education and managerial positions within industry.

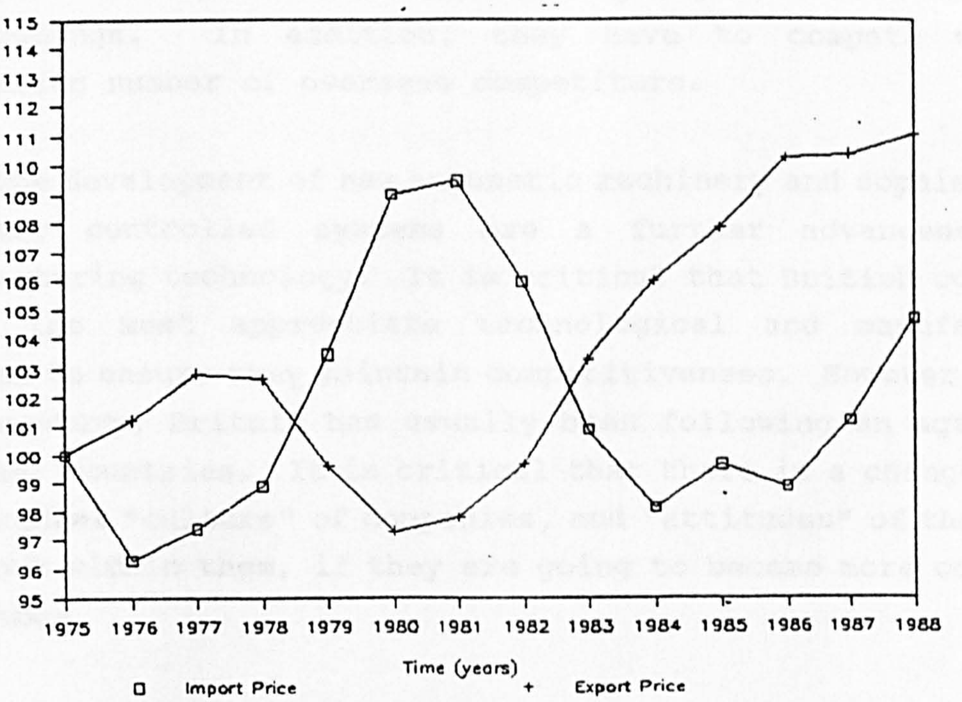
The problem illustrated by Chatterton and Leonard, (1979), shows that the education system never directed its curriculum towards industry's needs. Within industry itself the quality of leadership has been poor, with little scientific management, lack of reward for good work, and few opportunities for the working classes. They called this the "British Disease". The manufacturing and economic decline could not be halted until it was fully recognised that the greatest natural resource of a nation was the talent of its people, and adequate attention was given to the quality of working life.

Britain maintained its traditional labour intensive industries, and has never kept pace with new innovations, especially in micro-electronics (Scientific American, 1977). Despite continued economic growth during the 1950's and 1960's, the rate was not as high as our main trading competitors. This failure to develop new products and manufacturing processes resulted in industries becoming less efficient, flexible and competitive.

This is clearly shown in figure 1.3, which outlines the relative price of British exports and the cost of foreign imports. Since 1975, the government data illustrates how the export prices in 1988 are greater than the relative import prices. Overall, this makes Britain less competitive.

Figure 1.3

Manufacturing Trade Competitiveness from 1975 - 1988



Source : Economic Trends, Page 26.
Data in terms of US Dollars.

The oil price rises, in 1973 and 1975, trebled industry's energy costs and highlighted British companies' inability to respond quickly and effectively. These problems were exacerbated in many industries by conflict between management and their employees, leading to frequent disruption and stoppages. There was also a sustained period of high inflation and a falling value of Sterling, which diminished people's earnings, and resulted in poor working conditions due to a lack of appropriate investment, (Pagnamenta and Overy, 1984).

During this Century travel has become more extensive and relatively cheap, creating vital access to overseas markets. This globalisation of markets, with fewer trade barriers and restrictions, has opened up new markets, but also intensified competition.

It is with this background and under these circumstances that British companies have to operate and compete. They have to manage their resources of people, money, processes and products in a manner which is going to overcome past shortcomings. In addition, they have to compete with an increasing number of overseas competitors.

The development of new automatic machinery and sophisticated computer controlled systems are a further advancement for manufacturing technology. It is critical that British companies adopt the most appropriate technological and manufacturing systems to ensure they maintain competitiveness. However, during this century, Britain has usually been following an agenda set by other countries. It is critical that there is a change to the traditional "culture" of companies, and "attitudes" of the people who work within them, if they are going to become more conducive to change.

1.4 Structure of the Thesis

The objective of the thesis is to study the strategies and tactics to be adopted by a company facing the challenge of developing new products, introducing new systems and implementing new technologies within a UK environment. Where possible company strategies and tactics towards AMT are compared, and the major successful policies highlighted.

This work identifies the variables that have to be considered by a company, when it is formulating its strategies for implementing AMT and associated systems. It outlines the problems companies have to overcome, and the changes that have to be made.

The thesis, itself, is a systemic approach to the investigation. Initially it reviews existing advanced manufacturing technology, and the relative strength and position of the UK economy. It also outlines the definitions and theory relating to systems, strategies and tactics.

Since there is a large variety of technologies and practices in operation within industry, it was decided to conduct a survey of 20 companies. This was considered to be the best method, given the time constraints for obtaining adequate details of the technologies, the systems in operation, and the strategies and tactics adopted. The specific questions required by the research, the design and methods used, along with the characteristics of the companies surveyed, are given in chapter3.

With UK companies, in general, accused of being slow to adopt new technologies and complementary systems, the first stage looks closely at the initiation and implementation process. The process begins at the time when the company identifies that there is a "need for change" through the planning and preparation, to the installation and operation of the technology.

This research soon realised that the new technology was not a simple replacement for old conventional machine tools. If the new technology was being adopted on a large scale, it was having an influence on every aspect of manufacturing, including the process, positioning, labour and materials. The changes that have taken place with respect to these resources, and in the manufacturing strategy as a whole, are discussed in chapter 5.

The implications and effects are also experienced by areas other than the manufacturing departments. Those companies, who make the most of new technologies and systems, have to change the operations and procedures of other departments. This research looked at the maintenance, procurement, marketing, and design functions within the surveyed companies to see what effect the new technologies had on them, as a necessary part of the systems approach.

The final part of the investigative research looked at the factors which could influence the success of the new technology, but were not controllable by the individual company. These so called "environmental" issues include the equipment supply industry, the financial institutions, the trade unions and Government.

The work resulted in the development of a ten point model which describes how companies should tackle new investment in technology, and the systems that are required to complement it. It also highlights the areas where particular attention and resources need to be focused.

Chapter 1 References

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CHAPTER 2

BACKGROUND AND OVERVIEW TO ADVANCED MANUFACTURING SYSTEMS

Chapter 2

Background and Overview to Advanced Manufacturing Systems

2.0 Introduction

The chapter begins with a review of the major reports that have been conducted over the last 10 years in the field of AMT and robotics. This is followed by an overview of each of the main research areas within AMT.

There is then an outline of what is understood by AMT, and an overview of the rate of diffusion of robotics in the UK and the rest of the world. Similar to the adoption of many new technologies, the real lessons are only learnt from assessment of the pioneers. The research discusses the reasons for and against automating, with a brief assessment of the costs and benefits.

This is followed by a detailed review of the theory of "systems", and how it can be applied to AMT and the company. The section also provides a background to the need to study the strategic and tactical issues, and on the control of technology.

Recently, in the American journal Fortune, Kirkland, (1988), announced that "Britain is Back" from two decades of steady economic decline. Using the national economic data published by the UK government ministries, the research studies the trends in manufacturing performance, employment, and other economic indicators. Then comparisons are made with Britain's four main industrial competitors, United States, Japan, West Germany and France, before responding to whether Britain is restraining the fall.

2.1 Literature Review

2.1.1 Previous Reports into AMT

The first comprehensive study into AMT was made by ACARD, (1983), which gave clear recommendations to the government, AMT equipment suppliers, as well as to the users. It clearly concludes that companies wishing to remain competitive have no alternative but to invest in AMT. But there is a warning that the evaluation and implementation of AMT has to be a fundamental part of the company's corporate strategy.

On an international level the Economic Commission for Europe, (1985), conducted a report in which it collated the number of robots (and other related technologies), their rate of diffusion, applications, industrial characteristics and implications. However, the contributions, which came from many nations, were often incompatible, making comparisons difficult.

One further broad ranging report on AMT was conducted by NEDO, (1985). It gave detailed quantitative data of the changes that had accrued to the balance sheet, profit and loss account, and a selected number of performance indicators for eight anonymous companies. With the exception of outlining the reasons for the companies deciding to automate, and for the technology not living up to expectations, none of the quantitative data was analyzed. The two main conclusions were that, (i) the planning investment in AMT provides substantial financial and organisational benefits to companies of all sizes, and (ii) investment can be largely self financing with only short term requirement for external funding.

The first major study of robots in British industry was carried out by Northcott, (1986). From the users' viewpoint the report dealt with the number of robots, the characteristics of the industries in which they were being installed, the costs, the benefits, and the factors for success. It also looked at the robot supply industry, the effect on employment, the attitudes of the workers and the role of the government. The report found that :

(i) the users have found their robots to be worthwhile and profitable,
(ii) robots should be designed, marketed, installed and used as part of a wider AMT system,
(iii) robot support grants have been popular and effective and should be restored,

A full list of the report's conclusions appear in Appendix IX.

Much is reported about the traditional attitudes of Britain's trade unions, but there are fewer surveys on management attitudes to change. MORI, (1986), conducted a survey for Ingersoll Engineers on Britain's Directors and Middle Managers on their attitudes to change. The respondents surveyed felt that they had been more successful in managing industrial relations than in applying AMT. They acknowledged the need to improve communications through the application of Information Technology, (IT), and additional consultation with employees prior to any changes. However, the Directors and the Managers believe that the attitude of the shop floor workers is the main obstacle to success.

Two surveys by the Economist, (1987 and 1989), highlight the phenomenon of the "Factory of the Future" and "Business in Britain" respectively. They provide a general background to the problems and experiences of automating, and outline the state of British Industry.

Preliminary research results and working papers from the International Institute for Applied Systems Analysis, (IIASA), explained the factors of, and reasons for, the diffusion and the impacts of AMT (Ranta, 1988). The three year project, to be completed July 1989, concentrates on FMS and CIM, and covers Europe, Japan, and North America.

Most of the information regarding the numbers of robots in industry, are provided by the British Robot Association, (BRA) in their annual publication "Robot Facts". The sources of their data are the equipment suppliers, who are also the main sponsors and contributors to some of the trade journals, such as "Automation". This journal conducted their own survey, in which they described recent events within the robot supply industry.

Each year there are many conferences on AMT around the world. They include research into all the different aspects of JIT inventory control, "Quality Circles", laser technology, machine sensors, and software systems. The conference proceedings are a useful source of information, along with the first encyclopedia on Robotics (Dorf, 1988). This is the first attempt made to catalogue most of the different aspects of Robotics into one publication.

2.1.2 Research into AMT and its Areas of Influence

Zermeno-Gonzalas, (1980), was the first research student to conduct work into the development, and diffusion of industrial robots. The work which was carried out during the infancy stage of robotics in the UK, and studied employment aspects within the robot manufacturing industry. This work was continued by Fleck, (1984), and White, (1984), at the Technology Policy Unit (TPU), University of Aston.

The unit has also done research on the organisation and management of robotics (Fleck, 1987), and into the implementation of robotics in a food manufacturing company (Drayson, 1986). This thesis took a case study approach, and concluded that long term planning orientation and an integrated approach to implementation were crucial. The need for a multi-disciplined approach with specialist expertise was recommended. In addition, the inappropriate nature of "Payback", as an investment appraisal technique was restricting long term projects, and discouraging the formulation of corporate strategies.

Some joint research was conducted between the Technology Policy Unit, and the Technical Change Centre, (TCC). This also concentrated on the future prospects in the West Midlands for employment, training, and supply of robotic technology (Fleck, White, and Dickson, 1985). This was complemented and advanced by Dodgson, (1985), and Mahedeva, (1985). Their work concludes that there is much scope for AMT in small firms as they are more adaptable to change, and less unionised. In general, the key to the successful implementation of AMT is in carrying out the most appropriate training.

All research into robotics and new technology suggests that accounting conventions and practices, relating to both internal and external accounting, and especially investment appraisal techniques, are a major barrier to the diffusion of AMT. Despite well recorded discrepancies in Management Accounting by Kaplan, (1984), Coates and Longden, (1988), and Johnson and Kaplan, (1987), only Kaplan, (1987), and McMonnies, (1988), have made suggestions on how the methods should be changed. The claim is that Management Accounting, which was introduced to assist management in the 1920's to obtain a more accurate impression of the companies' performance, now contains irrelevant, and therefore useless information.

Companies are a little more flexible at relaxing the criteria for accepting investments. However, this does not detract attention away from the fact that present investment appraisal procedures, combined with the criteria included in them, discourage the implementation of new technology. Work carried out by the Total Technology Department, (TTD), at UMIST, has resulted in a computer programme named "IVAN" which uses 37 variables to evaluate a project. Primrose and Leonard, (1984), describe how an investment appraisal can be carried out which includes intangible, as well as tangible benefits.

Two further research centres, the Science Policy Research Unit, (SPRU), at the University of Sussex, and the Department of

Management Studies at the University of Glasgow, have both carried out studies within industry, and reported on the implications of adopting and managing new technology on an organisation (Senker, 1984), (Lim, 1986), (Boody and Buchanan, 1986). In addition, research by Bessant and Haywood, (1986), in their work on Manufacturing Innovation, believe that a totally new approach is required which begins with a strategic plan. This is because new technology, and particularly robotics, changes the fundamental economic structure of the company, requiring long term outlooks, planning and integration. These are also the findings of Meredith, (1987).

The problem, in many companies, has been the power and control of the accountants over the engineers. Hass, (1987), and Skinner, (1969 and 1978), highlight the importance of manufacturing to a company, and how the manufacturing strategy has to be part of a totally integrated system. Hayes and Wheelwright, (1984), and Hill, (1987), look at the important strategies and tactics required to formulate a manufacturing plan to advance, retain or restore a company's competitive edge.

In Western Europe and North America, many companies have been forced into adopting Japanese working practices. The new systems of inventory control, quality control, employee participation and harmonisation, and design for manufacture are well documented in Lee and Schewendiman, (1982), and Schonberger, (1982 and 1986). The new manufacturing systems are needed to react to continued greater productivity achieved by the Japanese over the Europeans and North Americans.

The combined effect of implementing new technologies and manufacturing systems have revolutionised many companies. These have lead to work on the Management of Innovation, the process for new products as well as new technologies (Bessant and Grant, 1985). The consequential effects on the learning or experience curves have been researched by Belkaoui, (1986), and, Abernathy and Wayne, (1974). These relate to company's products, and not necessarily to the AMT equipment. Indeed, information regarding the equipment suppliers is restricted to specific conference proceedings, and the trade journals, such as "Automation", "The Engineer", "The Production Engineer", and the monthly BRA newsletter.

The Work Research Unit, (WRU), a branch of the Advisory, Conciliation and Arbitration Service, (ACAS), provide information about developments related to the "Quality of Working Life". Details relating to the management of human resources, training, working practices, management attitudes and trade unions are included with references, and citations provided. They also promote government literature from the Department of Employment, (DoE), and the Department of Trade and Industry, (DTI), for instance "Employment Training", and the "Enterprise Initiative".

The concept that, to remain competitive, companies must automate is not a contentious issue (Stevenson, 1985). The key factor is the extent to which a company should automate, and how quickly it is done. In addition, the selection of the right technology process and organisational changes are also critical (Economist, 1988),(Hoffman, 1986). The failure of some companies not to fully utilise automation is because they expect too much and do not appreciate their capabilities. Therefore, to avoid making costly errors, careful planning and a "step by step" approach is needed (Spur, 1985),(Haxby, 1986).

There are many different impressions and perceptions of the so called "Factory of the Future". The man-less environment is still many years away, but the leading companies are employing fewer direct workers, and implementing CIM. Merchant, (1985), believes that only when CIM technology is exploited will the man-less factory become a reality. However, Kaplinsky, (1984), believes CIM will become reality when companies integrate their stand alone "islands" of automation, with other functional activities such as design and information technologies.

Research into AMT equipment has now diversified, with few companies and academics able to concentrate on all the areas. Engelberger, (1982), and, Ayres and Miller, (1983), are general texts covering the fundamental part of robots, their evolution, anatomy, and types of grippers. They also give an array of applications and highlight some of the social, economic, and management implications of adopting such technology.

There are then the more specialised studies into the activities of machine interfacing, programming, robot vision, control systems, artificial intelligence, expert systems and sensors. These topics are reviewed in papers by Alexander, (1983), Pugh, (1983), and, Brady and Paul, (1984). It is noticeable that the contributors are predominantly Japanese.

One major aspect of this research has been to make the systemic linkage of the different topic areas reviewed above, and which are usually treated in isolation. This has allowed the research to study some of the interfacing relationships which are often overlooked in individual studies, and singular case studies.

2.2 Advanced Manufacturing Technology

With the UK economy in steady decline relative to its major competitors for over 20 years, the research has highlighted AMT as a possible solution to reverse the trends. This section defines what the research understands AMT to be. It is acknowledged that AMT on its own, is no solution, and that it has to be accompanied by a new approach to the "whole" system in which the company operates.

AMT, being a broad definition, covers a large range of automation. Consequently, the research has selected robotics, which can be more specifically defined to illustrate the rate of diffusion into both a UK and world context. The attributes of robotic systems, that have been implemented, are then assessed.

The research then looked into the reasons why some companies decided to automate and others did not. This information is a mix of reported data from the experiences of those pioneering companies, and the information collected from industrial visits.

2.2.1 Definition of AMT

There are many different definitions in various studies that have been carried out on robots, automation, and AMT. The term "robot" originates from the word "Robota", the Czechoslovakian word for a "serf". The phrase was first used by the playwright K. Capek, in 1920, in a play titled "Rossum's Universal Robots", highlighting agricultural labourers being forced to work the land.

The first industrial robot was built by Unimation in 1961, and was sold to the Ford Motor Company. It was a die casting machine and driven by hydraulic systems. Hawker Siddeley was the first British company to utilise the services of a robot in the form of an arc welder, in 1974, to produce railway carriages.

Robot development was enhanced in 1975 with the introduction of the electronic drive. This increased the number of potential applications for robots, because it provided greater accuracy and control of continuous process operations. The technology has continued to develop, and with more refinement, has led to further applications, greater consistency and repeatability. In addition, the increasing sophistication and integration of computers, vision sensors, and lasers has made robotic technology the key to manufacturing success.

The internationally accepted definition of a modern day robot is provided by The Robot Institute of America, (RIA),

> "A robot is a reprogrammable, multi-functional, manipulator designed to move material, parts, tools or specialised devices, through variable programmed motions for the performance of a variety of tasks."

The definition from the British Robot Association is a more general variation of the RIA's, given above. Meanwhile the Oxford English Dictionary, (OED), is less technical and links the human, and intelligence factors.

> "Apparently human automation, intelligent and obedient but impersonal machine; machine like person."

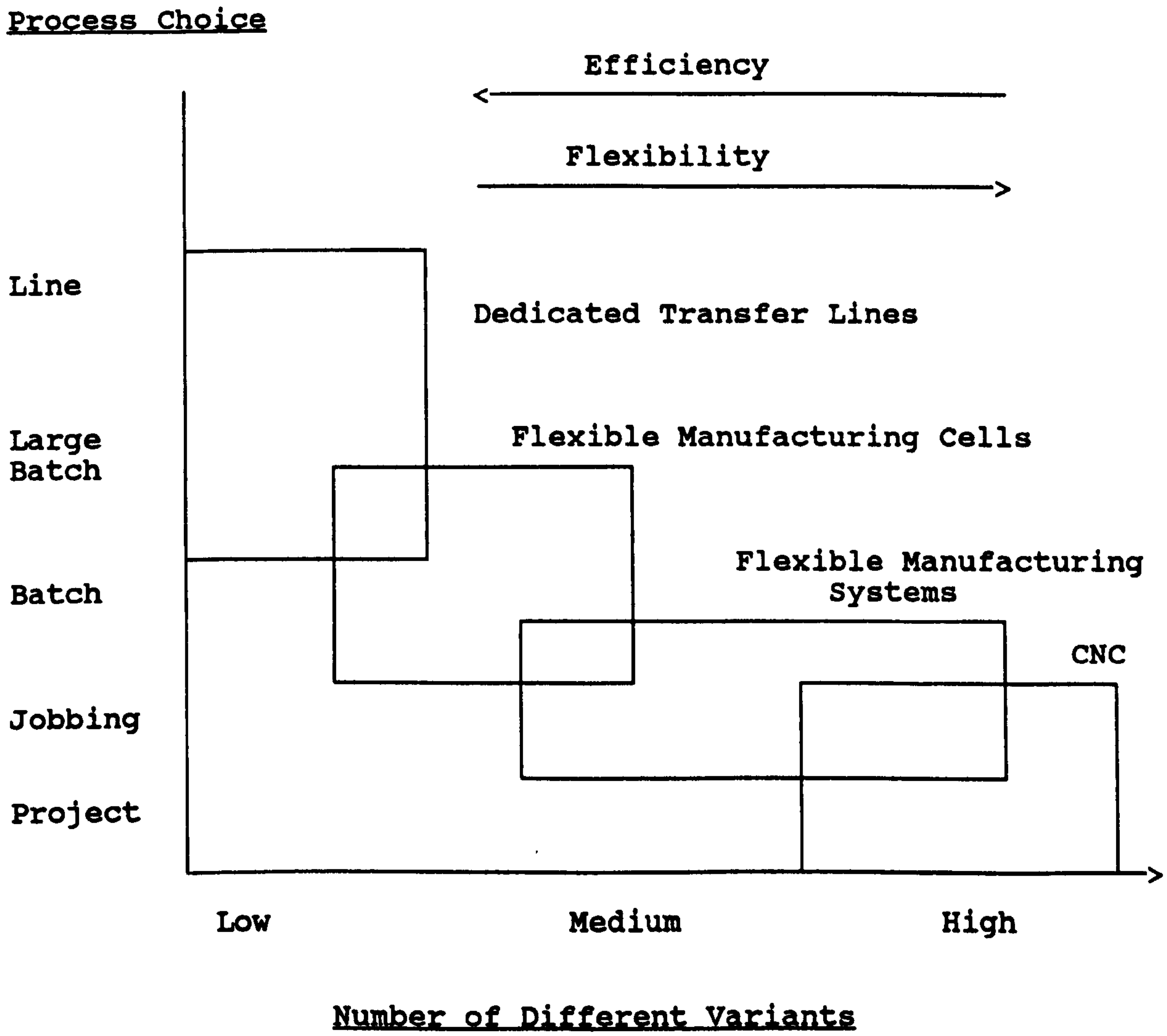
These definitions of an industrial robot were too specific for the research, and broader definitions on automation and AMT were required. The explanation below formed the basis for the research, as it covers a wide range of technologies and emphasises the implications on the rest of the company and its systems.

> "Advanced Manufacturing Technology is any substantial relevant and new manufacturing technique, the adoption of which is likely to lead to changes within a firm in manufacturing practice, management systems and approaches to design and production engineering of the product."
> (ACARD, 1983)

The AMT referred to in the above definition includes robotics, CNC, FMS and Dedicated Transfer Lines. The appropriateness of each of the four types of AMT is shown in figure 2.2(1). It clearly illustrates that the larger volumes require the less flexible automation. These points are discussed in detail by Hill, (1987), and Starky, (1986).

Figure 2.2(1)

Relationship Between Process Choice and AMT



The Computer Numerical Control machines were first made in 1950's, but were never fully utilised until 1970, when they became more reliable, as the control unit was based on mini-computers. In 1975 they were controlled by micro-computers. The CNC is a machine tool, which automatically performs the required operations according to a detailed set of coded instructions.

The operation of machine tools is most commonly carried out by numerical data stored on paper or magnetic tape. Developments in the 1980's have allowed the instructions to be passed directly from the computer to the machine.

The CNC machine tool is commonly used for metal cutting processes such as milling, boring, turning and grinding. However, their application has been broadened to include tube bending, shaping and sheering. Edquist and Jacobsson, (1988), illustrate how the share of the total machine tool investment spent on CNC rose from 19% in 1978 to 62.4% in 1984. This proportion is greater than that in Sweden, Japan and the US.

The stand alone CNC machines have received much more attention than FMS, which are associated with multi-purpose mid-variety products. The Flexible Manufacturing System is defined by Warnecke, (1983), as :

> "Several automated machine tools (such as CNC machines) ... interlinked by an automatic workpiece flow system in a way which enables the simultaneous machining of different workpieces which pass through the system along different routes."

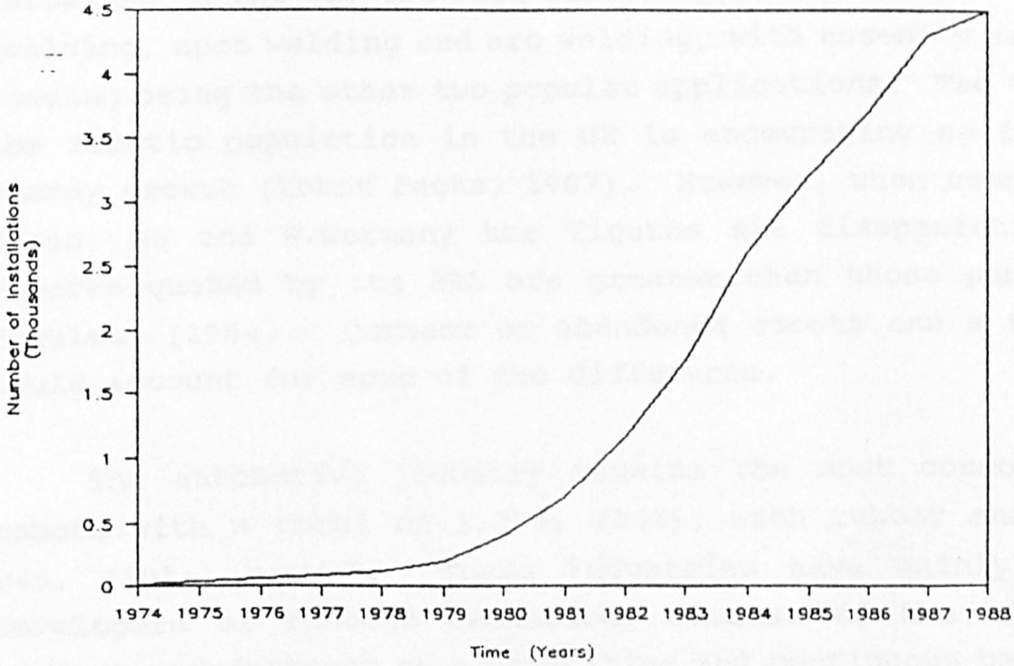
Dedicated Transfer lines involve the use of special purpose machine tools and automated work stations, interlinked by a work piece flow system along the same path. The machine is dedicated to only a limited number of tools, which cannot easily be changed.

2.2.2 Rate of Diffusion of Robotics

Graphical evidence, clearly shown in figures 2.2(2) and 2.2(3) from the BRA, illustrates that the UK has not been automating to the same extent as Japan, US, and a selection of other European countries. Data, from Eastern Europe and other parts of the world, are not known.

Figure 2.2(2)

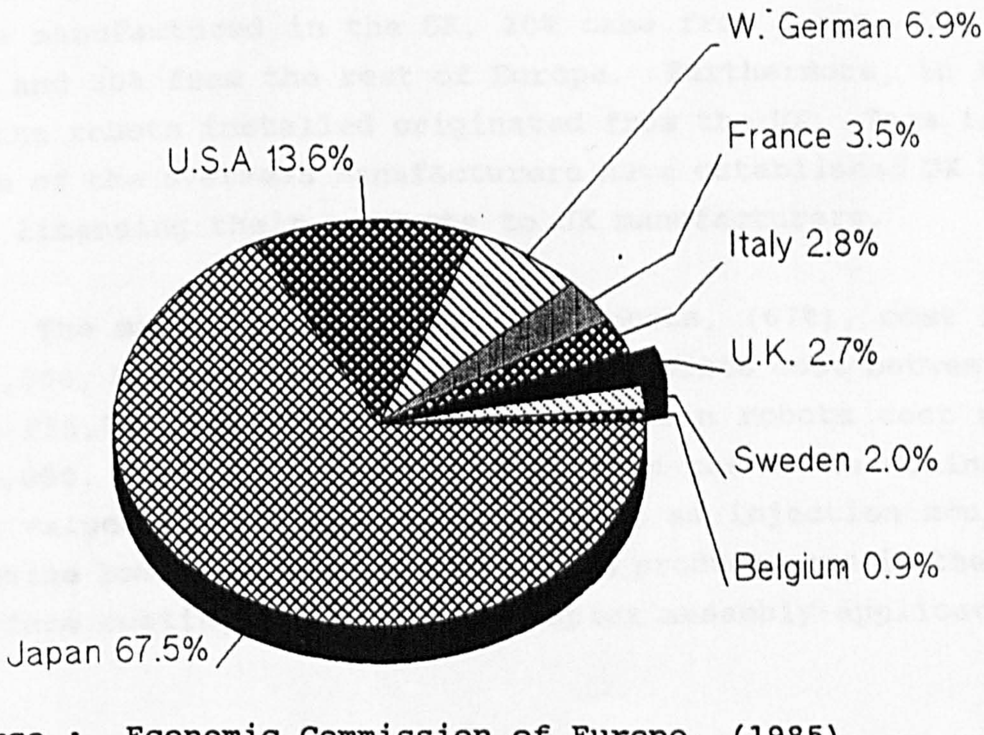
UK Robot Population from 1974 to 1988



Source : British Robot Association, "Robot Facts", (1988).

Figure 2.2(3)

World Diffusion of Robots at the End of 1984



Source : Economic Commission of Europe, (1985).

In 1987 there were 18,300 robots operational in the UK, compared with 38,600 in W.Germany and 68,000 in the US. Of those installed in the UK, the most common applications were injection moulding, spot welding and arc welding, with assembly and machine loading being the other two popular applications. The trends for the robotic population in the UK is encouraging as there is a steady growth (Robot Facts, 1987). However, when compared with Japan, US and W.Germany the figures are disappointing. The figures quoted by the BRA are greater than those published by Edquist, (1984). Dormant or abandoned robots and a time delay could account for some of the difference.

The automotive industry remains the most common user of robots with a total of 1,270, (30%), with rubber and plastics 845, (20%), second. These industries have mainly been the developers of robotic technology because of the high valued product manufactured on a repetitive and continuous basis, often in unpleasant and hazardous conditions.

It is claimed by some industrialists that there is not a sufficient robot supply industry to service the country's needs. However, of those robots installed before the end of 1987, 34% were manufactured in the UK, 20% came from Japan, 15% from the US, and 30% from the rest of Europe. Furthermore, in 1987, 44% of the robots installed originated from the UK. This is because some of the overseas manufacturers have established UK bases, or are licensing their products to UK manufacturers.

The majority of the UK made robots, (67%), cost less than £20,000, whereas 61% of the Japanese robots cost between £20,000 and £35,000, whilst 61% of the European robots cost more than £35,000. This is significant in that the UK is dominating the low valued robots applications, such as injection moulding and machine loading. The greater valued products are in the welding, surface coating and the more complex assembly applications.

The rate of diffusion of the four technologies are different. Jacobsson, (1986), outlines three phases to the conceptual life cycle of any product. These are :

1. slow diffusion,
2. growth,
3. saturation and maturity.

The profile for robotics and FMS, as isolated units, will be in between categories (1) and (2), where as Edquist puts CNC in (3):

> "Numerical Controlled Machine Tools for turning, drilling, and milling functions can be said to be mature technologies in terms of the "S" curve concept. They have already moved to the stage in their product life cycle where standardisation and mass production was essential by the latter half of 1970's. Today the main innovative efforts lie in "systems building".
>
> (Edquist and Jacobsson, 1988)

As the technologies move from stages (1) to (3), Hagerstrand, (1967), identifies three distinct characteristic changes :

1. Standardisation : fewer custom designed features and less need of specialised skills to use it.
2. Product Differentiation : move away from the specifications set by the larger customers, broader range of models available to include more simple types.
3. Price Reduction : consequence of simplification and benefits from "economies of scale".

Jacobsson, (1986), states that often new products or techniques are characterised by functional superiority, rather than by low price. This is because close contact has to be made with the market so that the producer can acquire the ideas for product developments. Hagerstrand, (1967), and Brown, (1981), both believe that the rate of diffusion of new products depends upon the effective flow of information and the resistance to its adoption.

2.2.3 Benefits that Encourage the Adoption of AMT

It has been illustrated how those countries, whose economies have been developing more quickly than the UK, have companies, who are adopting AMT at a faster rate. The implementation of AMT and AMS has become synonymous with competitive manufacture. The market place and customers have greater purchasing power, and are more particular about the products they buy. This is why companies need to be more flexible in the products they produce and simultaneously maintain a competitive price. The concept of buying the cheapest product has been replaced by "Value for Money".

Companies are often negative in their approach to automation, with management often stating the bad influences of their business that they wish to eradicate, rather than outlining the positive benefits of AMT. The problem for many companies is that AMT alone is not going to make a bad system good. Unlike previous equipment overhauls, to attain the best from AMT, it has to be part of a new strategy and philosophy.

Initially, the company must have good reasons why it should purchase any AMT system, whether it be a robot, CNC machine, FMS or dedicated transfer line. The long list of attributes and benefits of AMT has been compiled from the trade journals between 1984 and 1988. Specific work by Ayres and Miller, (1983), and CEDEFOP, (1986), give more detailed explanations.

The first four items in the list are the main direct cost benefits of AMT, and are the most common criteria used by companies, when conducting their investment appraisals. The second series of four items represent the attributes and capabilities of the AMT equipment. These are some of the intangible benefits, which are used to support investments in AMT.

1. Material Costs : Fewer reject parts, rework, and more consistent machining results in reduced tolerances and greater utilisation.
2. Labour Costs : The reduction in the number of shop floor workers is the main reported reason why companies automate. AMT is perceived by many companies as being purely labour saving devices.
3. Energy Costs : The individual equipment consumes a greater amount of energy, but since it often replaces several conventional machines, the overall energy costs are lower for an equivalent job.
4. Production Throughput : For an equivalent job, AMT production rates are higher. Furthermore, once set up, they may be left unattended, making it easier for the machines to work through "break" periods, and for 24 hours, thus increasing the machine utilisation.
5. Eliminate Tedious and Hazardous Jobs : The technology can be adopted to eliminate those jobs which are repetitive, dangerous, and demoralising.
6. Flexibility : Selection of appropriate equipment can lead to the same piece of automation being able to carry out many different functions, making it more adaptable than conventional machinery.
7. Quality : Automation has greater consistency, reliability, repeatability and accuracy in production. This results in an improved product or component, and fewer rejects.
8. Safety : New AMT is much safer than conventional machines as the main machining centres are protected by guards, which, when broken, can automatically stop the machine. In some cases the guards are also used to reduce the noise level.

These are the direct benefits to a company from the purchase of AMT. However, the company should achieve additional cost benefits that are not directly related to the equipment as outlined in points 9 to 12. In addition, there are some further non-quantifiable strategic benefits which accrue from the adoption of AMT. The variety of issues outlined in the list illustrates the broad sphere of influence large amounts of AMT can have on a business.

9. Design Costs : Large economies can be made by using CAD in the design process and its potential direct link with CNC machinery.
10. Inventory : With lower Economic Batch Quantities (EBQ), and incresed awareness of the opportunity cost of holding stock and occupying space, there is less need to hold buffer stocks leading to lower inventory throughout the factory.
11. Factory Space : Reduced inventory and more sophisticated technology carrying out jobs, previously done by more machines, have resulted in a greater utilization of factory floor space.
12. Marketing : AMT has allowed a greater variety of products to be made, which has improved total sales and profits.
13. Corporate Image : With more sophisticated machinery, companies have been able to give greater assurances that products are "good first time, and on time". This has resulted in improved public relations and corporate image.
14. Production Lead Times : Actual production times to manufacture a product are lower.
15. Product Lead Times : The whole system of developing new products is reduced.
16. Set Up Times : Machine change over times are lower.
17. Reduced Batch Size : Automation has the effect of reducing the EBQ, as set up costs and changeover times are often reduced.
18. Production Control : With properly implemented technology and complementary systems, fewer people, machines and inventory should make production control easier
19. Added Value : Several new technologies have additional functions and capabilities, which allow companies to add greater value to their products.
20. Communication and Integration : AMT allows departmental barriers to be broken and promotes integration between them.

At present automation is replacing the physical human tasks of production, and especially those relating to tedious jobs and requiring great attention to detail. The three quotes below are typical of those found in the literature, and refer to the three principal reasons for automating.

> "The basis for competitive advantage is flexibility."
> (Hayes and Wheelwright, 1984)

> "The prime issue is labour displacement, as in the period from 1979 to 1990 wage rate are expected to double. Labour saving is the principal reason for adopting robots."
> (Engelberger, 1980)

> "The performance of hazardous operations and undesirable tasks can often be a cost effective solution since there should be fewer complaints, stoppages, slow downs and less turnover of staff, absenteeism, grievances, sabotage and training of replacement staff."
> (Hunt, 1983)

Data on the Unit Labour Cost Index, given in section 2.4.2 for both the UK and the US, supports the statement from Engelberger, the president of Unimation, whilst the limited information on industrial stoppages could back Hunt's statement.

2.2.4 Reasons that Discourage the Adoption of AMT

If companies believed, uncritically, all the attributes and the benefits of AMT, then the adoption rate would be much greater. Below is a comprehensive list of the possible reasons why companies may not have automated their production facilities, or only implemented a low proportion.

1. Cost : The overall cost of AMT, including the actual price, accessories, control systems, special tooling, and changes to the factory layout and conditions, is expensive. There may also be additional costs relating to training, support services, and modifications required to the basic models.
2. Awareness of the Technology : In many instances companies, and particularly the smaller ones, may be unaware of the

equipment that is available, its attributes and capabilities.

3. <u>Suitability of the Technology :</u> Even when a company is aware of the technology available, it may be unclear as to whether it will be suitable or appropriate for the intended application. The problem often arises when the technology is observed in non-comparable applications.
4. <u>Trained Personnel :</u> It is clear that some companies are worried that they do not have the skilled personnel needed for such an investment at all the levels from operating, support and maintenance.
5. <u>Difficulties Experienced :</u> Often adverse reports from sources, who have experienced difficulties with the implementation, equipment suppliers or other problems outlined is 2.1.5, are an obstacle to the adoption of AMT.
6. <u>Trade Unions :</u> Any major changes to production equipment or methods require the agreement and support of the company's workers and trade unions. If wrongly managed, the trade unions can be a deterrent to the introduction of AMT.
7. <u>Financial Accountants :</u> Many of the benefits of AMT are strategic and often non-quantifiable financially. Therefore they are neglected for purposes of investment appraisals.
8. <u>Dogmatism :</u> At all levels of a company, from the board of directors to the machine operators, there can be a dogmatic attitude towards the introduction of new systems.
9. <u>Company Structure :</u> The organisation of a company, which is too rigid and departmentalised, restricts the interdisciplinary communication necessary for the successful implementation of AMT.
10. <u>Scepticism :</u> The quickening rate of development in AMT makes management sceptical of the intended attributes, whilst employees fear the change will result in job losses.

Despite the actual cost of the implementation of AMT the three main barriers to adoption are financial, attitudinal, and suitability. The attitudinal problem can be overcome, and if the need is great enough, so too can the financial obstacle. Therefore, the key criteria is the suitability of the equipment to do the intended task. Chapter 4 outlines how, only through detailed planning, this can be achieved.

Table 2.2

The Reasons Why British Industry is Reluctant to Invest in AMT

No	Reason	%
1.	Limited financial resources.	64.3
2.	Uncertain future market trends.	58.3
3.	Resistant to change.	7.8
4.	Difficulty in obtaining information on new technology.	7.0
5.	Uncertainty of continuity of labour.	10.4
6.	Obtaining suitably trained labour.	15.7
7.	Difficulty to change product design for new technology.	22.6
8.	New technology is never considered until well proven.	33.9
9.	Technology is advancing too quickly.	13.0
10.	Appraisal studies have NOT been carried out comparing new technology with existing method	17.4

Research conducted by IProdE, (1980), established the reasons why British companies were reluctant to invest in AMT with the results shown in Table 2.2. It is suggested that this revealed a list of excuses that illustrates the inadequacies and discrepancies of management, in planing and operating their business properly.

2.2.5 Problems Associated with AMT

There are three categories of problems that can be associated with AMT. These are technical, human and managerial. The job of implementing a major AMS is a long and time consuming task, in which great attention to detail has to be made. Below are some authors' thoughts on the technical problems associated with all forms of automation, and the reasons for the slow rate of diffusion in the Western industrial nations, and the UK in particular.

> "Diffusion failed due to high cost and technological problems especially in the area of control systems."
> (Lupton, 1984)

> "The credibility of AMT is a major obstacle to it's adoption."
> (NEDO, 1985)

> "There is a grave shortage of trained technical experts for installation, programming and maintenance. Technological literacy and competence is required in computer scientists, software engineers, engineers and technicians.
> (Hunt, 1983)

It is clear that in many cases the actual machinery, "per se", causes few problems. The main difficulties are the failure of management to formulate strategies that are devised to achieve specific goals. This is illustrated below by the list of reasons for technology not living up to expectations given in the National Economic Development Organisation, (NEDO report of 1985).

"-lack of management commitment,
-poor communications and incomplete involvement with employees,
-inadequate inventory records and engineering data,
-inadequate detailed planning,
-unsuitable organisation structure,
-a piecemeal approach to investment,
-insufficient training,
-under resource implementation programme,
-lack of involvement with equipment suppliers,
-understanding software requirements."
(NEDO, 1985)

It can be seen that none of the factors mentions the technical performance of the equipment. Therefore one of the key roles for management is to assess the suitability of automation, the form that it should take, and to match it to the workplace and system. Early problems with the accuracy and repeatability of automation and robots have, on the whole, been rectified, although problems are most likely to occur when the pick up load is close to the maximum, and new applications and specific adaptations are made. Other problems are outlined below.

> "The majority of existing company manufacturing systems and product designs have manual production in mind."
>
> (Morgan, 1984)

> "The reasons for the slow market uptake is that industrial robots of the current vintage are not yet as effective as humans in many jobs."
>
> (Ayres & Miller, 1983)

> "Are robots needed or is dedicated automation the better alternative."
>
> (Northcott, 1986)

The social and labour implications are well documented by Kaplinsky, (1984), and Woodward, (1965). It is generally accepted that new technology has brought about improved working conditions, especially where the machines have replaced dangerous jobs. The requirement of safety guards has lead to a safer workplace with fewer injuries.

The level of skills required and the amount of human stress are issues for debate. There are certainly some manual operators, who require fewer skills and incur less stress, as a result of automation. However, in general, it is believed that employees have to be more flexible, skilled and accountable for the work they do and consequently face greater stress.

> "The days of the unskilled labourer are passing and tomorrow's world will be built using highly skilled technicians, engineers and scientists."

> "Robots seem to induce a higher level of stress than other more conventional types of automation."
>
> (Morgan, 1984)

This highlights that the so called "skills" are being transferred from the factory floor into the backup support services. The change may be slow, but employees are always sceptical when changes are being made to the production technology, methods or products, which naturally result in a certain amount of opposition. This is especially the case when they fear for their jobs.

> "Opposition is as a result of fear, and fear is born of ignorance, but they have to be accepted eventually as "one of the men". Initial curiosity is supplanted by tolerance and finally rapport."
>
> (Engelberger, 1980)

The world is forever changing and companies cannot rest on their laurels. Imperialist and dogmatic attitudes may be a reason for Britain's failure to export their products to other world markets. Attitudes have to change, but the process is often slow. However, as long as the employees fear that new technology will increase productivity and unemployment, their will always be resistance to its introduction.

> "History, attitudes, institutions and beliefs are slow to change and are inappropriate to the challenges which face us."
>
> (Lupton, 1984)

> "The importance of work people having the right attitudes towards robots and robot systems cannot be over emphasised."
>
> (Morgan, 1984)

Having the right attitude and personnel management strategies are critical to any change in working practices. When automating, companies have to make a conscious effort to implement it in a manner that causes least disruption to the system as a whole. The well managed business will achieve this by planning its strategies and tactics accordingly, so that it remains competitive, in control, and responsive to change.

> "Enhancement of competitive position by reducing production costs and being able to meet changes in market demand quickly, and more cheaply and using the same production facilities."
>
> (Hunt, 1983)

However, there are concerns about the calibre of some management teams, their attitudes towards training and the rationale behind some of their decisions.

> "-management training is not taken seriously enough,
> -management training is not geared towards increased competitiveness,
> -manufacturing management does not attract enough high calibre and well qualified people."
>
> (Lupton, 1984)

> "Companies are not automating because their management adopt short sighted attitudes and fail to educate and train for AMT."
>
> (Brown, 1987)

> "Instead of driving for automation major manufacturing companies began to build new factories in the Less Developed Countries (LDC) where the local wages are low."
>
> (Kaplinsky, 1984)

The major criticisms of UK industry, and its management, is that it seldom knows what its corporate aims and objectives are, and only looks at the short term scenarios. Consequently, they are often unable to formulate long term and a cohesive business strategies. It is argued by Voss, (1986), that the reason for companies not adopting a systems approach is because they are more concerned with technical objectives rather than business ones.

Without strategic goals, management is unable to formulate its tactics to manage effectively production volumes. Once the objectives have been agreed the manufacturing strategy may then be formulated.

> "Companies have to adopt to a changing market place which is demanding greater flexibility...this requires a whole new manufacturing strategy."
>
> (Kirton, 1986)

> "The problem is the incompatibility between the technology and the organisation."
>
> (Bessant & Haywood, 1986)

"Disputes about whether robots are always the best solution depends as much on the company's products and production process as well as the characteristics of the robot system. Two key factors which have to be assessed are the product life cycles and the production work cycles."

(Morgan, 1984)

The result of research by Ettlie, (1986), into the major problems to the successful implementation of AMT, are given below:

	Reason	Response	Percentage
1.	Software and Programming	16	39
2.	System Integration	15	37
3.	System Design Flaws	14	34

Other less important problems were the aspects of not fully understanding the goal of the company, and its attitude to training.

This section has highlighted the need for a company to formulate corporate strategies with clear aims and objectives. Those problems relating to the AMT hardware, software and technical interfacing can be solved by the suppliers or their agents. However, problems relating to the effective implementation and management of AMT, is the sole responsibility of the adopting company. This research project studies the strategic and tactical issues a company's management have to consider when formulating their future development plans.

2.3 The Systems Approach

It is claimed that manufacturing companies do not operate, in general, as effective systems. Two possible reasons for this may be the evolution and development of their organisations over decades, in which their procedures have become bureaucratic and resistant to change, whilst the second is said to be short sightedness, with a large emphasis placed on short term planning by top management, in formulating their long term strategy.

The success of the Japanese companies in shaping the world's leading industrial nation has highlighted the need for a "systems approach", which effectively covers short, medium and long term strategies. However, despite the reported efficiency of Japanese industry in developing sound and logical systems, Gow, (1986), has found that there are failures as well as successes. Meanwhile, it must not be forgotten that their are some enormously successful UK and US companies (Peters, 1987).

To apply and develop the systems approach, the research adopted the definition by Hall and Fagen, (Buckley, 1968) to illustrate the operational level, and used Churchman's 5 basic characteristics of a system to show the internal and external business levels (Churchman, 1979). The management aspects become apparent when the two systems are linked together.

2.3.1 Advanced Manufacturing Technology - As An Operational System

The definition of a system :

"A SET of OBJECTS together with RELATIONSHIPS between the objects, and between their ATTRIBUTES related to each and to their ENVIRONMENT so as to form a WHOLE.

(Buckley, 1968)

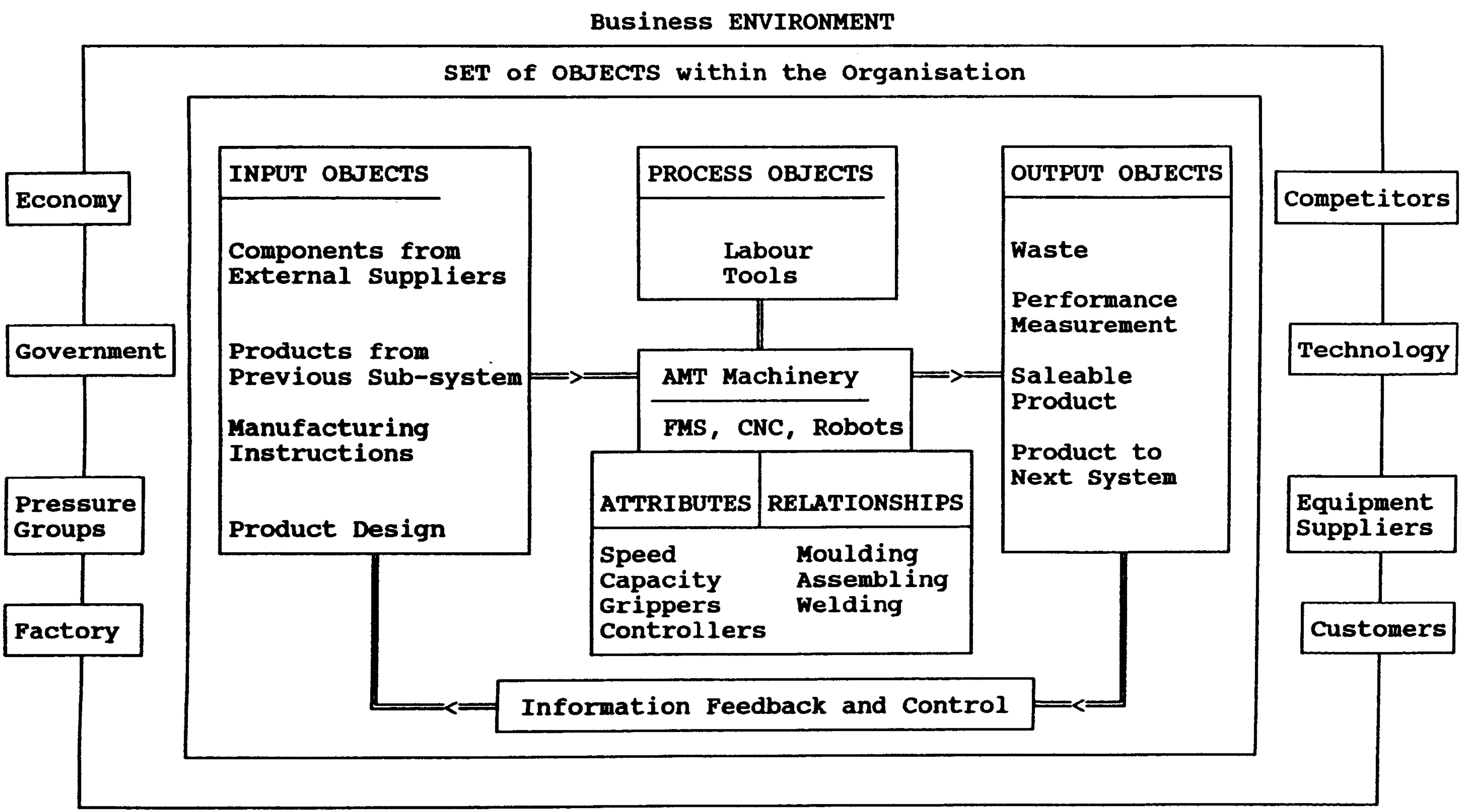
To describe how this definition relates to AMT, the example of adopting a robot has been made. The concept of the whole tries to create the idea of unity, and is an undefined area, which surrounds every influential factor of AMT. Schoderbek, (1985), believes that viewing the system as a whole is properly termed "The Systems Approach". In addition, he believes whole systems are often too large for individuals to comprehend, and they have often to be broken down into more manageable subsystems. Schoderbek's interpretation of the systems definition, given above, is summarised below.

The elements of a system are known as objects. There are three categories of objects, which are the basic functions performed by the systems parts. The Process object is the AMT equipment itself, which transforms "input", such as raw materials, into "output", like finished sub-assemblies. The ratio of output to input is often calculated as being a measure of the system's efficiency. The collection of inputs, process and output objects, are known as the set. This is because they are well defined and clearly belong to the system. Figure 2.3(1), showing the operational system, illustrates the system's objects as rectangles.

The objects, although being discrete, have to be linked together within the system. These linkages represent the "relationship" between the connecting objects. Schoderbek, (1985), outlines three categories of relationship, synergistic, symbiotic, and redundant. The "attributes" of the objects and relationships described above, refer to their properties and characteristics. Attributes of the process object and the AMT are the technical details regarding the parts and the speeds of performance. The attributes of the input and output objects are the material dimensions, and the quality of the part assemblies or final product. In contrast the attributes of the relationships and functions of the links can, for example, be the detail and intelligence given to an object by an information or feedback loop.

Figure 2.3(1)

Operational Systems Diagram for AMT Equipment



Finally, there is the system "environment", which includes all the factors which are partially or totally out of the system's control, but which can influence its performance. For instance, the suppliers of the AMT equipment are external to the operating system, but have a bearing on the success of the ultimate performance.

The management of planning, for selecting, justifying and training for AMT and its system, is critical to the overall success of any implementation.

This research builds on the work carried out by Drayson, (1986), and Morgan, (1984), whose work looked at the process of implementation, rather than at specific strategic issues, which is the aim of this project. The AMT equipment is a sub-system of the whole manufacturing process. It is therefore important to establish how well companies utilise all their sub-systems in determining the performance of the business as a whole, and the process of deriving new sub-systems and relationships between them.

The converse approach to this is to determine the type of sub-system in terms of the objects, relationships and attributes required to make the whole system function optimally. One of the key approaches is to decide whether companies, in any of their strategic plans, identify and formulate the requirements for the sub-systems. If this is the case then the choice of which form of AMT to choose, (if any at all), would be clearer.

2.3.2 The Company - as a Business System

Churchman, (1979), devised five basic considerations for a system, which will be used to discuss the business system. Initially, each system has to have objectives, which can be evaluated to monitor the performance of the system. Every company has both "real" and "stated" objectives for its system and all of its components. The stated objective might be for the system to produce a set number of units per year, whilst the real goal may be to monopolise the market, and maximise profitability.

The system environment is a consideration, which has been discussed previously, for the operating system. However, on a company level, the environmental factors include the group or holding company, national and international economies, Government and competitors. These are illustrated in figure 2.3(2).

Within each system there have to be resources, which the company has available to utilise, in order to achieve its aims and objectives. The resources, such as employees, machines and facilities, can be changed and adapted where necessary. Drucker, (1980), and Wickens, (1987), are convinced that the people are the most important and valuable resource in the system.

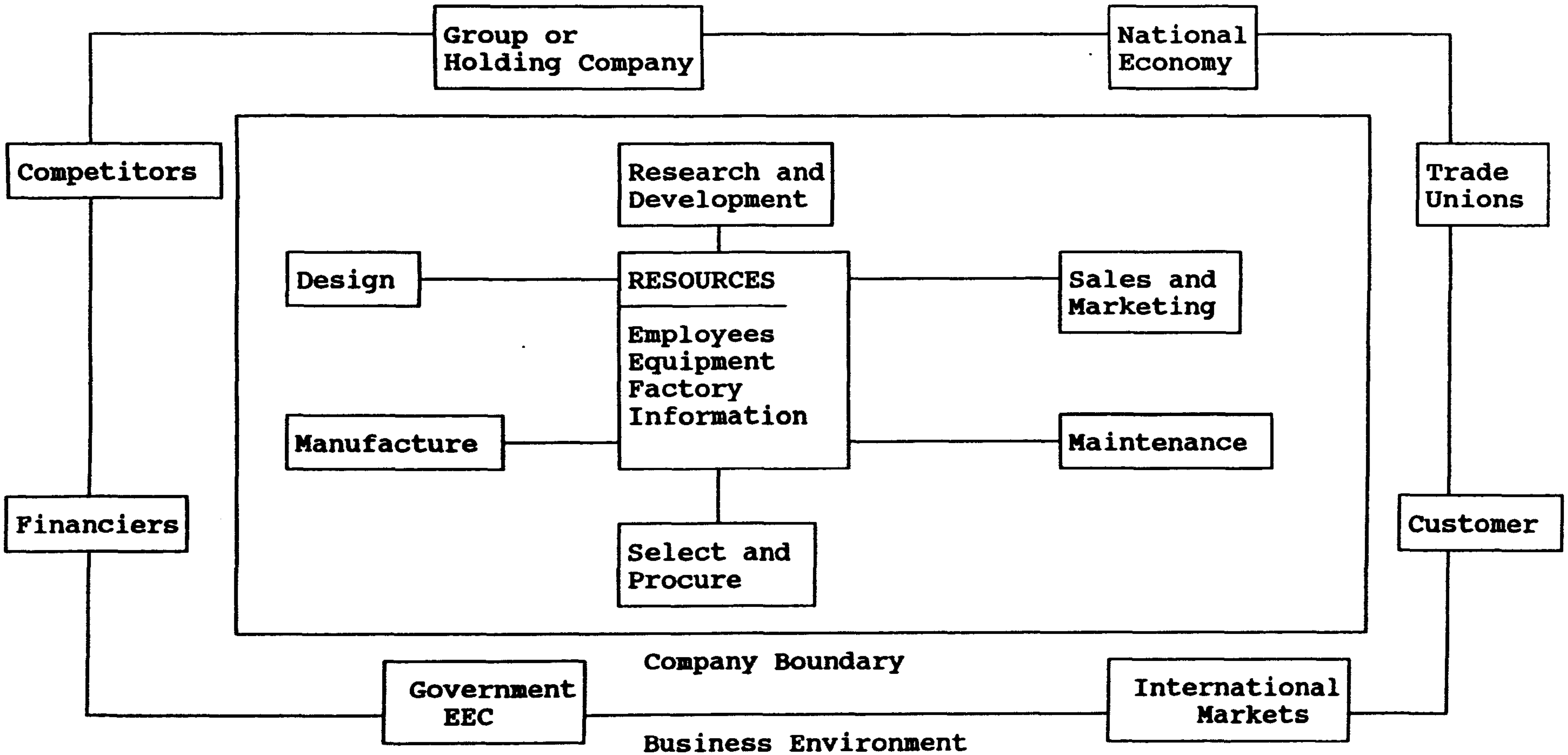
The system components are the functions or activities that must be performed for the company to realise its objectives. Within a company framework these include design, research & development, marketing & sales, maintenance, manufacture and procurement. However, Churchman, (1977), believes that there is a danger that each system component will become too departmentalised, by constructing barriers and deriving their own objectives, which will ultimately lead to the optimisation of sub-systems and not necessarily of the whole system.

The final characteristic of a system is the management of it, which includes the planning and control. To satisfy the aims and objectives of the company, the whole system has to be managed effectively at all levels. The purpose of the research is to highlight the key resources, components, relationships and objects, and to investigate how a broad variety of engineering companies have managed them.

Figure 2.3(2)

The Company as a System

Diagram Depicting C.W. Churchman's Basic Considerations of a System



Management of Resources within the Limitations of the Company's Objectives and Environment.

2.3.3 The Control of Technology

The social implications of new automated technologies have been well documented and reported by academics and psychologists, such as Kaplinsky, (1984), Wall, (1987), and Warnecke, (1982). They have discussed how dramatic changes to manufacturing techniques and methods will have adverse affects on society and employment. However, 20 years after the first AMT machines, similar articles are being written concerning the potential consequences of automation.

Manufacturing is only a component or sub-system of the whole business, with various constraints imposed, which restrict the rate of AMT adoption. It is a further aim of this thesis to isolate these factors, such as product design and to investigate them in more detail.

It is important at this stage to draw the distinction between the two possible types of "technology" within companies. First there is the actual equipment technology, which is discussed thoroughly by Collingridge, (1980). AMT is still young in terms of its predicted life cycle, (see section 7.1), and Collingridge believes that the real social consequences cannot be fully understood because our technical competence exceeds our knowledge of the social effects. However, there is a danger that, when the undesirable consequences are discovered, the technology will have become part of the whole economic and social fabric, making "control" difficult. This is termed the "Dilemma of Control", in which change is easy when the need for it cannot be seen, but becomes more difficult and expensive when the change is required.

With reference to the technological equipment, the project has tried to establish how the manufacturing companies have managed their introduction; for instance, to see how the introduction of AMT has affected the control of the manufacturing process, and to investigate how reversible, corrigible and flexible the systems have become. Research has also been conducted into the relationship that companies have with their AMT suppliers.

AMT has not to be confused with the product technology manufactured by the companies surveyed. In some cases, the companies' technology products were advanced, and could be individually related to the work of Collingridge. However, for the purpose of this project, the term technology refers to formal AMT equipment.

Collingridge focuses on six ways, in which the control of technology can be lost. These resistances to the control of technology of entrenchment, competition, hedging circle, lead time, scale and dogmatism are described briefly below. It is vital to understand the origins of the resistance of technologies to control, so that corrective action can be taken.

Entrenchment occurs when industries become dependent on their own methods and draw their smaller suppliers down the same route. The "rut" deepens with time, making change both expensive and slow.

Companies have to compete against each other. When the competition intensifies, companies have to react quicker to maintain a competitive edge, without necessarily thinking of the consequences. Therefore, competition can distract the attention of the decision makers away from taking a global view.

The rapid growth of some technologies, or product components, means that the opportunity cost of not having the technology is high. This is especially the case when customers expect the new technologies to be included. Collingridge refers to this as the "hedging circle".

Where products and technologies take a long time to develop, there is much uncertainty over the cost and problems that may arise in the future. With such long lead times, there is no urgency to discover potential problems early and solve them quickly.

Large scale plants and technologies are always associated with achieving "economies of scale", resulting in a lower unit cost. However, Collingridge, (1980), and Schumaker, (1973), both claim that the size and ease of control are opposed.

There are many instances where people and organisations resist change, because this will harm their own interests. This dogma can hinder the control of technologies, which would generally be desirable.

The research reveals the extent to which the surveyed companies' products, or AMT its self, fall into any of the categories given above. It will also study how the companies plan their strategies and tactics to rectify these problems.

2.4 The UK Economy

Economic and manufacturing performance indicators have been observed for a twenty year period from 1969 to 1988, the last full year of the thesis. This time period was chosen as it allowed a proper prospective to be made, and trends to be analyzed.

Initially, the common Retail Price Index, (RPI), London Inter Bank Offer Rate, (LIBOR), and the Gross Domestic Product, (GDP), and the UK labour market were monitored. This is followed by a more detailed investigation into the measures of performance for UK manufacturing industry as a whole. The aim is to outline briefly the position of the UK economy, within which the UK manufacturing companies operate and compete.

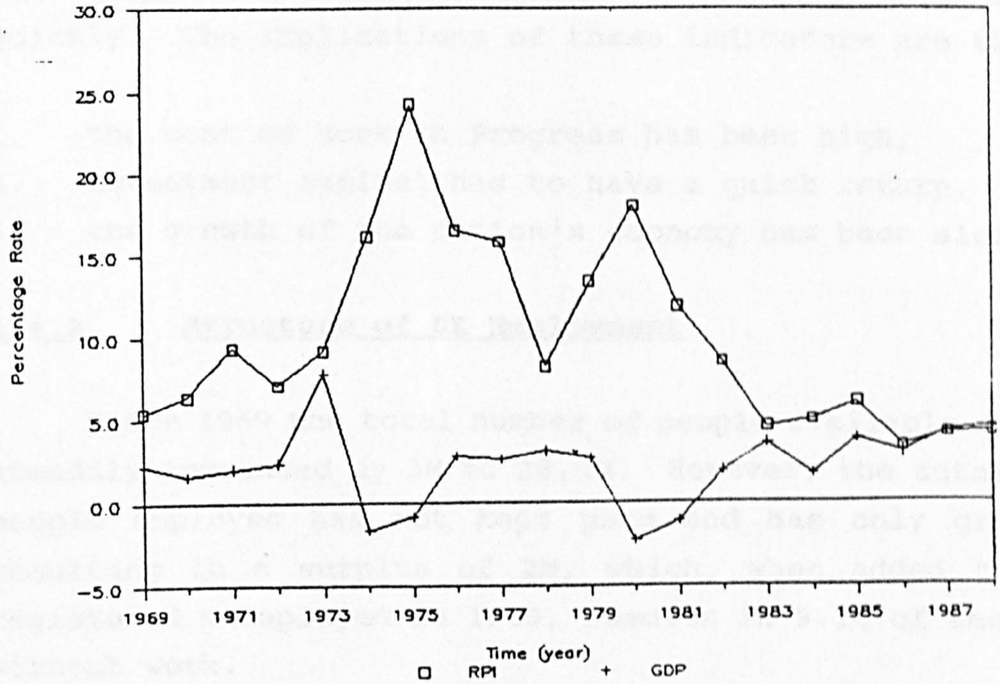
Four other major economies of the world, US, Japan, W.Germany and France, were looked at to assess the relative position of the UK, its standing and competitiveness. The information is a necessary background to UK manufacturing companies as they endeavour to export a greater proportion of their products.

2.4.1 National Economic Indicators

Since 1982 the GDP has had its longest sustained positive growth since prior to 1970. However, the average over the last 20 years is just 2.2% per year. The retail price index over the same time period averaged 9.9%, and only in the two years 1987 and 1988 has the GDP exceeded the RPI. The pattern, shown in figure 2.4(1), illustrates that peaks in inflation in 1975 and 1980, coincided with negative GDP rates. In addition the LIBOR averaged 10.7%, and only in 1971 was the mean rate below 7%.

Figure 2.4(1)

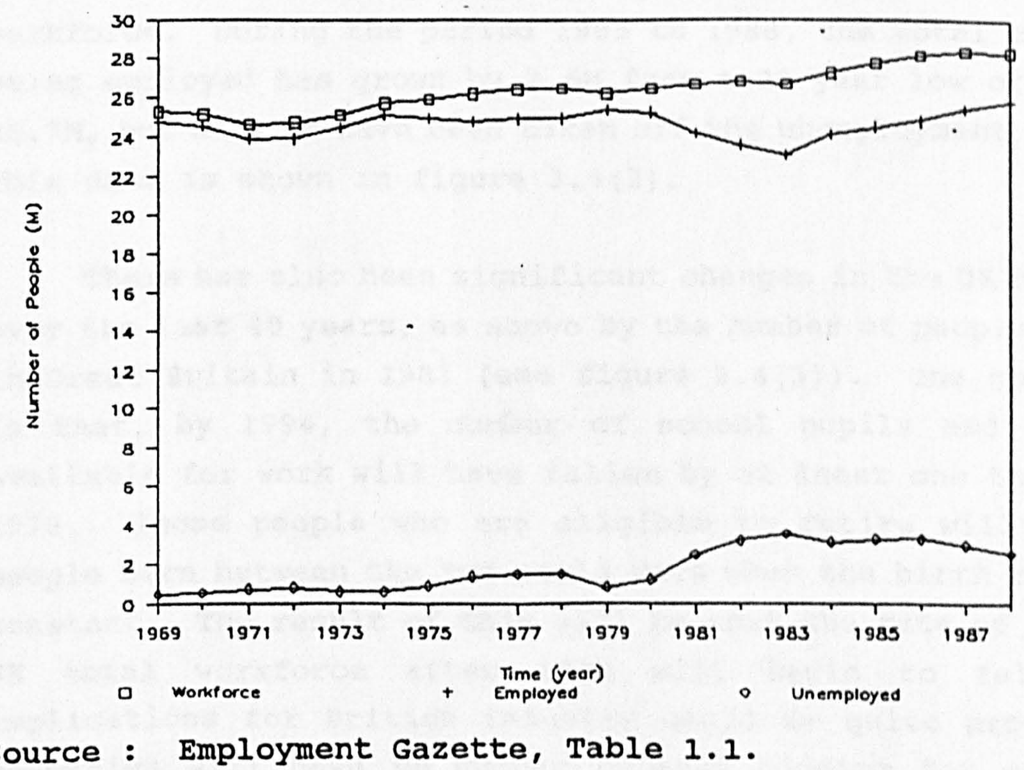
Retail Price Index and Gross Domestic Product (1969 to 1988)



Source : RPI : Economic Trends, Page 42.
GDP : Economic Trends, Page 14.

Figure 2.4(2)

The Total Workforce, Employed and Unemployed



Source : Employment Gazette, Table 1.1.

This shows that the cost of borrowed money in the UK has been high, and that the value of savings have depreciated quickly. The implications of these indicators are that :

1. the cost of Work in Progress has been high,
2. investment capital has to have a quick return,
3. the growth of the nation's economy has been slow.

2.4.2 Structure of UK Employment

Since 1969 the total number of people available for work has steadily increased by 3M to 28.3M. However, the total number of people employed has not kept pace and has only grown by 1M, resulting in a surplus of 2M, which, when added to the 0.5M registered unemployed in 1969, results in 9.1% of the workforce without work.

It was only after 1980 that a significant discrepancy appeared between the total workforce and the number employed, as the gap widened by 1M for two consecutive years. The result was that, in 1983, there were 3.5M unemployed, 13.3% of the workforce. During the period 1985 to 1988, the total classed as being employed has grown by 2.6M from a 20 year low of 23.1M to 25.7M, but only 1M have been taken off the unemployment register. This data is shown in figure 2.4(2).

There has also been significant changes in the UK birth rate over the last 40 years, as shown by the number of people resident in Great Britain in 1981 (see figure 2.4(3)). One consequence is that, by 1994, the number of school pupils and graduates available for work will have fallen by at least one third since 1978. Those people who are eligible to retire will be those people born between the two world wars when the birth rates were constant. The result of this will be that the rate of growth of UK total workforce after 1990 will begin to fall. The implications for British industry could be quite profound, as companies will have to choose between bidding for school and university leavers or retraining existing employees. Naturally those companies, who are aware of the situation, and have devised strategic plans, will be better placed than those who have not.

Over the past 20 years there has been major changes to the number of people employed in each of the main industrial sectors, primary, secondary and tertiary. The primary industrial sector of agriculture has remained in a slow, but consistent, decline at around 5,000 a year, with a 1987 value of 0.3M compared with 0.4M in 1969. The secondary industrial sector of manufacturing has witnessed the steepest decline, from 11M in 1969 to 6.5M in 1987, with the worst fall in 1971 and 1981. This decline of 41.9% is only countered by an increase of 29.4% in the tertiary industrial sector, which has grown from 11.2M in 1969 to 14.5M in 1987. The data is shown figure 2.4(4).

The discrepancy is taken up by an increase of 1.4M in the number of people classed as being self employed. These trends have been confirmed during the industrial visits, where the once large labour intensive companies have shed their labour and also subcontracted a greater proportion of their work.

Figure 2.4(3)

Resident Population in Great Britain

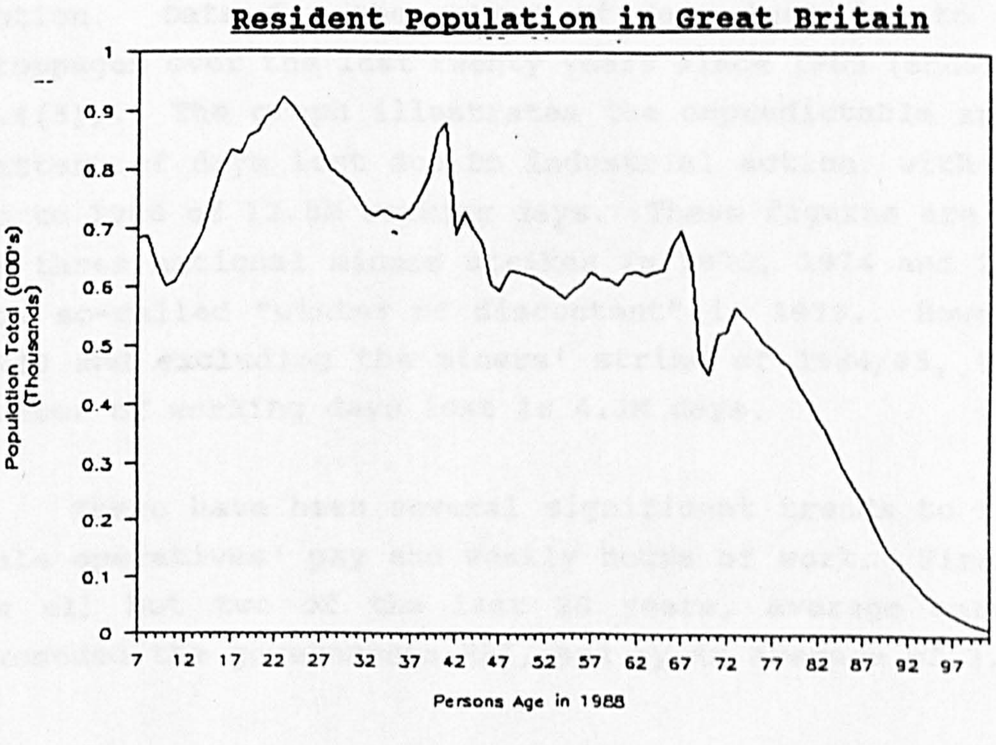
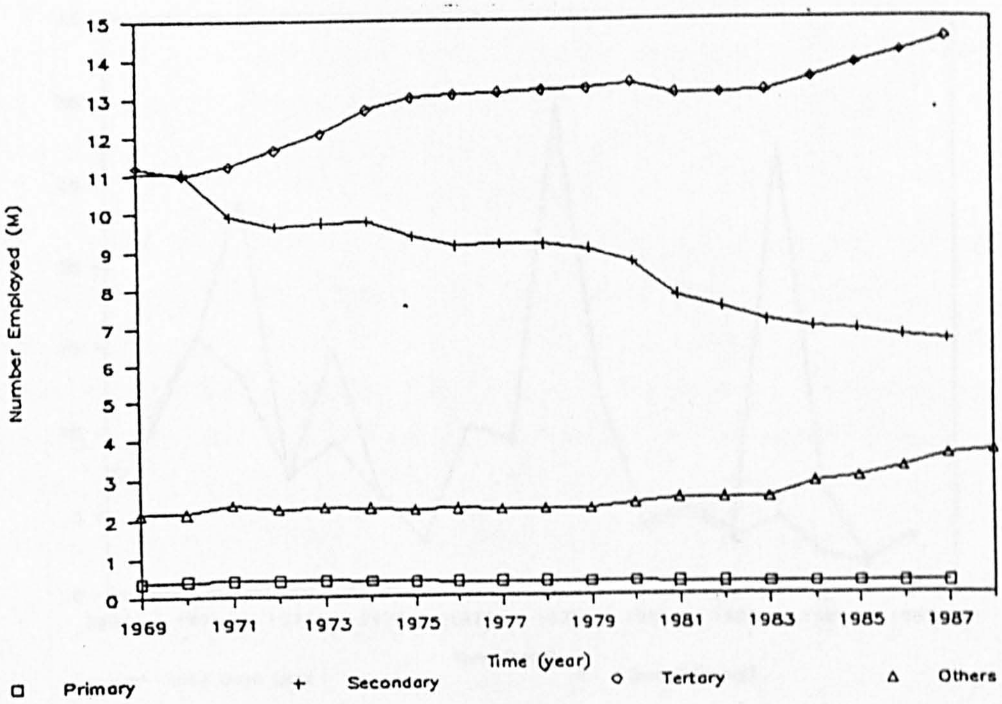


Figure 2.4(4)

Number of People Employed in Each Industrial Sector



Source : Employment Gazette, Table 1.2.

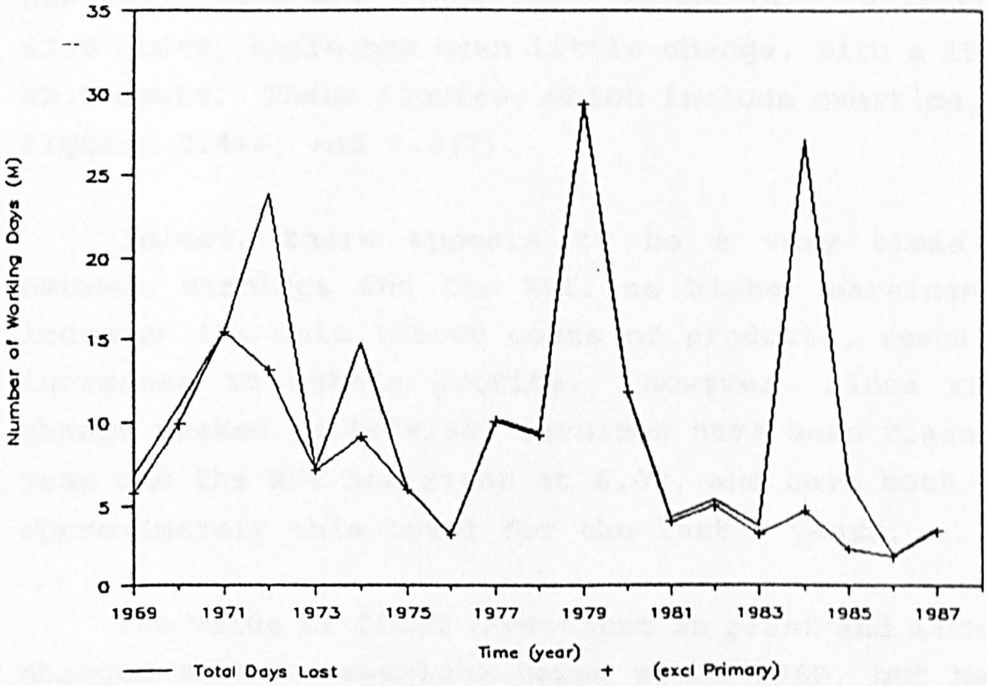
2.4.3 UK Manufacturing Industry

UK manufacturing industry has been plgued with poor industrial relations leading to frequent stikes and disruptive action. Data for the number of days lost due to industrial stoppages over the last twenty years since 1969 (shown in figure 2.4(5)). The graph illustrates the unpredictable and variable pattern of days lost due to industrial action, with an average up to 1980 of 12.5M working days. These figures are made worse by three national miners strikes in 1972, 1974 and 1984 and by the so-called "winter of discontent" in 1979. However, since 1980 and excluding the miners' strike of 1984/85, the average number of working days lost is 4.3M days.

There have been several significant trends to the average male operatives' pay and weekly hours of work. First is that, in all but two of the last 20 years, average earnings have exceeded the governments RPI, and by an average of 3.5%.

Figure 2.4(5)

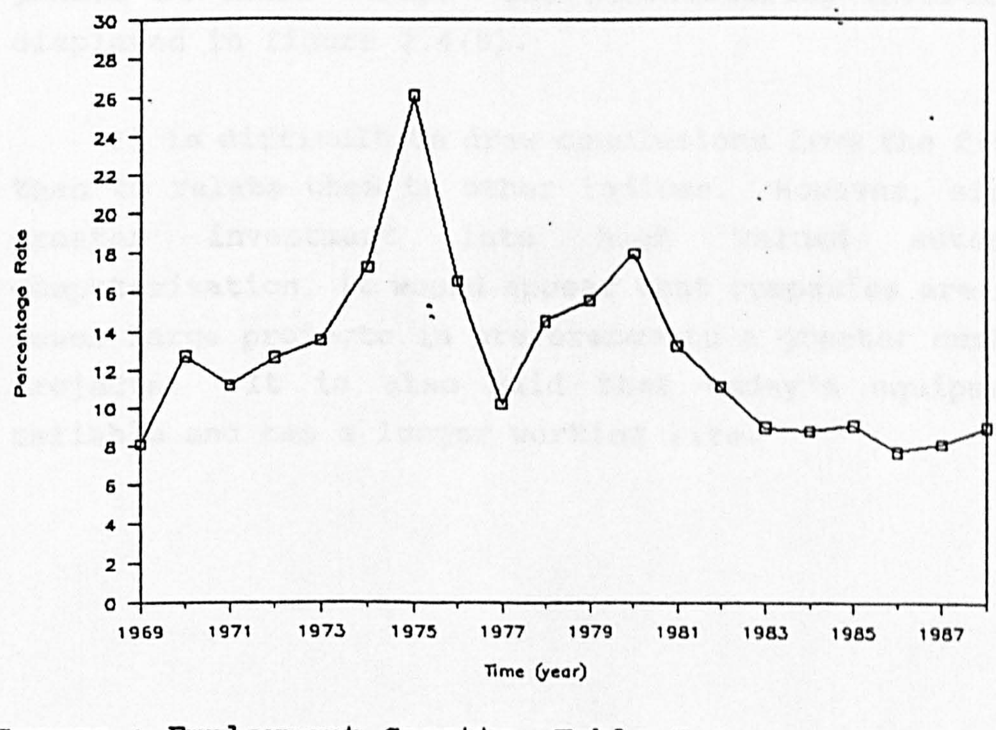
Days Lost Due to Industrial Stoppages



Source : Employment Gazette, Table 5.4.

Figure 2.4(6)

Earnings by Manufacturing Operatives



Source : Employment Gazette, Table 5.4.

The number of hours worked each week by a manufacturing operative has fallen from 46.5 in 1969 to 43.4 hours in 1984. However, there are signs that, since 1975, when the figure was 43.6 hours, there has been little change, with a 1982 minimum of 42.9 hours. These figures, which include overtime, are shown in figures 2.4(6) and 2.4(7).

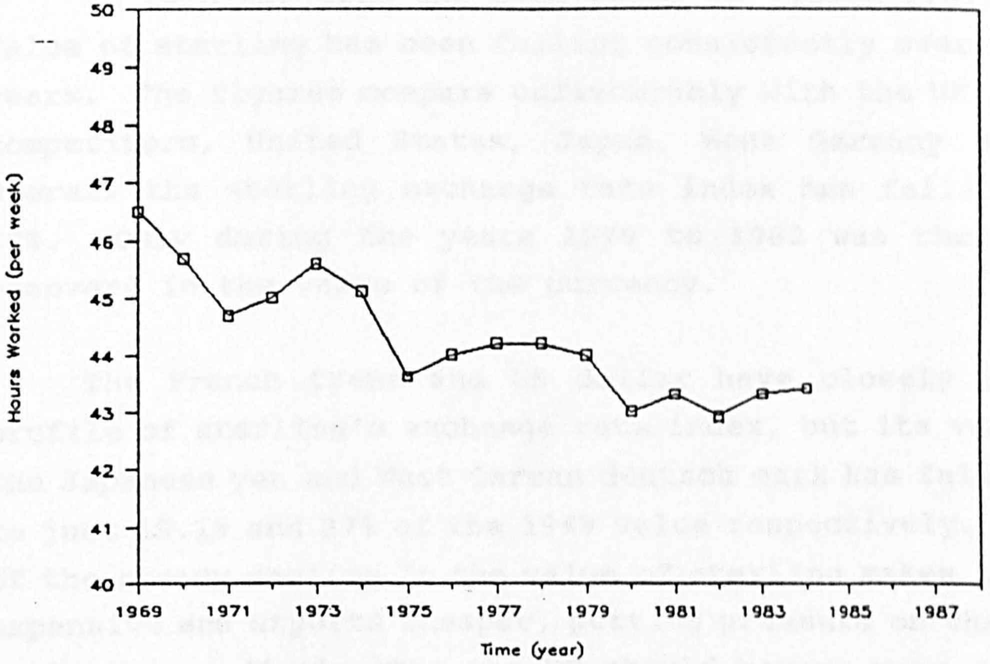
Indeed, there appears to be a very close relationship between earnings and the RPI, as higher earnings are said to increase the unit labour costs of products, resulting in price increases to retain profits. However, since the percentage change peaked in 1979/80, earnings have been rising at 9.5% per year and the RPI has risen at 6.0%, and have both stabilised to approximately this level for the last 8 years.

The value of fixed investment in plant and machinery has not changed much in absolute terms since 1969, but has fluctuated considerably. The least popular times for investing being in the years following times of industrial unrest in 1972, 1974, 1979 and 1985, when there were many industrial stoppages. There are also some connections with the RPI and average earnings which peaked at these times. The manufacturing investment data is displayed in figure 2.4(8).

It is difficult to draw conclusions from the figures, other than to relate them to other indices. However, since there is greater investment into high valued automation and computerisation, it would appear that companies are investing in fewer large projects in preference to a greater number of small projects. It is also said that today's equipment is more reliable and has a longer working life.

Figure 2.4(7)

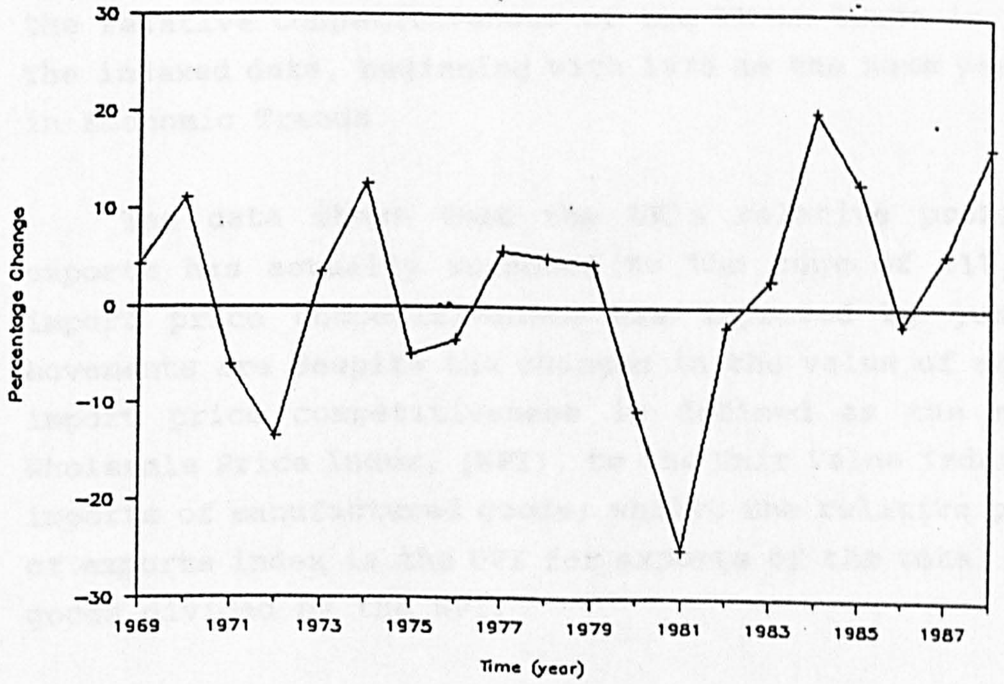
Mean Hours Worked by Manufacturing Operatives



Source : Employment Gazette, Table 5.4.

Figure 2.4(8)

Annual Percentage Changes to Manufacturing Investment



Source : Economic Trends, Page 18.

2.4.4 Comparisons with World Competitors

It is clear from the data shown in figure 2.4(9) that the value of sterling has been falling consistently over the last 20 years. The figures compare unfavourably with the UK's four main competitors, United States, Japan, West Germany and France. Overall the sterling exchange rate index has fallen by nearly 40%. Only during the years 1979 to 1982 was there a slight recovery in the value of the currency.

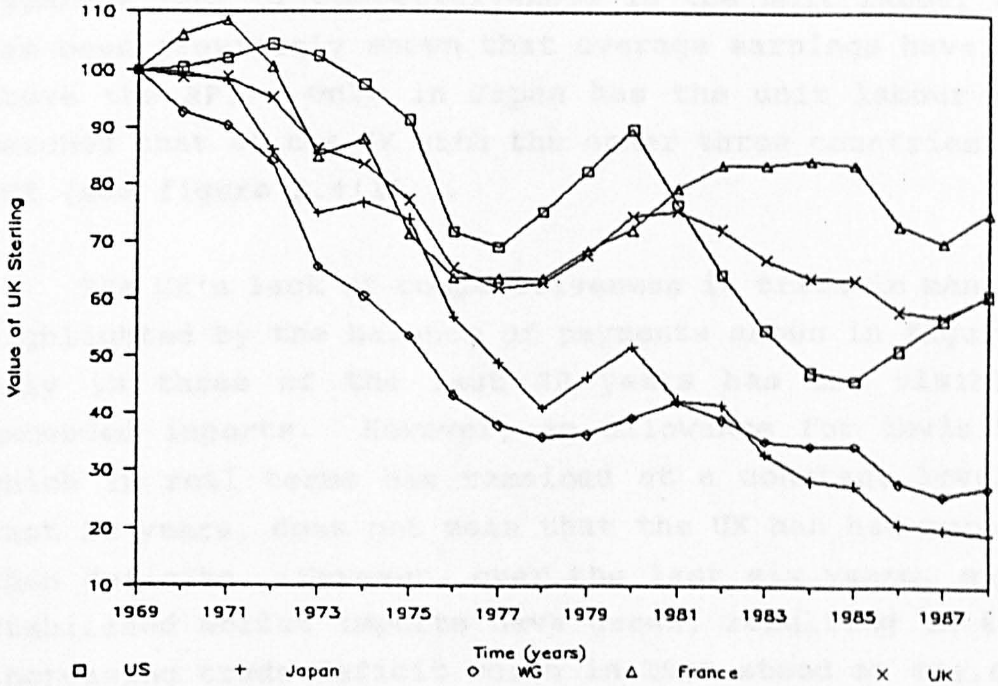
The French franc and US dollar have closely matched the profile of sterling's exchange rate index, but its value against the Japanese yen and West German deutsch mark has fallen the most to just 19.1% and 27% of the 1969 value respectively. The effect of the steady decline in the value of sterling makes imports more expensive and exports cheaper, putting pressure on the RPI. This would then indicate that the UK should become more competitive, making its manufacturing products more attractive overseas.

Data from the government, and published in "Economic Trends" by the Central Statistics Office, shows that this is not the case. It publishes a series of statistics, which try to measure the relative competitiveness of the UK in trade in manufacture. The indexed data, beginning with 1975 as the base year, are shown in Economic Trends.

The data shows that the UK's relative profitability of exports has actually worsened to the tune of 11%, whilst the import price competitiveness has improved by just 5%. These movements are despite the changes in the value of sterling. The import price competitiveness is defined as the ratio of the Wholesale Price Index, (WPI), to the Unit Value Index, (UVI), for imports of manufactured goods; whilst the relative profitability of exports index is the UVI for exports of the total manufactured goods divided by the WPI.

Figure 2.4(9)

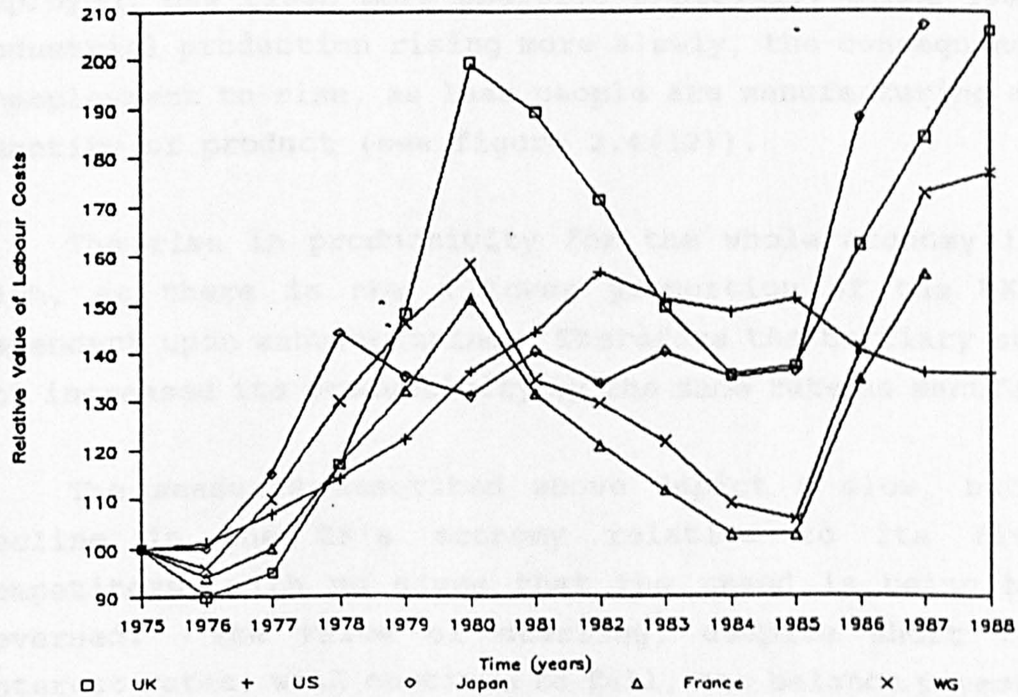
Value of UK Sterling (1969 to 1988)



Source : Economic Trends, Page 46.

Figure 2.4(10)

Labour Unit Cost Index (1969 to 1988)



Source : Economic Trends, Page 26.

Indeed the UK is the worst of the five major countries analyzed by an average of 10%. One of the reasons for this apparent lack of competitiveness is the unit labour costs. It has been previously shown that average earnings have grown 3.5% above the RPI. Only in Japan has the unit labour cost index matched that of the UK with the other three countries 15% better off (see figure 2.4(10)).

The UK's lack of competitiveness in trade in manufacture is highlighted by the balance of payments shown in figure 2.4(11). Only in three of the last 20 years has the visible exports exceeded imports. However, an allowance for invisible trade, which in real terms has remained at a constant level over the last 20 years, does not mean that the UK has had more surpluses than deficits. However, over the last six years, exports have stabilised whilst imports have grown, resulting in a large and increasing trade deficit which in 1988 stood at £14.6 billion.

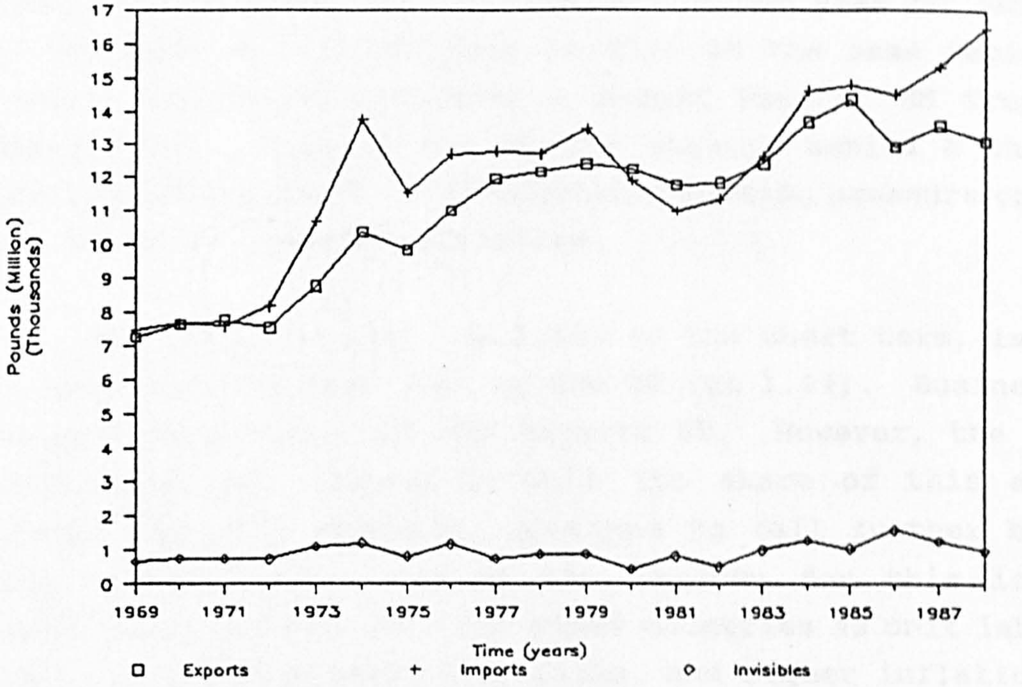
The industrial production data is also not encouraging, as it has risen by less than 1% a year over the twenty year period. Productivity rates, measured by manufacturing output per person employed, has risen more sharply, especially since 1981. With industrial production rising more slowly, the consequence is for unemployment to rise, as less people are manufacturing a similar quantity of product (see figure 2.4(12)).

The rise in productivity for the whole economy is not as high, as there is now a lower proportion of the UK economy dependent upon manufacturing. Therefore the tertiary sector has not increased its productivity by the same rate as manufacturing.

The measures described above depict a slow, but steady, decline in the UK's economy relative to its five major competitors, with no signs that the trend is being halted or reversed. The value of sterling, despite short term high interest rates, will continue to fall, the balance payments trade

Figure 2.4(11)

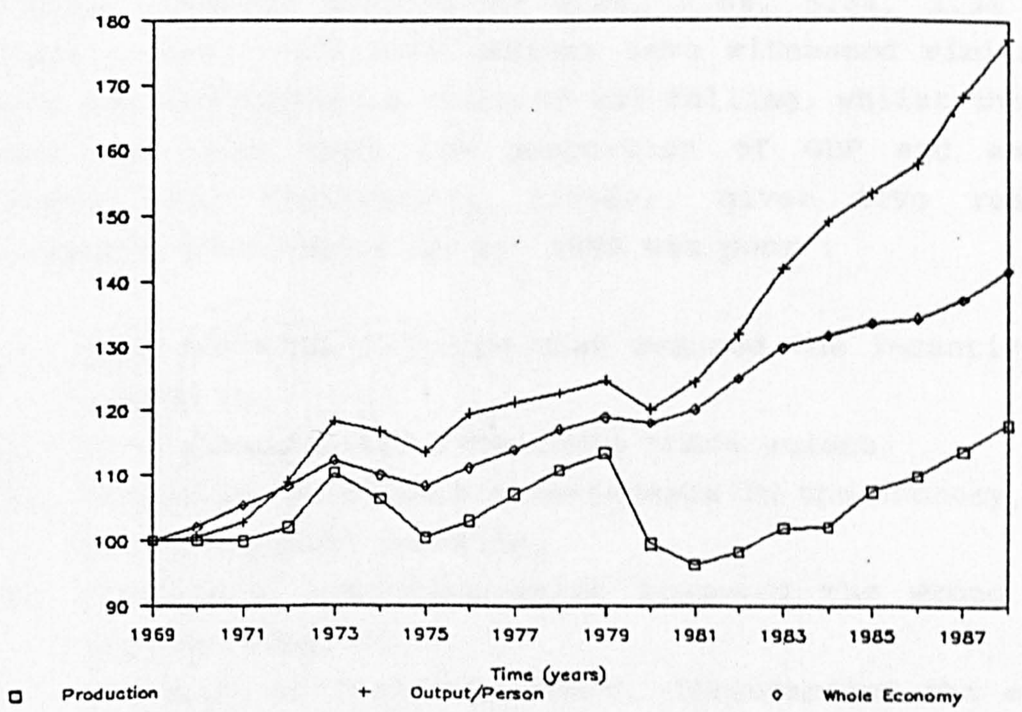
UK Balance of Payments (1969 to 1988)



Source : Economic Trends, Page 17.

Figure 2.4(12)

UK Industrial Production (1969 to 1988)



Source : Economic Trends, Page 27.

deficit is growing, inflation is increasing and the brief recovery in productivity and GDP is levelling off. Furthermore, unemployment which fell by 530,000 in the year to January 1989 is forecast to "...continue to fall at the same rapid rate in 1989." (Financial Statement & Budget Report, HM Treasury, 14 March 1989) This is one of the reasons behind a shortage in skilled labour which is consequently putting pressure on earnings for those in work and inflation.

The world economy (at 2.5%) in the short term, is forecast to grow quicker than that in the UK (at 1.2%). Business growth is said to average 12% and exports 9%. However, the UK is not performing well enough to take its share of this additional trade, and will therefore continue to fall further behind its main competitors. One of the reasons for this is that UK investment is lower than the other countries as unit labour costs rise, relative productivity falls, and higher inflation reduces profit margins and business confidence.

In the twenty years after 1967 the economies of the five major industrial nations of UK, US, Japan, France and West Germany grew on average by 2.2%, 2.6%, 5.3%, 3.3% and 2.8% respectively. All five nations have witnessed similar trends with the manufacturing share of GDP falling, whilst the services have increased both its proportion of GDP and employment. However the "Economist", (1988a), gives five reasons why Britain's performance up to 1980 was poor :

i. high personal taxation that reduced the incentive to work and save,
ii. over powerful and inflexible trade unions,
iii. excessive government interference in the economy, with too great a public spending,
iv. investment subsidies which promoted the wrong sorts of capital expenditure,
v. the goal of full employment, disregarding the effects of inflation and long term efficiency.

The election of the Conservative government, in June 1979, brought an alternative economic policy aimed to defeat inflation and dampen short term demand management in favour of improving the economy's supply side. Kaplinsky, (1984), also believed in this philosophy.

> "Economic growth fuelled by supply side motor with entrepreneurs pursuing the goal of monopoly profit and achieving these profits by introducing new products and production technologies."
>
> (Kaplinsky, 1984)

It is claimed that both Japan and West Germany have made strong economic performance, because they have both been able to invest heavily into less energy and labour intensive plant and machinery, that manufacture goods of increasing quality and technological sophistication to the rest of the world.

The series of five articles in the "Economist - Schools Brief", (Economist, 1988b), emphasises these points. They also conclude that Britain's labour market is riddled with rigidities, trade unions, the housing market which impedes mobility between regions, and inadequate training which restricts mobility between occupations.

The depressing facts are that British industries, in general, despite assistance from the depreciation in the value of sterling, have been unable to manufacture products that can meet domestic demand, or be attractive to overseas customers. The result is greater imports and lower exports, a widening balance of payments, and a lack of confidence in the competitiveness of UK industry. The ACARD report of 1983 gave its response, but there is little evidence to suggest that its advice has been carried out.

> "The rate of technological innovation in UK industry will need to increase if its products and manufacturing processes are to match those of our major competitors. This is a necessary condition of our future survival as a trading nation."
>
> (ACARD, 1983)

Therefore it is necessary to look at some of the reasons why some UK companies are loosing competitiveness. The aim of this project is to study the implications of AMT and automation on the competitiveness of individual companies. Its apparent "need" is uniformly agreed from the government, industry and the trade unions.

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CHAPTER 3

THE RESEARCH

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3.0 Introduction

Having outlined the background to the research through discussion of AMT, the UK economy and a selected number of reports, it is possible to outline the hypotheses and research investigations. This chapter initially outlines the sixteen hypotheses adopted by the research, and then describes the different forms of research design adopted to obtain the information. This is followed by a brief assessment of the research methods used, the sample of companies chosen and the validity of any research deductions.

3.1 Research Design

There are three types of social research design; the case study, the survey and the controlled experiment. Campbell and Stanley, (1966), describe the different aspects of research design in detail. One section outlines the different forms of survey used to carry out the research and obtain the necessary information. The value and limitations of the chosen designs, in relation to this research, are also discussed below.

3.1.1 Research Hypotheses and Investigations

The research was commissioned to investigate how companies managed their AMT, and the implications they had to face. Several "areas for investigative research" were developed, based on statements which might form useful working theories of AMT adoption. The formal testing of these hypotheses in a statistical sense has, however, been less important than the analysis of specifics within the case studies.

General Research Hypotheses

Hypothesis 1 : The adoption of AMT is essential to build and maintain a company's competitive edge.

Hypothesis 2 : Companies do not formulate cohesive corporate strategies in which an equal emphasis is given to each business activity.

Hypothesis 3 : Companies optimise their individual activities and resources rather than the system as a whole.

Implementation of Advanced Manufacturing Technology-Hypotheses

These required an investigation of the strategic and tactical decision making process within those companies adopting AMT.

Hypothesis 4 : Standard accounting procedures and investment appraisal techniques undervalue AMT systems.

Hypothesis 5 : The strategic and tactical considerations of implementing AMT are discussed in isolation and not as a whole.

Hypothesis 6 : The characteristics of a company's development plans and strategies, have an influence on the implementation of AMT.

Hypothesis 7 : Companies invest in automation intuitively, and for the wrong reasons.

Manufacturing Systems - Hypotheses

The effect AMT is having on the resources of materials, labour and machines within the manufacturing systems of a company, was investigated.

Hypothesis 8 : Management demands for new employee agreements are a direct attempt to install Japanese working methods and practices.

Hypothesis 9 : Advanced Manufacturing Technology is the main factor behind the changes to the production systems and procedures within a company.

Hypothesis 10: Information collected to monitor the performance of the company's manufacturing systems is not directed towards assessing the strategic aims and objectives.

Hypothesis 11: There is always some form of AMT available that can provide an appropriate solution to a production problem.

Business Activities - Hypotheses

The investigation centred on the role and influence of maintenance, procurement, marketing, and product design in the adoption of AMT.

Hypothesis 12: AMT has no direct benefit to the Marketing department.

Hypothesis 13: The true cost of "designing for manufacture" is not fully appreciated by the design department.

Hypothesis 14: Component suppliers are not included as an integral part of the business system.

External Influences on the System - Hypotheses

The study covered the business environment activities of the suppliers of AMT equipment, the financial institutions, the Trade Unions, and the Government, with particular emphasis on their attitudes towards AMT.

Hypothesis 15: Trade Unions are a positive restriction to the adoption of AMT.

Hypothesis 16: Companies have to manage the external bodies, such as management consultants and the AMT equipment suppliers, as well as their own personnel and operations.

3.1.2 Main Survey

In order to obtain all the information required a survey of twenty companies was conducted. This had preference over a large scale questionnaire, since it was felt that many of the issues had to be discussed in detail, and the questioning would need to be adapted for different companies. The single case study approach was rejected on the grounds that there would be reduced scope for comparing various company strategies. However, whilst carrying out the survey the research was able to look in greater depth at some issues, particularly relevant to the individual company.

The advantage of the survey design was that a variety of companies in different industries were investigated. In the time available, twenty companies were visited over an 18 month period from July 1987, to January 1989. Every company contacted was known to have some form of AMT in their manufacturing operations, although the quantity or extent was not known.

The procedure for selecting the sample of companies chosen is described in section 3.2.1. During the preliminary visits to companies, four central issues were isolated for further investigation. They were: designing for manufacture, industrial relations, finance and management accounting, and the equipment supply industry. These studies took place at the same time as the main survey.

Details of the questions asked to the various managers and engineers from within the sample of twenty companies are given in section 3.2. Appendix XXII gives the basic outline of the semi-structured questionnaire. The flexibility was necessary to allow for follow up questioning to clarify individual answers. Furthermore, since the sample of companies surveyed covered a large spectrum of the engineering industry, it was important to be able to adapt certain questions in specific cases. The answers to these questions formed the basis of the researches comments in chapters 4-7, and were the primary source of evidence for the hypothesis testing. Once an attachment had been completed the information was transferred onto data sheets (as shown in Appendix XXIII), to catelogue each company's response to a series of questions.

3.1.3 Questionnaire Surveys

The sections on product design and the equipment supply industry were researched by questionnaire. This was the only research design available, which could reach a large national sample. Initial pilot studies were conducted at the "Automan '87", "Des '87", "Pemec '87" and "Eed '87" exhibitions held at the NEC in Birmingham. The results of these investigative questionnaires lead to the development and design of two full scale questionnaires. The benefit of attending the exhibitions was that many people could be contacted quickly and contemporaneously.

The main problem with the design questionnaire was in trying to identify the most suitable person within a manufacturing company, who had some insight into both product design, development and manufacturing. Meanwhile, contact had been made with the Institution of Engineering Designers, (IED), who expressed an interest in the research, and offered to distribute the questionnaire to named members, who would be selected at random through their branch network.

A pilot group of 50 questionnaires was despatched in February 1988. On receiving the replies, minimal modifications were made to clarify questions and improve the layout. Then in April 1988, a further 250 questionnaires were distributed. From the 300 questionnaires, 62 replies were received of which 12 were from people who were not in a position to complete the questionnaire properly due to retirement, or because they were from non-applicable industries, such as the service sector and education. If the sample of replies was representative, this reduced the number of effective questionnaires despatched to 250, with a response rate of approximately 20%. In addition, a further 10 questionnaires were completed by respondents from the main survey, resulting in 60 complete replies from 260, (23%). The questionnaire, in its formal layout is shown in Appendix I.

The questionnaire directed at the AMT equipment suppliers was less successful, resulting in a response rate of less than 11%. One of the main problems appears to have been the disjointed nature of the industry and the relatively small size of the companies. However, deductions have been made from the forty contacts questioned at the different exhibitions, five who were visited in person, and the 33 replies to the questionnaire (shown in Appendix II).

In addition, contact was made with about 20 suppliers of maintenance equipment, who gave their opinions on those companies who were purchasing their systems and how they were influenced by AMT. The questions asked in an informal method are given in Appendix III.

3.1.4 Additional Studies

To complete the "systems approach" to the research it was necessary to obtain the opinions of those bodies, external to the business system, who may have an indirect influence on the company and its strategies towards implementing automation.

Initially, visits were arranged to five professional institutions or research associations. These were preliminary studies into the role of the institutions, their thoughts, their experiences of AMT, and their perspective of the British companies (see Appendix XXI).

It was evident that the trade unions had been influential in the development of British Industry, and that it would be necessary to have independent discussions with the trade union leaders on the issues regarding AMT. Four officials were asked for their thoughts and perceptions about AMT and British Industry and its effects on their members' pay and conditions.

Since AMT is expensive to both develop for a supplier and purchase for a user, the companies have to consider how they can raise the necessary capital. This problem lead to discussions with five different types of financial institutions, the clearing banks, the merchant banks, venture capitalists, technology transferers and leasers. They were asked to give information on the form of finance they offered, its suitability to either a supplier, or a user, the conditions imposed on the financiers, and the criteria used to assess their customers.

Finally, a visit was arranged to the AMT Group from the Department of Trade and Industry, (DTI). The purpose was to obtain information on their support schemes for British companies. This was followed up by meetings at the National Engineering Laboratory, (NEL), and with commercial consultants, who have been involved in conducting government financed "feasibility" and "implementation" studies.

3.1.5 Effect on Internal and External Validity

The "internal" validity of the research is determined by how well the independent variables, in this case the level and type of automation adopted, caused the observed response, in terms of the strategies and tactical methods employed. Unlike experimental research designs, there was no opportunity to manipulate any variable, with the possible exception of the companies sampled and the personnel interviewed. With the evolution of the project and the decision to conduct additional studies to explore in greater detail observed results, the internal validity of the research was increased.

The basis for applying the results obtained from the sample to the whole population is known as "external validity". The initial studies carried out in two local companies highlighted the importance of direct personal observation to obtain a full understanding of the company's strategies and to clarify any ambiguity in the questions asked and the answers given. Thus, even though the questionnaire approach may have given a broader and more representative sample, the evidence could not have been wholly convincing from that approach alone.

The combination of the 20 surveyed companies along with the supplementary studies on design, trade unions, financiers and the AMT equipment supply industry has given the research a balance of both internal and external validity, and some clear indications of successful and failed policies.

3.2 Research Method

Campbell and Stanley, (1966), outlined three main forms of research method : observation, document analysis and asking questions. Due to the broad nature of the research project, all three forms have been adopted at some stage, although asking questions was the method most frequently used. The following sections discuss the method used for each section of the work, the data that was collected and the people from whom the data was obtained.

3.2.1 Sample of Companies Surveyed

The companies, who were asked to participate in the survey, were selected from one of the following sources : Members Directory of the BRA, DTI Demonstration Firms, entrants to the 1986 Willis Faber competition for manufacturing effectiveness, or reports of companies in the trade journals. It was known that all the companies had purchased some form of AMT since 1985, two years prior to the selection procedure.

Initially, letters were despatched to named contacts or the Managing Director of the company. From the 25 letters targeted on Scotland and West Yorkshire, 14 replies were received of which 8 resulted in positive contacts. These companies were predominantly low volume, heavy engineering industries. In an attempt to redress the balance, the second series of letters to the remaining areas of the UK were directed towards the larger volume manufacturers.

From the second batch of 40 letters, a further 12 contacts were made. This resulted in a total sample size of 20 companies spread around the UK and representing a broad range of industry, company sizes, traditions and forms of AMT adopted. The characteristics of the companies surveyed are give Appendix IV, and an individual summary on each of the twenty companies is given in Appendix V.

In total some 52 days were spent in the companies, and over 100 people were questioned. The time spent in each company varied from 1 to 8 days. However, the companies who were visited for one or two days usually had a prearranged schedule of interviews, whereas in some of the longer attachments it was a question of waiting for the personnel to become available between their other commitments.

3.2.2 The Contact People

It is difficult to specify the actual job descriptions of those people, who were interviewed, as the different companies had differing job titles and experience. Where practical, an introductory visit was arranged to outline the information required and plan future interviews with suitable personnel.

The usual primary contact was a project manager or engineer, who was able to provide information concerning the planning and implementation of the AMT into the company. These initial contact people could usually provide information on the implications of AMT on the factory floor, and, depending on their background, expand on their experiences and knowledge in other areas. Meetings with a manufacturing or operations manager were then arranged, as they could discuss the company's manufacturing strategy as a whole. Depending on their seniority, knowledge and willingness to talk, they could expand on the wider business strategies and issues.

In those companies where a longer attachment was negotiated, people in the areas of design, marketing, personnel, management accounting and systems development were interviewed.

3.2.3 Methods used in Data Collection

Each interview had a semi-structured format in which questions were asked to the respondents, who would usually describe their company's approach and position. Where permitted, and practical, the interviews were recorded on a dictaphone to simplify transcription. This approach was possible in all but 12 of the 100 interviews.

It was not thought prudent to structure questionnaires too much, due to the various levels of experience and knowledge of the respondents, and the differing nature of the production processes. However, there were specific areas and topics to be explored which were common to all the companies

In order to obtain a better impression and understanding of a company's manufacturing process, it was necessary to observe the manufacturing facilities and operations. This allowed a conceptual picture to be built up of the AMT and its position relative to the other machinery. No actual data was collected from the observations, other than to put the answers to the questions into context.

In addition to the recorded interviews and factory tours, several of the companies provided written reports and papers concerning different aspects of their business. This data was also supplemented by articles from the trade journals and newspapers on the individual companies. Finally, copies of the companies financial accounts were obtained.

3.2.4 Questions Asked

The research initially studied the reasons why the companies purchased automation, and the implementation process. This involved investigating everything from the companies' competitive position to their manufacturing operations. The scope for potential research in this area was broad, and many trade journals had given several examples of how companies automated. They all described how and when companies installed, and implemented their automation, and gave preliminary results of their performances and problems.

It was then necessary for the project to focus down on a few aspects involved in the implementation of AMT at a strategic level, and concentrate on the constraints imposed on these aspects and the consequences they would have on the company as a whole.

The two major issues chosen for further research were the product the company manufactures, its design features, and how well the company's manufacturing system adapts to AMT. These two aspects are closely related by the fact that the product will determine the nature of the specification required for AMT equipment.

In taking a systems approach the other main issues such as company organisation, factory layout, employee relations, equipment selection and justification, methods and procedures for implementation, the involvement of external bodies and consideration of environmental issues on a local, national, and international scale, were all considered.

Finally, the responsive nature of the whole system to AMT enabled the research to investigate the flexibility and adaptability of the company to change. To do this, it was necessary to see the upstream implications, such as the system for stock control, plant layout, training and maintenance. Information systems are also of importance.

General Questions

The first line of questioning was to obtain a brief history of the company and its development over its life and particularly the last decade, to know of any major external or internal events that may have influenced the company.

Questions were also asked to establish the aims and objectives of the company and on how the company formulated its corporate strategy, and development plans. This was followed by questions on the detail of these strategies and plans to see whether or not there was a role for AMT.

Implementation of Advanced Manufacturing Technology

It was necessary to find out why the company decided to change its existing machinery, and the methods it used to identify the areas for attention and possible change. The questioning then followed a sequential path by trying to establish how the company became aware that AMT could be a possible solution, and whether any alternative methods or solutions were considered.

The second phase was to find out the procedures the company used in selecting the AMT and the process of implementing it into their manufacturing operations. The questions asked were aimed at extracting information regarding how the AMT fitted into their manufacturing system. For this it was necessary to know the companies previous experiences with AMT, and the preparations and alterations that were required for its installation.

The questions then progressed to finding out the major implications and consequences of the AMT, and on the company as a whole. Many difficulties and problems were highlighted and this provided a good introduction to the next series of questions on the company's operating system.

It was usually most appropriate, during this section of the questioning, to know about the dialogue and relationship that existed between the company and the AMT supplier, the training programmes, and support services that were required. In addition, it was appropriate to talk about how the company justified its investment and to understand the assistance or involvement the company had with the government, consultants, and professional institutions. This gave information on the employment of AMT as a system, and how it was linked to other aspects of the company's operations.

Questions on Manufacturing Resources

This was one of the main foci of the research, as it was a critical activity in the business system. Therefore, it was necessary to discuss the impact of new AMT systems on the manufacturing strategy, and whether or not it was compatible with the stated objectives of the company. Then the research investigated the changes that manufacturing had made and whether they were as a result of AMT or other business trends, in particular, whether AMT complemented the manufacturing system and how it affected its "focus".

Discussion usually covered the areas of maintenance, stock control, industrial relations, working practices, proportion of in-house manufacture, and product costing. The most difficult part of the enquiries was to obtain information on the performance of the AMT, and indeed the performance of the whole manufacturing or business system. It was observed that performance measures were frequently unknown by the interviewee, or lacking altogether. Only a few companies had a clear understanding of the information required and what was available. This problem is developed in section 4.4.4, and 5.4.

Questions on the Business Activities

Information was required on the remaining activities of the company, and how they were being influenced by business trends, products or the implementation of AMT. For all the functions of design, R&D, marketing, purchasing, and systems development it was necessary to gain an understanding of the level of integration, and how they communicate with each other, and use common data.

The design activity was picked out for further attention, as the link with manufacture takes on greater importance. It was therefore necessary to know more about the company's product, specification, the restrictions placed on designers by manufacturing, the machinery, and whether there was an effective "design for manufacture" procedure.

3.2.5 Problems of Data Collection

In retrospect eight areas of difficulty were encountered:

1. identifying the people within the company, who were in a position to discuss the issues,
2. soliciting accurate, unambiguous and sincere responses,
3. gaining the confidence of the company and their personnel,
4. finding common criteria or variables which could be used to measure the performance of the whole system,
5. comparing operating systems where the form and extent of the AMT was extremely variable,
6. obtaining a common level of detailed information from all the companies,
7. differing characteristics of the companies (as described in Appendices IV, and VIII) in age, size, product mix and historical development,
8. selecting the key questions when a time limit was imposed.

Chapter 3 Reference

Campbell, D.J. and Stanley, J.C. (1966), "Experimental and Quasi-Experimental Designs for Research", McNally.

CHAPTER 4

IMPLEMENTING ADVANCED MANUFACTURING TECHNOLOGY

Chapter 4

Implementation of Advanced Manufacturing Technology

4.0 Introduction

The purpose of this chapter is to discuss the decisions that management has to take concerning AMT. Particular emphasis is placed on the strategic and tactical issues that are raised during the initiation and implementation process. The research is restricted to the management aspects, and is not concerned with specific technical parameters.

The research is concerned with the strategic issues relating to the planning and preparation for AMT, as well as the key factors in the selection of AMT, and its proposed supplier. Some of the problems in the education, the training, and the justification for investment appraisal in AMT are also highlighted.

The planning for implementation section of the research established the degree to which companies formulated and implemented a development plan for the AMT and manufacturing system. In addition to the reasons for a company's decision to automate, there is also the strategy behind the timing of the implementation.

When isolating the area for attention, the company has to decide on the most appropriate action to take. The introduction and use of AMT could be just one of the possible solutions. The research then assessed the company's characteristics, to see how well they matched their strategies on the selection of the AMT, notably in the validation and operational experiences of the supplier, equipment and personnel.

4.1 Planning for the Implementation of AMT

The plan for the implementation of AMT should begin with a systematic analysis of the way a job or task is carried out at present. Method study is a procedure through which a "Scientific Examination" of a company's activities can be conducted. It is defined as :

> "The systematic recording and critical examination of ways of doing things in order to make improvements."
> (Evans and Ford, 1984)

The three key words of the definition are systematic, critical, and improvements. "Systematic" refers to a logical and consistent sequential procedure of recording the activity identified for further study. The assessment and review of the activity is the "critical" examination, whilst the "improvements" is the consideration of the alternative solutions to discover (if possible) a better way of conducting the activity.

Evans and Ford, (1984), referred to the six stages involved in Method Study. These are outlined below :

1. Select : Identify the job to be studied.
2. Record : Record all Known facts about the job/task.
3. Examine : Critically examine the recorded information.
4. Develop : Define detailed proposals for improvement.
5. Install : Install new method.
6. Maintain :Check new methods are being followed.

The first three steps concern the initial stages for any company wishing to implement a new system such as AMT. These are discussed in section 4.1, whilst the remaining three steps are explained in section 5.3. It is important to note that method study is a continuous and not an isolated process. Once the six stage sequence has been followed, this should initiate a new study on a different job or task.

4.1.1 Development Plans

In general, the companies surveyed only had a manufacturing development plan for the length of time it took to complete a particular implementation, or until the existing budget was exhausted. This time scale would usually be 12 to 18 months. Some plans are said to roll, in that decisions are made on the next phase of capital investment on allocation of the next budget. The common processes and relationships between the different stages of an AMT implementation as outlined by this research are shown in figure 4.1.

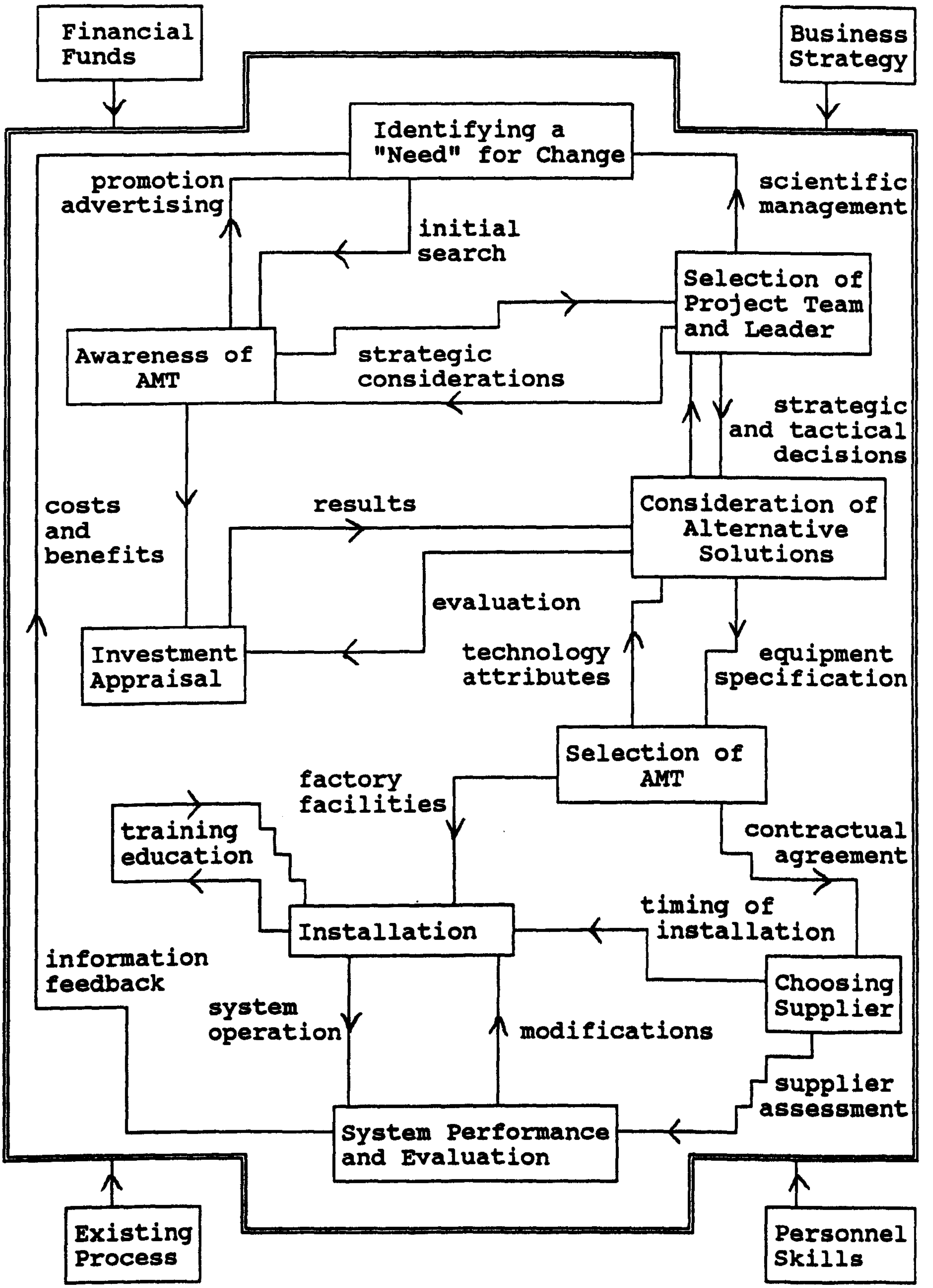
Thus, in practice, on an operational level, investments take place incrementally, but without conforming to any overall plan. However, the higher one goes up the management hierarchy the more one is told that a long term and cohesive plan exists. One observed problem was that the plan did not filter down to those responsible for the selection of AMT, such as the project managers and chief engineers, at least in a comprehensive, or definitive way.

It is not surprising that there is a direct relationship between investment cost and the management level required for approval. In general, the project leaders know the technical aspects of the equipment, the senior management know more about the development plans, but the quantity of informational dialogue passing between them is negotiable. Without appropriate dialogue, one is unlikely to obtain an optimal outcome.

Over half (65%) the companies visited gave evidence that they had some sort of plan to which they were working, and only half of these had annual updates (ie a rolling plan). Those, whose plans for future AMT investment were fixed, would perhaps review their plans only if significant changes had taken place which were not expected.

Figure 4.1

The Process of Implementing AMT



4.1.2 Project Team and Leader

Detailed information is difficult to obtain about the formulation and aims of the team responsible for the implementation of AMT. The team leader is usually a chief engineer or the departmental manager of the most affected area, acting under a manufacturing director. Within the company there may be many project managers, and only in one of the smaller companies was one person responsible for all the projects.

Every company claims that all affected functions of the company are consulted. However, the representation on any committee tends to be limited to those areas, particularly on the shop floor, which will be directly affected. This means that there are occasions when departments that are only indirectly affected, are not represented.

The project leader is a key figure in the equation, as the person responsible for the successful implementation from the company's viewpoint. He is the link between the AMT suppliers, management, manufacturing and all other functions of the business. The team leader, whose background is usually more technical than managerial, has to ensure that other people, such as the AMT suppliers do not take over the effective management of the project. In addition, the link with direct functions becomes neglected, since they are not considered essential.

In none of the companies surveyed were any strategic guidelines given to a project engineer on how he should manage an AMT implementation. Relevant meetings occurred on an irregular haphazard basis, their frequency appeared to vary according to the size of the investment, and the stage of implementation. There were more meetings in the early stages of the project; these became less frequent as the equipment specification and job tasks were identified, and delegated to the team members.

Research by Ettlie, (1986), into the management of AMT projects concluded that "Management of the innovation process has been all but overlooked or forgotten". In a questionnaire survey, Ettlie asked the respondents to comment on the key variables which determine whether a project is a success or a failure. The results are given below.

Table 4.1

The Key Variables that Determine the Success of a Project

No	Variable	Response	%
1.	Supplier - user relationship	22	54
2.	Product - process dependency	19	46
3.	User strategy	17	41
4.	Training	15	37
5.	Incremental implementation strategy	10	24
6.	Human resource policy	10	24
7.	General management support	10	24

Source : Ettlie, (1986).

4.1.3 Identification of those areas in "Need of Change"

> "Technology only makes sense when it is used to help solve genuine company problems and, because of this, it is important to start by identifying the problems that have to be solved before going on to look for appropriate technology."
>
> (Primrose, 1988)

Before a company decides to invest in AMT it has to identify that there is something wrong with the existing system. Potentially this could be to do with any component of the business, from unreliable components suppliers to an ineffective marketing campaign. However, the company must have some performance measure by which it monitors the system. This is discussed further in section 5.3.3.

Only about one half of the companies visited could comprehensively outline the performance measures they were utilising towards identifying those areas of the company requiring attention. Personnel in the remainder were using their intuition and experience to identify the areas of concern, together with implicit rather than explicit criteria.

In most of the companies visited the manufacturing operations were the major cost centres, and consequently were targeted as areas for improvement. This is especially the case with high interest rates and inflation, which in the long term reduce a company's profit margins. Therefore, it would appear important, in identifying the ares for attention, to have performance measures that complement the aims and objectives of the company. Only in this way can the company systematically sequence and prioritise the "bottlenecks". It is also of paramount importance to have adequate information systems, which are able to record and transmit information accurately.

In every case some form of cost was mentioned as being the measure used for identifying "bottlenecks", and consequently areas for attention. The overall cost per unit produced is often the target for reduction. Price was the Order Winning Criterion, (OWC), quoted by the companies. The second most important criterion was that of reducing production lead times, so as to offer more attractive and responsive delivery dates to customers. This was most prevalent for those companies in the heavy engineering sector, who were manufacturing products to specific customer specifications and not to a general consumer market.

However it is unclear as to how companies actually measure their systems' performance to highlight accurately the areas of exceptional high cost, or long lead times.

The companies believe that the time for change began towards the end of the 1970's and beginning of the 1980's, when the Western World was entering a recession. To compete with reducing markets, companies were forced to reduce their manufacturing costs to maintain profit margins, or to increase their prices which would lead to an inflation spiral, less competitiveness, and a deeper recession. In general, companies were not prepared, both managerially and operationally, for the world recession.

Those companies who invested heavily at this time claimed that their actions were necessary to maintain competitiveness, and for survival. The research has isolated two different types of approach. These can broadly be characterised into the traditional engineering workshops, manufacturing low volumes, and the higher volume lighter engineering facilities.

The first category of company was finding that it was having to embark on a strategy of replacing many old and outdated machines, which were at the end of their useful lives. Many were written off entirely, whilst the new AMT enabled many functions to be carried out by large sophisticated systems. These companies also witnessed greatest change through the rationalisation of the production methods and working practices.

The second category of company took a more gradualistic approach, with development and rationalisation being spread over a number of years. In these cases the change was not as severe. In general, those companies, taking the incremental approach, were in less need of taking drastic action, and could phase their AMT over a longer time period.

In most of the companies sampled top level management initiated the process of change, but the actual solutions came from the more technical employees. In terms of the relative position of their product in the market seven companies considered themselves as being behind their competitors, eight were on a par, whilst the remaining five believed that they were market leaders. This is in terms of the design, quality and cost of products manufactured.

For those companies who were behind their competitors, the timing of the AMT implementation took on additional significance. To reduce the gap, their was a greater urgency to adopt the new system as soon as possible. Meanwhile, those companies who were on an equal footing, required the AMT to remain competitive, whilst the market leaders wished to maintain their competitive advantage.

There were six companies who thought that it was necessary to be market leaders in the technology they were using to manufacture their types of products. Consequently, the AMT installations were larger investments, with purpose built or modified equipment. Four of these companies were in the low volume product category and had special strategic reasons for investing in the "one-off" project. In these cases the financial justifications may not have reached the required corporate criteria, and were accepted on the importance of their strategic significance.

Another finding is that only four companies actually invested in AMT in anticipation of an increase in production volumes. The remainder were expecting, at best, to keep production at a constant level. In contrast, only four companies invested in AMT with the intention of maintaining or increasing employment levels. The direct labour was often deployed into other areas of the business. In the remaining organisations, reductions in labour force were needed to justify the investment. Two other main reasons for adopting AMT were to reduce the production lead time and improve the consistency of product quality.

There is no evidence to suggest that companies actually delayed potential projects so that they could allow further development to AMT equipment. This meant that no company specifically waited to "leapfrog" their competitors. Those companies who were late in the automation process naturally had some advantage over those who had begun earlier, in the maturity of the equipment. However, the initial adopters would be already taking advantage of the AMT equipment and gaining valuable experience.

In many instances commercial pressures, in preference to more rational scientific management, were found to dictate development plans and corporate strategy. Therefore, if a particular application is required, then companies are probably prepared to take the risk and accept the "state of the art" technology. This is because time is money, the future is uncertain and technological advancements are continuous. Thus the opportunity cost of not automating is of greater concern. For this reason companies will tend to invest continually (on an annual basis) adopting an incremental tactic to utilise their capital budget quota.

4.1.4 Awareness of AMT

The sample of manufacturing companies and their technical employees were aware that AMT existed if only in a general form. This awareness has accrued from promotions and advertisements in the trade journals, television, visits to other companies, government initiatives, and from suppliers sales brochures.

Since AMT covers a broad range of technologies and applications, attempting to match AMT to a company's manufacturing operations is no simple task. This is especially true for the smaller companies, who are known to have visited larger companies, be impressed, but are unable to envisage how AMT can be applied to them. The result is to seek professional advice from consultants, the equipment suppliers or their agents.

Small companies are more sceptical of "consultants", because they rarely understand the companies' business and are not responsible for the actions they take. Similar scepticism exists of equipment suppliers or their agents, who, it is frequently believed, may not sell them the most suitable equipment.

Larger companies, or those companies who are part of a group of companies, are at a distinct advantage. They have the in house resources, and sometimes the specific expertise to study their company's requirements. In addition they have the time to assess the individual supplier credentials, AMT equipment, and to derive a standard for their company, which will usually involve having "priority" suppliers in return for financial discounts.

Evidently, the smaller companies have not automated to the same degree. The inappropriateness and unawareness of the available technologies are only two of the problems they face. However, the time will come for component suppliers of the larger companies to be pressurised into change, in order to maintain their customers, who are gradually becoming more demanding on their component suppliers concerning cost, delivery, quality, and ability to have computer communication. In these special circumstances the smaller component suppliers may seek guidance from their major customer, in regard to the type of AMT and computerised equipment to be purchased.

4.1.5 Consideration of Alternative Solutions

Once an area has been identified for change it is often pre supposed that AMT is the automatic solution, the only considerations being made concern the form of AMT and the actual supplier. It appears that little assessment is made of the alternative solutions, which should be taken into account prior to the decision to purchase AMT. In many cases several of the options, given below, were being carried out :

1. Purchasing machines for replacement.
2. Subcontracting the work.

3. Using a different form of automation.
4. Improving present products on existing technology.
5. Improving present manufacturing techniques and methods.
6. Using more cost effective materials.
7. Overhauling the existing machinery.
8. Doing nothing.

This research has observed that inadequate attention is given to the above factors at the appropriate time in the identification and planning stages. Too often it appeared that the automation chosen was the only option considered at the time.

Four of the twenty companies surveyed decided on the methods of manufacture, when they were introducing new product lines. Initially they would consider the cost per unit of manufactured product by manual means. Then they would systematically go through each production area in turn deciding on the AMT, which would reduce the overall cost per unit. However, even this approach does not necessarily embrace all the alternative approaches to actual solutions mentioned above, especially if a machine can be transferred from the old product line to the new one with only minor modifications.

4.2 Positioning of AMT

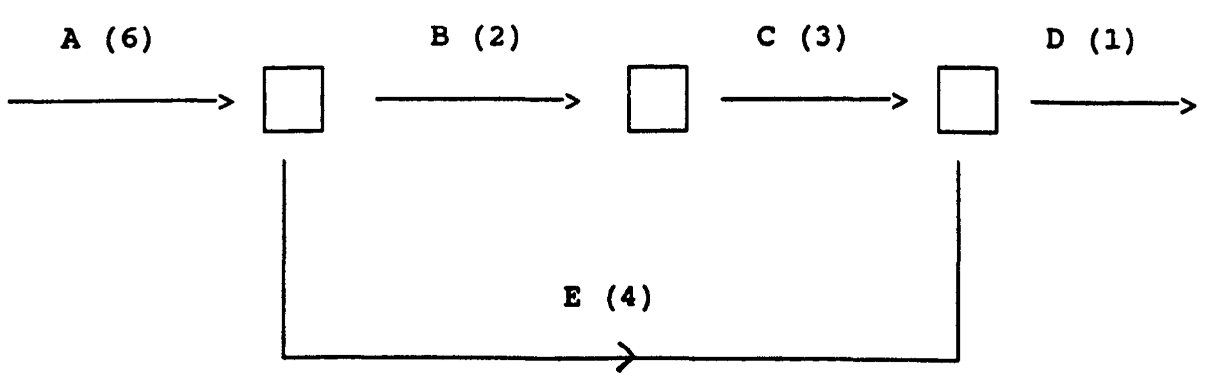
4.2.1 Manufacturing - Product Level

The process of manufacturing a product can be represented by portraying it as a series of activities, which, together, form a network. This enables analysis to be carried out on the activities, which are critical to the time taken to manufacture a product. Delays to any critical activity will automatically result in a delay to the whole project, unless some subsequent activity can be shortened. This, however, is usually achieved at some cost in the way of additional resources, which have to be weighed against the opportunity cost, or penalty for late work.

In much of the literature reviewed earlier, one of the main reasons for automating was to reduce the lead time of the production process. This, in some companies, would increase the attractiveness and competitiveness of their product. The companies were questioned on whether they would place AMT on critical activities, and why. None of the companies had considered the problems in terms of a formal network analysis. However, each company expressed their opinions when questioned.

Figure 4.2

Example of a Simple Network Diagram



Letters : Activities
Figures : Time (hours)

This illustration is a simple example of a manual product, which goes through five work stations. The critical path is ABCD with a lead time of 12 hours. If the company becomes aware that they can purchase a series of robots that can merge activities B and C, taking 3 hours to complete both tasks, then the lead time for the product falls to 10 hours, which means that the installation reduces the production time by 16.7%.

This is assuming that the equipment works reliably and to schedule. But if the robots are new to your production process and employees, then you will almost certainly encounter some problems due to unfamiliarities. Therefore, for a given period of time, activities B and C would be kept available as a back up for use when problems arise.

This is commonly done for the period of implementation and is usually disbanded when the robotic equipment is working to specification. In some cases factory layout restrictions mean that even this is not possible, and that activity B/C has to replace both B and C during a plant shutdown period. This often means that the lost opportunity cost of a breakdown is even greater. However, most of the company's engineers say that most of the problems are corrected within the normal one year warranty.

In a minority of companies, activity E would have been automated first to allow the engineers to gain experience. The approach is not widespread because it is easier for production to justify investment on a critical activity than one which is on a non-critical activity.

In total, 78% of companies visited had automation on critical activities. Of these companies 6 had no alternative method of manufacturing the product or bypassing the automation. These six companies are therefore operating a higher risk strategy as they are dependent upon the automation operating with high availability from the outset. The actual situation is further complicated when one takes into account the length of time the automation is scheduled to operate each day, and the expected speed relative to the rest of the production line. Of these six companies one said that they would require to call in the suppliers if there was a malfunction, due to the lack of in-house expertise.

Some 33% of companies had their first AMT installation on a critical activity. Of these, two were using well proven technology from established suppliers, a further two had the ability to utilise alternative manufacturing channels. The remaining two were using unique automation, but had built up strong support teams to service and maintain the machine.

However, in one case the company had automated a non-critical sub-assembly part of its production, as well as its main assemblies, because of the value of the product and the saving it would make on manpower. To this company, the actual lead time was not a major order winning criterion.

Thus companies, where orders are won on fixed completion dates, tend to automate a critical activity. In those, companies where the lead time is less crucial, they are more selective in the activities chosen for automation.

The fact that no company could show a network diagram illustrates that the people, who are in the decision making process over automation, are rarely "consciously" thinking or taking into account network analysis.

A company wishing to adopt new technology for the first time might prefer to automate a non-critical activity. This will allow the company and its employees to learn about automation and reduce the probability of losing high value production time. Twelve companies took this approach, and eight have since progressed to installing automation onto critical activities.

The argument that companies should always begin with proven technology, (IMechE, 1985), has not been upheld in the companies surveyed, as seven have unique AMT equipment on critical activities, but, of these, five appear to have good in-house support services and personnel. The two that did not have such support continually faced problems long after the warranty expired.

4.2.2 Manufacturing - Business Level

Taking the business as a "whole", from the time the order is received to its delivery to the customer, will include all the activities from procurement, marketing, sales, design and manufacturing. It also includes all the information links, in addition to the physical links and transportation.

Network analysis at this level shows that automation need not necessarily relate to manufacturing alone, and could refer to design and information systems. It also highlights the need for a company, whose objective is to reduce lead time, to look at all aspects of their business and not simply manufacturing. So a CADCAM link, or computerised stores system, could be equally as worthwhile as AMT in satisfying a company's objectives.

This analysis is necessary if the company is going to adopt the "systems approach" described in section 2.3. Manufacturing is only one business activity and cost centre. This also highlights the need for the team investigating the "areas in need of change" to have a broad remit that covers the whole business system.

4.2.3 Layout of Manufacturing Facilities

Several companies have had difficulties in making space for their AMT. These particularly apply to the large FMS, which require set floor space usually with new foundations. This means companies, who have purchased many new machines and systems, have had to make major changes to the layout of their factories.

The implementation of new machines and the displacement of old ones gives the company the opportunity to change the factory layout. This is due to the fact that companies are very conscious of the physical material flow, and inventory control. Twelve companies have changed the layout of their manufacturing facilities as a result of AMT. These were mainly plants which had functional layouts. In contrast those companies with mass production lines or jobbing shops did not change for differing reasons. It is very difficult to change a production line, so the AMT has to be built into one, whilst a jobbing shop usually has specific designated areas for the machines to go.

The companies who are changing their factory layout are generally in batch production, where the average batch sizes have been in decline. They were generally moving towards a "Group Technology" layout structure.

In total ten companies had decreased their production areas over the last few years. Four had stayed the same, whilst the remaining six had increased their plant facilities. Those that had increased their floor space were all witnessing increases in production volumes, requiring factory extensions, or allocating a greater proportion of existing floor space to production. The four companies, who had retained the same production space, were all constrained by their existing factory sites. Meanwhile those companies who had reduced their production areas were mainly those companies, who had experienced declining sales, although two had merged factory sites so that increased volumes had also resulted within a smaller area.

4.3 Choosing the AMT Equipment Supplier

4.3.1 Selection of the AMT Equipment

The careful selection of AMT is a vital component to the success of the overall project. The smoothness of the implementation is greatly influenced by the relationship that exists between the company and the equipment supplier, agent (or integrator). It is rare that one supplier is able to supply all the equipment, so it is important to be in a position to manage the implementation, and the various suppliers at the same time. Quite often the major supplier will take on the responsibility of managing the technical equipment from all the supplying companies.

The concept of having to work with a number of different equipment suppliers to produce a single system is often new. Multiple suppliers naturally add to the complexity of the process and is the main reason why companies would like the responsibility for all the equipment to be put onto a single representative. Due to the sophistication of some AMT, companies like the equipment supplier to be responsible up to the stage of commissioning. This is known as a "Turnkey" installation and is especially favoured by those companies, who do not have in-house resources and expertise.

Major differences do occur in the other aspects of the implementation process, such as the level of modifications required, the reliability of the equipment, training and involvement of the companies engineers in the process.

Few companies manufacture identical products, which often leads to greater demands on equipment suppliers to make modifications to their basic AMT models. These additional variables make the manufacturing systems more complex than what they were originally designed for.

Those companies, who do make these adaptations, may also limit the reliability of the equipment. This is particularly relevant to those companies, who lack the detailed in-house expertise to maintain and service the equipment. Ten of the companies made major modifications to the supplier's basic equipment. However, many underestimate the difficulties involved in modifying equipment, even from the well established suppliers.

Most of the equipment suppliers offer various forms of training to companies for operators and engineers, either at the supplier's base, or on the company's premises. The courses vary in length from one day to a couple of weeks. All the companies take advantage of these courses. However, the number of representatives who attend is unclear. Sometimes all those affected will attend whilst in some cases, to cut costs, a sole representative will attend, who is then expected to train the remaining employees. This approach is surprising when one considers that the training cost is usually only a small proportion of the overall project cost, and the importance of ensuring that the equipment operates optimally for long periods of time.

The equipment suppliers usually train to a basic operating standard, and include simple maintenance. This may be a strategic policy aimed at obtaining lucrative service contracts, and additional specialist training courses. If the company wishes to train their employees to understand the technology more fully then they will need to attend educational establishments. Two companies had direct links with local Polytechnics to train their engineers in return for sponsorship.

The equipment suppliers favour the "turnkey" approach and minimum intervention from the company, once the equipment specification and contract have been agreed. However, it is in the company's interest to involve their technical staff at an early stage so that they can familiarise themselves with the equipment. It is difficult to judge the level of in-house expertise within the company and the precise nature of supplier to user collaboration and relationship.

Formulating and negotiating the equipment specification is a key part of the planning and implementation process. It is paramount that the company knows precisely what it wants from the AMT. Many companies admit that their initial project specifications were not realised until many months after commissioning. This would suggest that there is a definite learning curve period for the company's project leader and why it may be better if established procedures were derived.

4.3.2 Equipment Specification

When a company has identified an area in need of change, in which AMT is a potential solution, it is then able to draw a formal equipment specification. The depth of detail required in a specification depends upon the complexity of the operation to be automated and the size of the investment. In addition, if the AMT is a unique application, which is special to the company, then a more detailed specification will be required. Specifications are rarely required for the purchase of common stand-alone AMT. However, if any modifications or adaptations are needed, then a specification is advisable.

When the supplier(s) have been selected a legally binding contract will be signed. Therefore, it is important to ensure that as much attention is paid to detail as possible. During the research only one equipment specification was seen although one contact claimed they were usually ten pages in length.

4.3.3 Choice of Supplier

The companies, who were new to AMT, tended to contact all the potential suppliers and naturally became overwhelmed by the mass of technical and sales information. Those companies, who had previously implemented several AMT systems, had organised procedures for future investments. One successful company was required to appraise three different suppliers for each potential investment.

The process of choosing a supplier should take place simultaneously with deriving the specification. This enables the company to match the company's specification with the supplier's equipment. Once a supplier (or a group of suppliers) has been chosen they can then modify the specification, and draw a mutually agreed contract. The suppliers are naturally more willing to spend their time and resources in constructing and formulating the specification, when they know there is a good chance of obtaining a contract. The contract will also specify performance measures for the supplier on delivery, budget and commissioning to a predetermined level of reliability and production.

The company has strategic decisions to make on the reputation of the supplier and the premium they will pay for this, and the after sales service. Like the purchase of any new product one has to be aware of all the hidden costs such as employees time, production lost during implementation and any additional safety requirements.

The suppliers complain that too many companies require financial targets to be met, in preference to operational ones. If the company had sufficiently detailed and well thought out manufacturing strategies, then the operational performances would automatically lead to financial targets. This emphasises the strongly held belief by the suppliers that the company accountants have too much control, and that companies take each new investment in isolation, and not as part of an overall strategy.

It is during the implementation stage that suppliers recommend that, where appropriate, the company may need to change some of its employees' job descriptions. The retraining of existing employees is always preferable as they retain knowledge of the business. This emphasises the importance of a good relationship with the equipment suppliers, who experience and observe a broad range of company operations and management techniques.

4.3.4 Case Study - Program For CAD Implementation

For some production applications the choice of supplier and system may be restricted. However, in the case of the more mature technologies such as CAD/CAE and CNC machine tools, the choice is large. Company 17 became aware of the benefits of adopting CAD in the design and engineering departments throughout its UK plants, (details of which are given in section 6.1). In June 1984, the company established a "CAD Selection Group" to :

i. identify the requirement of each site,
ii. evaluate the available systems,
iii. select the most appropriate system,
iv. prepare timetable for the systems installation,
   - review working practices,
   - review each sites standards,
   - select and prepare data for CAD,
   - physical alterations to design room,
   - training programme,

v. monitor the systems operation,
vi. set out the timetable for the implementation of the system. (The programme is shown in Appendix XI).

The group identified the requirements for the design and engineering departments, taking particular note of system compatibility and communication. It was acknowledged that the system could be developed to include production requirements, but these were not of immediate concern. This resulted in a 17 page CAD system specification, which was to form the basis of the evaluation procedure for the selection of the most suitable CAD system.

In total, 137 CAD suppliers were found and contacted. The list was reduced to 10 because :

3 did not reply,
4 could not offer a system,
33 only had single user systems,
54 could only offer a 2D capability,
11 had no mechanical engineering software,
10 had no data or database management system,
9 had no combined surface and modelling facilities,
3 were rejected as being hardware suppliers, who did not offer complete integrated systems.

The group then derived 23 criteria, which were given a weighting factor from 1 to 5. Potential suppliers were evaluated in detail by attending demonstrations, visiting the sites, and studying the technical literature. Marks were awarded for each category on a scale of 0 to 3. These were multiplied by the weighting factor to give each supplier a score. Four systems were short listed from the original ten, to undertake a "benchmark" test, from which a supplier was chosen. The final contract was agreed in June 1985. Appendix XI shows how this process, (items ii. and iii. above), had taken one full year, and twice as long as originally intended.

The company and the supplier agreed the timing of the installation, and an "Acceptance Test Schedule", to ensure that the CAD system was technically sound. During the installation period new working practices, shift working and training programmes were being initiated. The company was undergoing a period of rationalisation, with new management, who were insisting on the adoption of new procedures for all their future capital investments.

4.4 Justification of AMT Investments

The job of submitting an investment appraisal is the responsibility of the project manager, who follows company guidelines, which are usually laid down by the finance departments. They stipulate the investment appraisal technique to be used and the procedures that have to be followed. They also outline the criteria that can be used to assess future cash flows and benefits. Any supporting information and assessment of intangible benefits have to be given separately.

Often the financial constraints and criteria for investment appraisals have been imposed by an external source, like the holding company. It is usual for only those criteria, which can be quantified in financial monetary terms, to be involved in investment appraisals. The key criterion, common in all projects, is the reduction in labour. This is because it is easy to calculate the direct cost savings made from a reduction in manpower.

4.4.1 Criteria for Investment Appraisal

The problems relating to entrenched company accounting systems, and the inaccurate picture they portray, are discussed in section 7.2. Similar attitudes and accounting conventions have been imposed on the methods for investment appraisal. However, since it is an internal management accounting function, there is much more flexibility.

Ayres and Miller, (1983), and Engelberger, (1980), both highlight the limited and restricted approach companies take to the justification of AMT projects. It is because the current methods of appraisal do not embrace all the benefits of AMT that many potentially feasible projects are rejected. Primrose and Leonard, (1984), and a series of other papers, review the difficulties in appraising AMT, and suggest an approach to avoid many of the traditional problems.

It is claimed that, in the following cases, financial evaluations are not necessary.

1. Where safety is of paramount importance.
2. When there is no alternative solution.
3. When no economic justification is needed.

4.4.2 The Costs of AMT

The costs associated with AMT are mostly direct, and easily accounted for as they need to be purchased, as given in the list below. In several instances, the actual cost of the physical equipment may be less than half the final cost.

1. AMT equipment.
2. System Design.
3. Tooling.
4. Component Conveyors and Orientation equipment.
5. Controls and Interfacing.
6. Guard rails and Safety devices.

However, there may be many indirect costs associated with the implementation of AMT. For instance :

7. Site Preparation and Equipment Relocation.
8. Installation Programming.
9. Personnel Training.
10. Production Loss during start up.
11. Redundancy or Retraining costs.
12. Maintenance and Insurance.
13. Energy (eg Electricity).
14. Consumables (eg Hydraulic Fluid).

4.4.3 Tangible and Intangible Benefits

There are three types of benefit to a company that adopts AMT, "tangible", "intangible" and "strategic". With few exceptions AMT is implemented on the basis of computing the tangible benefits, such as reduced labour, capital tied to work in progress and increased sales.

The case study described below gives the direct benefits adopted by the surveyed company, who had the most comprehensive investment appraisal. The first appraisal was to compare the robotic and manual options for the packaging of a new product.

Table 4.4(1) Investment Appraisal for a Robot

	Robots (£000's)	Manual (£000's)	
Cost of Equipment	47.0	0.0	
Cost of Accessories	25.6	30.0	
TOTAL	72.6	30.0	
10% Contingency *	7.2	3.0	
Government Grant +	29.6	0.0	
	50.3	33.0	-17.3
Annual Benefits:			
Material Saving	103.0	103.0	
Additional Labour	0.0	21.3	
TOTAL	103.0	81.7	21.3

* Company Policy to have a 10% contingency on all costs
+ See section 7.4 for Government Assistance
Project payback 9.7 months and a DCF of 62%.

The second appraisal was for an automatic assembly cell of four robots. The project took six months to plan, and was installed during 1984, and resulted in 13 people being redeployed.

The larger companies, and in particular the car manufacturers, usually introduce automation when they build a new model. This is because a new production line is required in which little of the original equipment is reused. Therefore, the engineers calculate the cost of manual production and then, stage by stage, calculate an automatic option, electing the cheapest one. However, the dominant cost saving factor is labour.

Table 4.4(2)

Investment Appraisal for a Four Robot Cell

		(£000's)	
Investment Costs :	4 Robots	96	
	Ancillary Equipment	42	
		138	
	10% Contingency	13	
	Total Costs		151.0
Cost Savings (Annual) :	Direct Labour	64.3	
	Indirect Labour	10.0	
	Space	7.5	
	Inventory	5.0	
	Total Savings		86.8

This results in a 4 year DCF of 35.2% and a 7 year DCF of 46.8%.

In taking a systems view, it is important that the benefits accrue to the whole business. This is because it is no good if the benefits improve one department at the expense of any other. There are criteria known as intangible benefits, which are the unquantifiable attributes of AMT. These differ greatly in value from business to business and industry to industry. They also cover a broad spectrum of the business operations.

For instance, how does one quantify the ability of a company to become more responsive and flexible as a result of the technological adoption? In some cases, a company increases public perception and awareness of its capabilities by the introduction of new manufacturing technologies.

There are many benefits to a manufacturing company, which are intangible, and therefore cannot be calculated or quantified. This often leads to the abandonment of potentially successful projects. One further consequence is for the engineer or project manager to place greater emphasis on the direct, quantifiable savings which are acceptable to the accountants. The problem is that effort is concentrated on reducing the direct savings to the detriment of potentially greater intangible benefits.

The distinction between tangible and intangible benefits depends upon a company's ability to monitor, record and analyze the information. For instance, some companies keep account of all their work in progress at every stage of their manufacturing operations. Those with accurate records can use a reduction of WIP as a tangible benefit, whilst the remainder will have to estimate it as an intangible benefit.

The investment appraisal of the companies surveyed include a description of intangible benefits to support a marginal case. These include such phrases as greater flexibility, quality, safety and material utilization. Primrose and Leonard, (1984), believe that many of these so called intangible benefits could be quantified if they were redefined. For instance a "better quality product" could be redefined as :

i. reduced scrap,
ii. reduced rework,
iii. reduced disruption to production,
iv. reduced warranty payments,
v. reduced quality control costs,
vi. increased sales due to a better quality product.

The benefits that accrue from improving the social factors and working environment are usually policy decisions and have no financial benefit. However, the company could benefit financially through :

i. reduced insurance payments,
ii. increased production due to less absenteeism,
iii. reduced labour turnover.

The full list of quantifiable benefits, given by Primrose and Leonard, is given in Appendix X. They believe that all benefits can be redefined in terms of performance measures (expanded on in section 5.3), which can actually be quantified financially.

4.4.4 Investment Appraisal techniques

Three quarters of the companies assessed their investments on the basis of two year payback, which could be extended to three years on the strength of a good argument for the requirement and analysis of any tangible assets. Some of the companies specified additional IRR constraints of between 20% and 30%. One company allowed for payback times of between three and four years. Two companies would not reveal the techniques they used, whilst the other two were not solely constrained by the investment appraisal technique. On no occasion was the NPV figure used as a decision criterion.

Payback is the most commonly used technique by management, as it is conceptually the easiest to understand. However, since the method takes no account of the relative cash flows beyond the payback time it does not give a realistic measure of the value of the investment to the company. The method is particularly unsuitable for larger AMT investments, which often need up to a year before they become fully operational.

The internal rate of return technique does not take into account the time value of money for the expected life of the project. The percentage interest rate given equates to the present value of future returns to the investment outlay.

The net present value provides the most thorough technique for appraising investments. The method gives the present value of future returns discounted at the appropriate cost of capital, minus the cost of the investment. If the cost of capital equates to the opportunity cost, then Weston and Brigham, (1979), favour the NPV method to make budgeting decisions.

The 14 costs (see section 4.4.3) and 23 benefits (see Appendix X), together form the variables used in a 1200 line Pascal computer program known as "IVAN". The program was developed at UMIST to calculate the NPV for any AMT project. It is said that the complex array of data is unsuitable for a spreadsheet model.

The life cycle of AMT is uncertain, as much of the equipment is in its infancy. Warnecke, (1982), worked on the principle of a five year life span and NEDO, (1985), used a seven year time period. However, Primrose and Leonard, (1984), believe that, with additional development to increase the reliability of AMT, the working life will be longer. This information is necessary for the DCF analysis, which is judged to be the most accurate method of appraising investments.

The Advanced Manufacturing Systems Group (at NEDO) conducted research into 8 companies, who had invested in AMT before 1984. There is a great deal of information given but little analysis has been conducted on the trends or comparisons between the companies. Using the information given on the annual cumulative net cash flows, it has been possible to conduct an investment appraisal on the 8 projects labled A to H. The results are shown in Table 4.4(3). The initial capital investment is assumed to have been incurred in year 0, and the cumulative net cash flows from years 1 to 7. These figures were then discounted at a 10% rate, giving the NPV for an assumed 7 year life. In addition the IRR was calculated.

Table 4.4(3)

Investment Appraisal Analysis for the 8 NEDO Models

Model	A	B	C	D	E	F	G	H
Capital Investment (£M)	0.7	0.7	4.3	4.3	4.0	9.0	8.4	9.2
Net Present Value (£M)	0.2	0.1	-2.0	-1.4	-0.7	-1.0	0	3.2
Internal Rate of Return (%)	16	12	-2	2	6	8	11	16
Payback (years)	6	7	>8	>8	>8	>8	7	7

Taking the life of a machine to be 7 years, the NPV and IRR financial indicators are low. Only in two projects were the IRR greater than 14%, the current bank base rate (July 1989). Furthermore, four of the projects result in a negative NPV and the shortest payback period was 6 years. This highlights that investments into AMT are primarily for strategic and long term reasons.

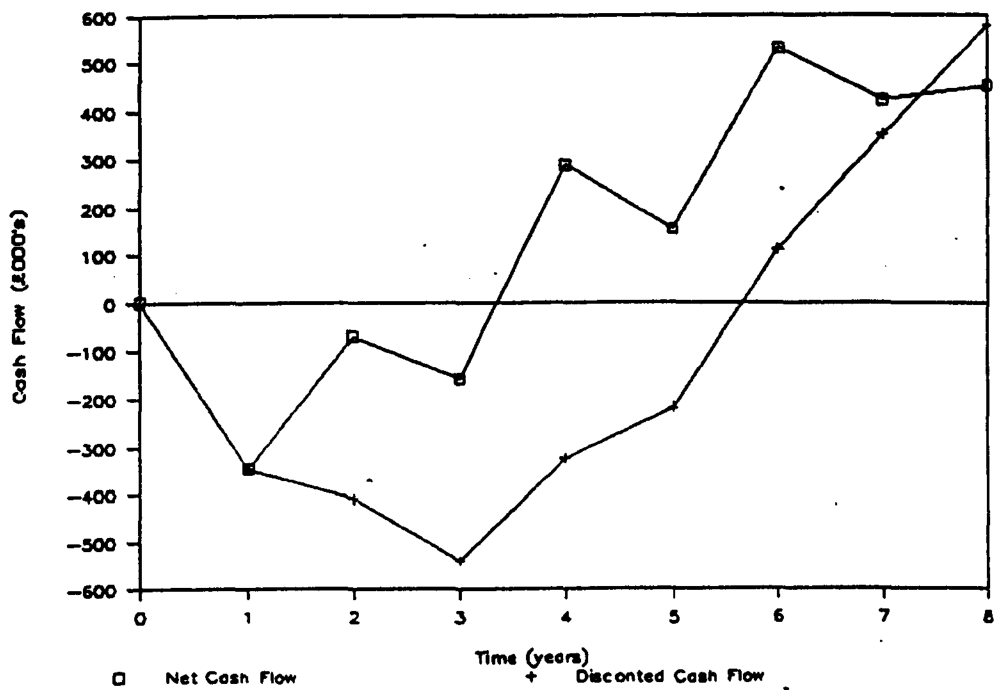
Considering that most company's criteria for accepting an investment appraisal is between 2-3 years, then none of the models in the study would have been implemented. The reason the systems were adopted was due to substantial government assistance through the DTI and regional grant aid schemes. These schemes, which are expanded on in section 7.4, effectively cut the initial investment cost in the early 1980's by up to one half.

Figure 4.4(1) shows the annual and cumulative cash flow data for model A, assuming that the capital investment was halved. It clearly shows how the actual annual cash flow figures improve steadily over the five years, before stabilising. The intersection of the zero cash flow line with the cumulative discounted cash flow indicates the payback period, which, in this case, is 5.75 years. It is not clear why the actual cash flow data appears to be rather erratic.

The profiles for all eight models are similar, and closely resemble the conceptual models given in Twiss, (1986). It must be noted that the expected life of the AMT is greater than seven years, therefore improving the long term value of the investment.

Figure 4.4

Investment Cash Flow Profile - NEDO Model A



Source : NEDO, (1985).

Having achieved a DCF value, it will be necessary to carry out sensitivity analysis on the key variables. This is to allow for risk and variations to forecasted variables. For example, the equipment may not perform as initially intended or projected sales may be inaccurate. When the investment appraisal has been subjected to potential changes to certain variables, then a range of DCF values will be attained.

It is this range of DCF values that have to be used by the management when deciding whether or not to accept the investment. In many companies visited, several appraisals may be submitted at once to the management, who then have to make strategic decisions in their selection process. It is therefore important that each project appraisal considers the same variables so the consistency makes the decision making easier.

The research has found that companies in the sample do not take into account intangible assets. If the basic form of investment appraisal does not roughly match the criteria, then the project is not accepted. The only exception to this is when the particular project is so prestigious to a high ranking individual that it becomes classed as a "do or die" investment.

It can be seen that the process of conducting an investment appraisal requires many strategic decisions to be taken. The company has to decide on the :

1. cost that can be considered,
2. benefits that can be considered,
3. working life of the equipment,
4. discount rate to be used,
5. method of investment appraisal to be used,
6. criteria for accepting or rejecting an appraisal.

Naturally, these will be different for each company, because of the differing impact the AMT will have on the manufacturing operations and the business. The different forms of finance available for funding projects is discussed in section 7.2. If an external source is being approached, then it is clearly important to conduct an accurate investment appraisal, which justifies the project financially and socially. Primrose, (1988), believes that there is little difficulty in raising finance as long as the appraisal is attractive.

> "The Merchant Banks and Venture Capital companies say there is no shortage of available capital. The real problem seems to be in the inability of engineers to convince their company's accountants that projects are sufficiently attractive to make it worthwhile raising the funds."

The recent development of visual active simulation packages allows for various technologies and shop floor layouts to be analyzed in detail. Information on production rates, queuing, and stocks can be attained, along with sensitivity analysis for a relatively small capital outlay. Simulation software begins at £10,000, but can be used repeatedly. This approach is advocated by Hollocks, (1985), and White, (1987). Simulation aids management decision making, and reduces the probability of purchasing a wrong system. The more sophisticated packages are easily adaptable and can compare many different scenarios. Only one of the companies sampled had used a simulation package to assist with the design of their production systems and AMT. One reason for this is that using simulation packages can be a time consuming process for personnel with limited experience.

Summary

Table 4.SUM

Tabulated Summary of Results from Survey of 20 Companies

Strategic and Tactical Activities Within the Sample Group	Responses No	%
Formulate a Development Plan	13	65
Update Development Plans Annually	6	30
Identify the key Performance Measure	10	50
Market Leaders in the Products Sold	7	35
On a Par with the Competitors	9	45
Behind Competitor Products	5	25
Market Leaders in the Technology Adopted	6	30
Invested to Increase Production	4	20
Maintained Constant Production Levels	10	50
Still had Reducing Sales	6	30
Install AMT "step by step"	16	80
Install AMT by production line	4	20
Placed AMT on Critical Activities	14/18	78
Had no Alternative Production Routes	6/14	43
First Installation on a Critical Activity	6/18	33
Decreased the Factory Floor Space	10	50
Increased the Factory Floor Space	6	30
No Change to the Production Area	4	20
Changed the Layout of Production Facilities	12	60
Heavy Engineering	4	20
Medium Engineering	6	30
Light Engineering	10	50
Trade Union Representation	16	80
Single Trade Union Companies	3	15
More than One Trade Union	13	65
Manufacture the Same Products	4	20
Change the models of the Basic Product	10	50
Completely changed the Original Product	6	30
Companies that rely on one customer for more than 50% of their Business.	6	30
Full Vertical Integration of Activities	5	20

The chapter has highlighted the key strategic and tactical decisions involved in the process of implementing AMT. The need for a development plan, which is part of a corporate strategy, and for a broad based project team, with a leader capable of effectively managing the implementation, is emphasised.

The research has shown that the implementation of AMT should not be treated as an isolated event. It is a process requiring detailed planning that involves prior understanding of the implications and communications with all affected parties.

Choosing the most appropriate equipment, and selecting the best combination of suppliers are crucial factors. Detailed consideration has also to be made on the equipment specification and contract. In addition, the necessity of the team leader to manage the system changes, required within the production process, cannot be overlooked.

The importance of having a reliable and accurate Management Information System for identifying the areas in need of change, and evaluating the criteria for the investment appraisal, is also shown. The inadequacies of existing appraisal methods and criteria are outlined, and the necessity of making a strategic assessment of the investment on the "whole" company is stressed.

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CHAPTER 5

IMPLICATIONS FOR THE MANUFACTURING RESOURCES AND OPERATIONS

Chapter 5

Implications for the Manufacturing Resources and Operations

5.0 Introduction

In developing a manufacturing strategy for the future it is necessary for the company to be aware of all the business activities. This chapter looks in detail at the resources of the manufacturing system, and how they are affected by, or influence the adoption of automation. The three resources being considered are those of materials, manpower and machinery.

The research primarily draws upon the knowledge and experience attained from the industrial visits, the "Design Questionnaire", and the NEDO report of 1985, to establish the implications of AMT on the manufacturing process. It is necessary for companies to be aware of the effect for the development and evolution of future strategies. In addition, consideration is given to some tactical aspects of adopting a manufacturing strategy.

Figure 5.0

Three Main Resource Components for Manufacturing Operations

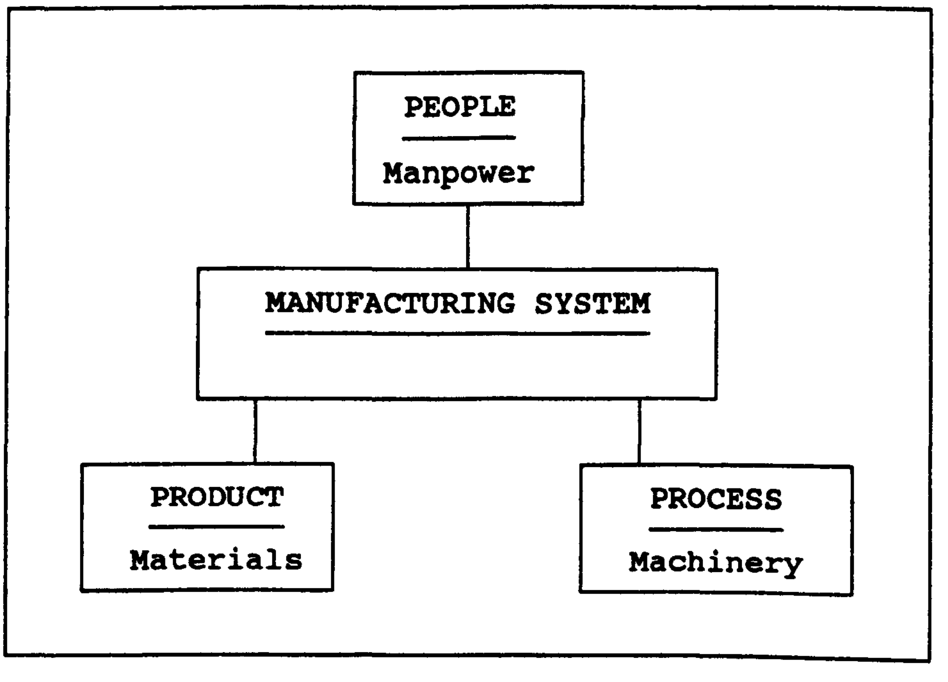


Figure 5.0 shows how there are four sections that are required to formulate a future manufacturing strategy. Consideration has to be made of the boundary of the business as well as the commercial environment as a whole. Within this context the strategy is evolved around the materials that make the product, the process technology that manufactures it and the people who operate the machinery. Collectively, they function as a system which requires measurable objectives, as described in section 2.3.

5.1 Implications of AMT on the Manufacture of Products

This section concentrates on the changes that have taken place over the past decade in the management of materials. It then assesses the role of AMT in influencing these changes. Particular attention is paid to the proportion of products manufactured in house, the quality of products manufactured, quality control, the inventory control systems and the cost structure of products.

5.1.1 Trends in Manufacturing

One of questions in the design questionnaire was targeted at design engineers to try and establish the impact of AMT on any one of eleven manufacturing activities. The questionnaire was designed so that those companies, who had automated, could easily be separated from those who had not. In addition, respondents had to note whether, over the past five years, the manufacturing activity had increased, not changed or decreased. The results are displayed in Table 5.1.

It was intended to conduct a chi-square test on each of the eleven parts, with the null hypothesis that AMT made no difference to the individual manufacturing activity. In every case the intended 3x2 contingency table had to be condensed to a 2x2, table due to just 60 responses, resulting in a number of cells having less than 5 entries. The tests were all carried out at the 5% significance level.

Only three of the activities resulted in a chi-square value greater than 3.84, the critical point beyond which the null hypothesis is rejected. Therefore, we can conclude that the design engineers believe AMT has significantly increased :

1. The number of product types manufactured.
2. The opportunities for creative design.
3. Communication with the production department.

With respect to the remaining parts, although there may be distinct features, one cannot differentiate between those companies who had automated and those who had not. Figure 5.1(1) illustrates the proportion of respondents who recorded increasing, no change or decreasing for each part.

Two thirds of the companies with AMT had increased the number of types of products they manufactured. This underlines one of the advantages of AMT, which is to reduce the set up times and allow for quick changes to be made for machine settings, and hence allow opportunities for additional production.

The respondents also suggested that AMT and CAD increased opportunities for creative design. This is because the new computerised systems allow for a greater number of trials to be made and immediate analysis on the outcomes of the results to be carried out. The reply profile was similar to that for the number of types of products manufactured. Since, in a different question, 70.8% believed that CAD was a pre-requisite for AMT (and that no respondents had AMT without CAD), it is clear that, in general, AMT and CAD allow for more variation in product ranges and greater opportunities for creative design.

The advent of AMT has increased the amount of communication between design and manufacture departments. With greater scope for efficiency gains as a result of direct linkages between CAD systems and AMT, it is not surprising that there has been increased communication. Those companies not having AMT (35% of the survey) are not taking advantage of the benefits.

In conjunction with the increase in the number of models manufactured, there is also an increase in the number of times a product model is redesigned or modified during its lifetime. This is probably a result of both AMT and changing consumer demand.

The number of components, per product, has been reduced slightly, as companies attempt to simplify their products and production processes. However, in some cases, products are becoming more technically sophisticated, and therefore require more components, which opposes the general trend.

To complement the downward trend in the number of components per product, the number of standard components per product has increased. The reason for this is a move towards single sourcing of components, and utilising new materials which are capable of replacing many old ones. Plastic moulding is an example of a manufacturing operation, which has simplified production, assembly, and in some cases the maintenance of the product.

In the drive to improve the quality of products and, at least, maintain market acceptability, companies, both with and without automation, are increasing the number of quality checks in their manufacturing process. Indeed no respondent indicated that new equipment resulted in a reduction to the number of quality checks.

Figure 5.1(1)

The Impact of AMT on Eleven Manufacturing Functions

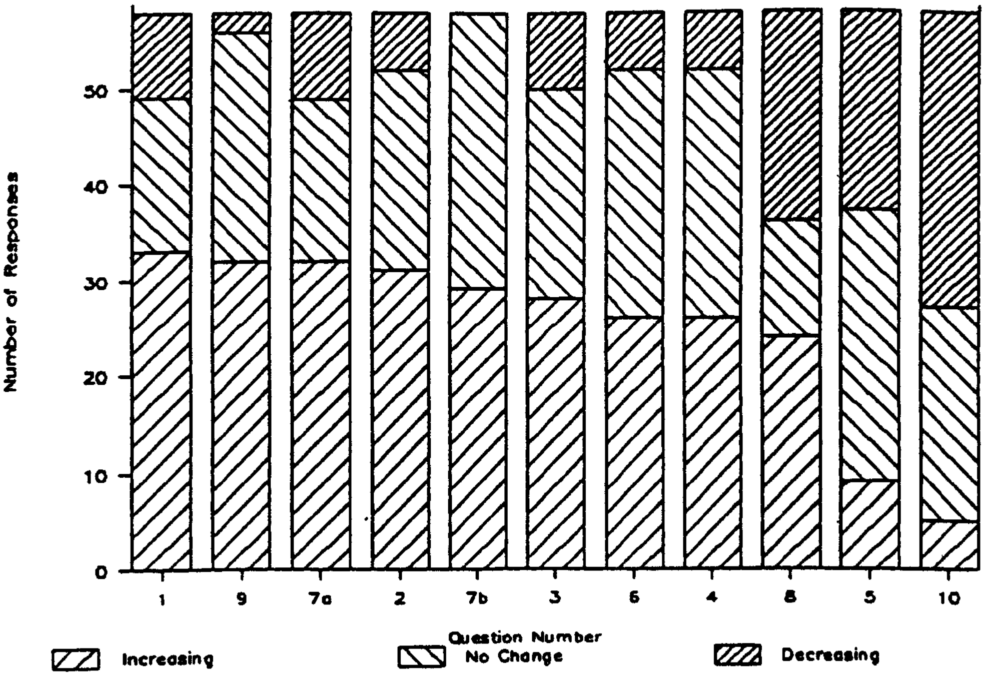


Table 5.1(1)

The Impact of AMT on Eleven Manufacturing Functions

Manufacturing Function	Mean	I	NC	D
1. Number of Models Manufactured	2.4	33	16	9
2. Opportunities for Creative Design	2.4	31	22	6
3. Communication with Production	2.5	28	22	8
4. Modifications in Product Lifetime	2.3	26	28	6
5. Components Per Product	1.8	9	28	21
6. Standard Components Per Product	2.3	26	26	6
7a. Manual Quality Checks	2.4	32	17	9
7b. Automatic Quality Checks	2.5	29	29	0
8. Number of Component Suppliers	2.0	24	12	22
9. Proportion of Products Bought In	2.5	32	25	2
10. Number of Manual Operations	1.6	5	22	31
I = Increase (3) NC = No Change (2) D =Decreasing (1)				

The question, which showed the lowest number of respondents electing for the no change option, (20.3%), was regarding the number of component suppliers. However, the 79.7%, who had witnessed a change, were equally split between increasing and decreasing. This probably indicates the conflict between the single sourcing of component supplies, and the increased technical sophistication of the products, which results in purchasing more components.

The previous points raised, concerning the increased technical sophistication of products, is emphasised by the increase in the proportion of components bought from suppliers. This trend may also illustrate how some companies are beginning to specialise and focus on the activities they do best.

Finally, there is a reduction in the number of manual operations carried out by companies. This could be an illustration of the combined effects of rationalising the manufacturing facilities, as well as the introduction of AMT.

5.1.2 Proportion of Product Manufactured "In House"

The development and growth of many large UK manufacturers led to strategies of "self sufficiency", in which the manufacturer built as large a proportion of their final product as possible. However, these non-essential manufacturing sub-systems became inefficient due to improper utilization. Furthermore, the specialist manufacturers were offering consistent components at a lower price, and were also becoming more reliable with their delivery schedules.

There has therefore been a trend for UK companies to specialise in their major function and focus on certain operations. This strategy takes advantage of the economies of scale and expertise offered by the component suppliers. However, there are certain operations which, despite being uneconomical, are classified as being critical to preserving the company's security and esteem. In some companies these operations will be carried out internally, even if it is non-profitable.

In many companies large investments in AMT provide the first opportunity for the company to assess the real costs of components and sub-assemblies. Often the reason is because the companies have not monitored the production operations in sufficient detail to assess the true cost of each operation.

It is accepted by many personnel within the manufacturing companies that the company did not appreciate the capabilities of AMT until some time after it had been installed. These companies are naturally learning, but have missed the opportunities that could have given them a competitive edge earlier.

The situation evolving is one where companies are placing more emphasis on special sub-assemblies from suppliers, which the manufacturer can use to broaden its product range. These are also more modular in design. The critical point, as far as Mather, (1987), believes, is that the diversification of product range takes place at the later stages in the production process. This research has observed that different levels of manufacturing process flexibility are being adopted at different stages of production. Dedicated machines are used in the initial stages and more flexible equipment in the later stages. Indeed some companies adopt temporary human labour to add to the flexibility, especially in the later stages of production.

One example of the change has been the introduction of electronic gadgets in a wide variety of products. Here, a traditional manufacturer cannot compete within his own existing business, and, at the same time, diversify into other areas such as electronics. This consequently leads to the purchase of modular sub-assemblies, and expertise from external suppliers.

5.1.3 Quality of Products Manufactured

One of the main reasons why companies are persuaded to purchase AMT is the greater accuracy and consistency, compared with manual labour techniques. This allows the product to be manufactured with lower tolerance levels, which ultimately improve the quality.

People have different perceptions of the term "Quality". Writers on the topic, such as Gavin, (1987), believe that quality is not an isolated concept, and that it requires "multi-functional teams" from marketing, engineering, purchasing and manufacturing, to look beyond purely statistical control on quality, by considering eight separate dimensions :

1. Performance : Primary operating characteristics of products.
2. Features : Characteristics that supplement the basic product.
3. Reliability : Probability of failure in a given time.
4. Conformance : Degree to which the operating characteristics match the product design standards.
5. Durability : Measure of the product's life before it deteriorates.
6. Serviceability: Speed, courtesy and ease of repair.
7. Aesthetics : How a product looks, feels, tastes or smells.
8. Perceived Quality : Inferences on image and brand name, rather than reality.

Quality is not just the designer's objective, but also the aim for every activity within the system, when providing the product required by the consumers. To this extent, providing "quality" adds to the product's cost. The implementation of new technology can have a considerable impact on the conformance, durability, reliability and performance of the product, as long as it has been adequately designed and engineered.

The process of involving all the business activities and functions involved in attaining a "quality" product is known as "Quality Assurance", (QA). Fido, (1988), outlines three objectives required for quality assurance.

1. Strategy for setting a company's standard of quality.
2. Specification of technical and human factors, which could affect the attainment of a desired product quality.
3. Control of working procedures, testing procedures, human responsibilities and data collection.

The objectives and activities call for the understanding and commitment of all personnel, from management to process worker, and from designer to sales staff. To contribute to an effective management system, the objectives must be documented, explained and accepted by all company personnel.

The subject of quality is high on the agenda of all the companies sampled. Strategies for tackling the production related problems revolve around the implementation of automation. However, the larger companies are appointing specific personnel to look into the whole aspect of quality. This usually results in a cross-departmental systems approach, with particular emphasis on Design, and its links with Marketing and Production.

Some forms of AMT, notably robots, will only accept and work on accurately dimensioned components. This acts as an effective "on-line" quality control inspector. Other automation also has the ability to test and measure its own work, to check that it is conforming to the specified standard. In addition this makes it is easier to adopt a quality management system and reduces the need for manual quality controllers.

The machines are capable of recording measurements and analyzing the results. These can be transferred directly into a computerised Management Information System, (MIS). This not only allows the management to control the system, but also gives a foundation on which the company may develop a quality systems standard (such as BS 5750) with its customers. It may also be used as a basis for attaining other technical and scientific standards relating to the products' dimensions, materials, safety and performance. This is increasingly important in the light of more strict European standards, and the common trade market in 1992.

Producing rejects, or adding value to non-conforming component supplies, is expensive. AMT can prevent this and reduce the amount of actual rejects and re-work required. The effect is to increase the productive time of the equipment, and of the manufacturing system as a whole. This also increases the opportunity costs of not implementing AMT.

Due to the subjective nature of "quality", the criterion is rarely included in any justification for an investment. However, the opportunity cost of not adopting AMT should be considered as a benefit in any analysis. This opportunity cost should allow for the reduced quantity of rework, rejects, and for the additional production. However, it is often ignored because of the uncertainty and inaccuracy of previous records, which do not allow for a true assessment of the real benefits to be made.

In addition to AMT improving the quality of machined parts, British companies, and especially those which are American owned, are introducing "Quality Circles" into their organisation. This is where a group of workers and supervisors, within each area of the organisation, meet to discuss ways of improving the quality of the product, and to monitor progress. It is a concept that originated in Japan, where it is closely matched to their culture. The problem with trying to implement such systems into the UK is that the employees and employers have had conflicting objectives, and it is alien for them to be seen to work together, in an attempt to solve common problems.

There are also quality issues associated with the AMT equipment itself. It is difficult to obtain information on the reliability and availability of the machinery, but the engineers and technicians interviewed claimed that the machines do not breakdown as often. Indeed a Japanese company, with a manufacturing base in the UK, only employs two maintenance engineers for their whole plant. Other companies, with large quantities of AMT, have said that often their maintenance engineers spend most of their time on routine facilities maintenance.

5.1.4 Inventory Control

There are various forms of inventory control systems, such as Materials Requirement Planning, (MRP), which, when taken to the "limit", result in inventory arriving "Just In Time", (JIT), for production. The initiators of JIT were Toyota of Japan around 1970. However, it did not become a popular concept in the UK until after 1980, when companies realised that holding large quantities of stock was expensive to the company and reduced their profit margins.

To many companies it was a surprise that a good inventory control system brought other benefits as well. For one example, each major machining centre had an optimal batch quantity, calculated by using the Economic Batch Quantity, (EBQ), formula (Bestwick and Lockyer, 1982). The implementation of stringent stock control forced companies to have just one EBQ for the manufacturing operations as a whole, which in turn eliminated the need for buffer stocks (except in the case of special, or critical components).

However, most of the companies surveyed agreed that changing the old stock control system was not easy because the employees had to be taught a new philosophy. The approach, which required additional training and education, was only forthcoming when there was large investment elsewhere in the company. For instance, resources would only be made available for stock control if they were part of a package. Whilst in Japan JIT always precedes any AMT, in the UK the changes take place in parallel.

"Kanban" Inventory System

The aim of the Japanese "Kanban" (Japanese word for a bin) system is to ensure that there is a smooth flow of materials through production. The system provides repetitive product manufacturing plants with an uninterrupted flow, in which the lead times are balanced with the processing times. The system operated by Toyota is an example of a "Pull" system and is summarised below and illustrated diagrammatically in figure 5.1(2).

1. There are two cards, a MOVE card, and a PRODUCTION card.

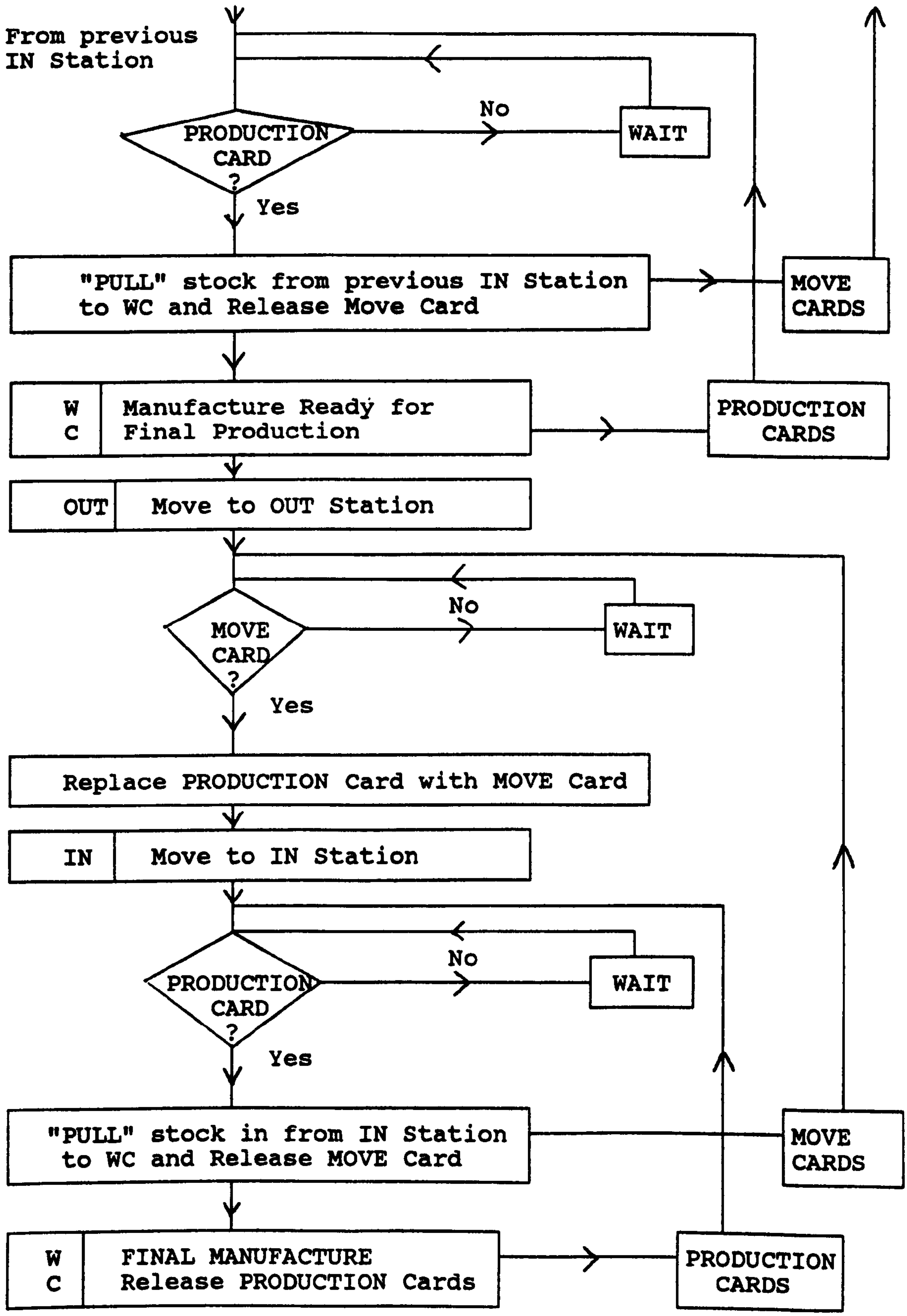
2. Each card defines the :
   (a) Work Centre,
   (b) Inbound Stock Point, and
   (c) Outbound Stock Point.

3. The work centre uses components from its inbound stock point. These will have a MOVE card attached to them.

4. When the "Kanban" is required by the work centre for manufacture the MOVE card is detached and returned to the outbound stock point of the previous work centre.

5. The MOVE card then replaces a PRODUCTION card in the outbound stock point of the previous work centre. This then allows a "Kanban" to be transported to the inbound stock point.

Figure 5.1(2)
Flow Diagram of the "Kanban" Inventory Control System



WC = Work Centre IN = IN Station OUT = OUT Station

6. The PRODUCTION card is returned to the work centre, where it permits another "Kanban" to be filled. When sufficient products have been manufactured to fill a "Kanban" production stops.

7. The "Kanban" is then given the PRODUCTION card and is moved to the outbound stock point.

The batch size of the system is equivalent to one "Kanban". The system is initiated at the inbound stock point of the final assembly work centre, when MOVE cards would be sent to the appropriate outbound stock points of the previous work centres to "PULL" the material.

The quantity of stock held is controlled by the quantity of cards in circulation, and therefore the system can be controlled and introduced over a period of time. The system will only work if it has the full cooperation of the workforce and if there is a fixed repetitive sequence of events. More detailed explanations of the "Kanban" system can be found in Lee and Schwendiman, (1982).

It is said, by Nakane, (1982), that the oil crises at the beginning of the 1970's were the real catalyst for greater productivity through stock control. This was especially the case in Japan and West Germany, who do not have any known oil reserves. Once the "Kanban" system had been implemented companies would identify production bottlenecks more easily, to which one possible solution may be to automate.

5.1.5 Cost Structure of Products

The economic recession in the UK at the beginning of the 1980's combined with tight monetary policy creating high interest, foreign exchange, and inflation rates meant that companies could not maintain high profit margins without cutting unit costs. The result in many labour intensive companies was to reduce manpower to a minimum, and decommission old surplus machine tools. This, in many cases, had the short term effect of reducing unit costs, by decreasing overheads and increasing productivity. However on a national scale this created mass unemployment which officially rose to over 3.4M in 1986, (see figure 2.4(2)).

The consequence of this action was to reduce the proportion of a product's cost attributable to direct labour. Those companies, who have adopted AMT to a large extent, have further diminished the proportion of direct labour. The capital depreciation is calculated as an overhead expense, along with the increase costs associated with additional support services, such as computers and specialist engineers. One engineering company in the Midlands claimed that the costs attributable to direct labour, overheads, and materials had changed from 50%, 15%, and 35% in 1980, to 20%, 20%, and 60% respectively in 1987. In five of the companies surveyed the material content of the product cost was in excess of 80%.

The NEDO, (1985), report gave detailed quantitative information on the materials, labour, and overhead costs from the companies profit and loss statements. The data obtained from the NEDO research has been tabulated in Appendix XII. The result of the analysis is shown in table 5.1(2).

The NEDO data primarily came from the appropriate company accounts and, as a result, will reflect company wide strategies, and not just those directly related to AMT. The mean figures are displayed in column B of table 5.1(2), and illustrated in Figure 5.1(3). It is clear that significant savings are made to all the cost components, with the largest being direct labour. The pie chart showing the mean proportion of a product's cost attributable to each cost component, after the adoption of AMT, illustrates how materials have become the major cost, (see figure 5.1(4)).

The remarkable feature of the information is that the magnitude of the improvements are very similar for all eight models (see Appendix XII). It is clearly shown that the largest improvement is in the direct and indirect labour savings. In contrast, the material saving of less scrap and greater utilization only accounted for between 5 and 8 percent. The results from the eight models shows that the mean cost saving was around 20%, which resulted in large increases to both operating and retained profits.

Table 5.1(2)

Cost Structure of Products - Summary of NEDO Data

A : Savings attributable to each cost component.

B : Proportion of the total savings made by each cost component.

C : The proportion of the total product cost made by each cost component before automating.

D : The proportion of each cost component after the adoption of automation and production systems.
Figures given in percentages.

Cost Component	Mean A	Mean B	Mean C	Mean D
Materials	14.2	6.0	39.0	46.1
Direct Labour	56.6	23.1	13.4	8.1
Indirect Labour	46.9	18.1	9.9	7.2
Staff Labour	35.9	14.1	8.4	7.5
Fixed Expenses	23.4	9.7	1.8	1.9
Variable Expenses	33.1	13.6	9.2	8.4
General and Admin Staff	28.3	11.6	9.0	8.9
General and Admin Expenses	8.9	3.8	9.3	11.7
		100	100	100

Figure 5.1(3)

Mean Savings Made by each Cost Component as a result of Adopting AMT

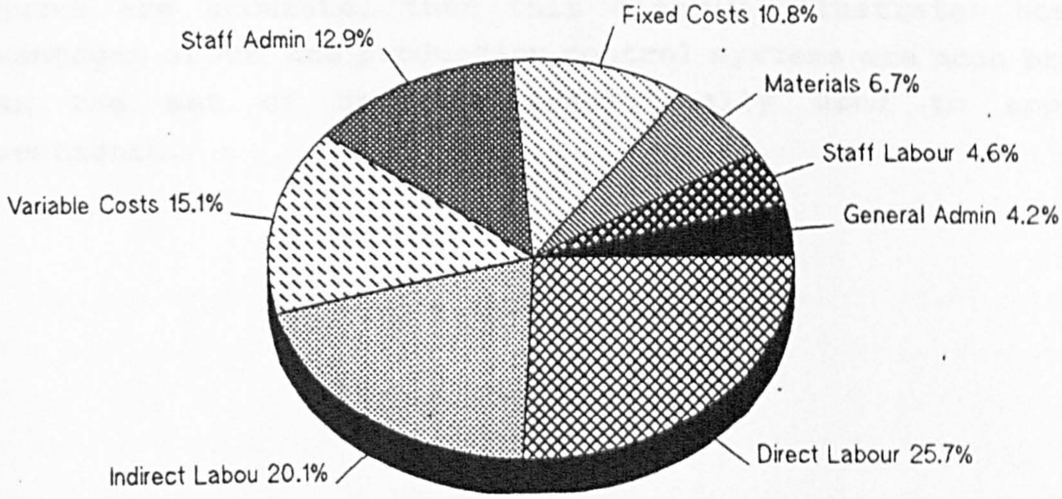
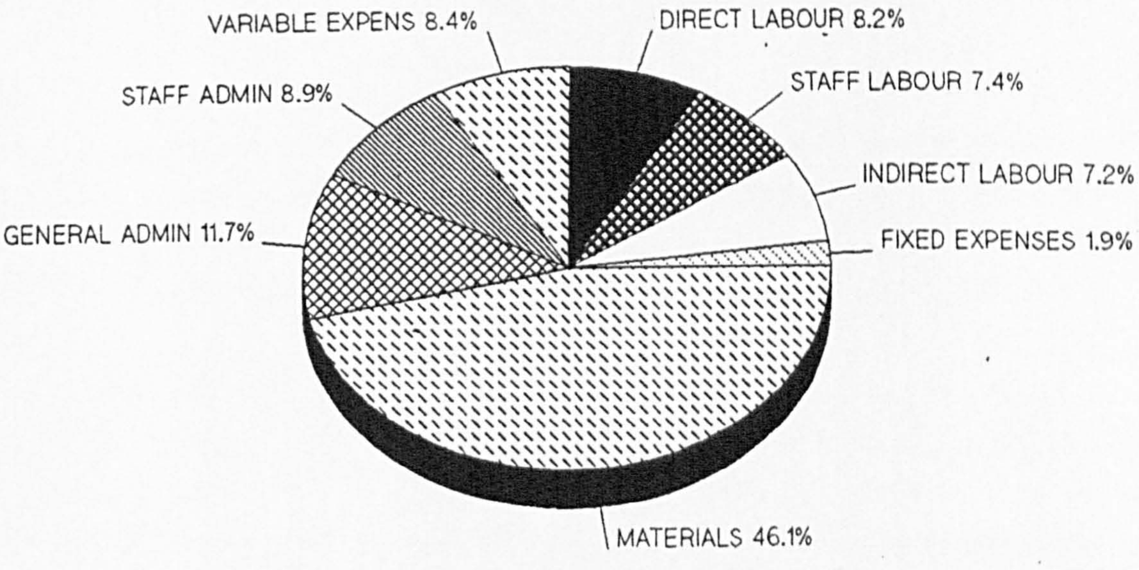


Figure 5.1(4)

Mean Product Cost Structure After the Adoption of AMT



The report was produced to show the implications of adopting AMT. Indeed the balance sheet data is most encouraging. However the investment appraisal measures, analyzed in section 4.4, are poor by comparison. Assuming the figures are accurate, then this clearly illustrates how the advantages of AMT and production control systems are much broader than the set of criteria traditionally used to appraise investments.

5.2 Management of Human Resources

When AMT is introduced into a factory the management cannot automatically expect the employees to operate the equipment straight away. First, the company has to agree with the employees (or through their trade union representative), to accept the new AMT or system. Then the operators have to be trained, and maintenance engineers updated on the technology prior to operation.

Under a well structured project plan, these factors should have been agreed and acted upon before installation. One company visited had installed equipment, which lay dormant for nearly a year before an agreement was reached with the trade union. Some companies take a piecemeal approach, in which settlements are reached for individual AMT implementation. However, many companies have tried to arrange more general and widespread agreements covering whole company operations. These are usually known as "New Technology" or "Flexibility" agreements.

The drive for these agreements has been four fold and it is difficult to distinguish between them, namely :

1. The introduction of new technology.
2. The commercial pressures for increased productivity.
3. The influence of overseas competitors and their working systems.
4. Imposition of greater control over employees.

The involvement and attention of people is critical to the success of any system and cannot be disregarded. To a business, people, like machines and materials, are resources, and have to be fully utilised in an effective and efficient manner. The success of business depends upon the optimum utilization of its resources. However, the human resource has to be treated differently from machines and materials, because people have attributes such as "feeling" and "intelligence", and have therefore to be treated accordingly.

5.2.1 Labour Flexibility - Case Study

The case study discussed concerns an agreement titled "The Future of Employment", signed 3 April 1986, by company management and trade union officials. The company involved had several trade unions and manufactured heavy engineering products. Its main product base was declining and so the company was looking to diversify, in the hope of attracting larger quantities of business. Indeed, by 1988, the core business only accounted for around 50% of the total turnover.

To attract this additional business (and maintain employment) the company believed it had to increase productivity and illustrate that it had a good progressive working relationship. It was also recognised that their main competitors were trying to enforce similar agreements, but, as far as the company was involved, "The Future for Employment" flexibility agreement was the most comprehensive.

Aims and Objectives

The company had four intentions that it hoped the agreement would cover.

"i. to ensure the continuation of a high productivity, low cost, manufacturing, engineering and contracting facility at the factory, capable of meeting the demands of the market place in the UK and overseas.

ii. to provide opportunity for discussion and consultation, and understanding of the changes required, by employees.

iii. to equip the company and its employees with the skills, tools, methods and attitudes needed to make the company competitive, and to secure employment.

iv. to engender an understanding that future employment with the company can only be possible if based on an employment environment free from wasteful practices (which increase cost and reduce productivity), and containing firm agreements on flexibility, interchangeability, mobility and deployment of personnel. The company therefore seeks to create an environment where employees are willing to undertake alternative tasks required subject only to their level of skill, expertise, or safety requirements. This represents a significant change in the working life of all personnel working for the company, and is essential if our future prosperity is to be secured."

The trade unions welcomed the agreement and accepted most of the rationale behind it. However, their chief concerns were:

1. maintaining present employment levels.
2. ensuring their members were rewarded financially for any additional skills they attained or responsibilities held.
3. maintaining or improving safety standards.

Functional Flexibility

The following group of five statements of intent describe the functional flexibility required by the company. It illustrates both the intended changes to working practices and the methods that operated prior to the agreement. The key issues were the abolition of trade demarcation barriers, cross trade flexibility, and multi skilled employees.

"1. Management and unions accept the obligation to ensure that the company operates with the most effective methods, the best utilisation of manpower, the highest possible levels of job satisfaction and free from the introduction, or continuation of management or union based wasteful practices.

2. In order to utilise manpower resources fully, all employees will perform alternative work within their skills and capability and to achieve this, individuals will accept any necessary training, and be prepared to move from task to task, or job to job, as the needs of the operation require.

3. In directing the allocation and method of work (that is who does what, how and when) the accepted overriding need is to find the most efficient route, without restrictions, based on precedent or previous practices.

4. Historical demarcations, including barriers existing between various trades, and staff employment categories will be removed.

5. When workload, efficiency considerations, advances in technology, or changes in organisation systems or procedures require the acquisition of new skills, new working practices or the assignment of individuals to different work areas, the only limitations will be : (i) the skill that people have or can acquire, and (ii) the requirements of safety."

The purpose of removing so-called restrictive working practices was because the company's business was unevenly distributed throughout the manufacturing departments. The situation, where some workshops would be overworked (and incurring large overtime costs), whilst others were without work, occurred frequently.

New Technology

The introduction of new CAE and CNC machines was also a major reason why the employees were keen to have the agreement. Trade unions, in general, welcome the introduction of new technologies as a sign of confidence, and investment for the future. The dilemma for the trade unions is to agree on how their members should benefit from the introduction of new technology, individually or collectively. National leaders believe that the problem should be tackled on a local basis at the company.

In principle, the trade unions do not agree that a few members should benefit financially on something that is not available to all. The solutions, for some companies, are to have a bonus scheme whereby everyone benefits, or to introduce a different job grading structure. The abstract below outlines the agreement on new technology and the payment to the operators.

> "Employees will cooperate fully in the introduction of changes in technology, equipment, systems, procedures, etc. in an endeavour to maintain competitiveness and efficiency, without additional specific payment. It is accepted by management and unions that improvements in earnings can only be generated from profitable, cash efficient activity; that investment in new technology etc. is essential to retain competitiveness, and is in the long term best interests of the company and its employees."

Financial Flexibility

The company saw no reason why it should change the job titles or grading structure. It also accepted that each employee could retain his main trade craft name, to ensure that there was a core of tradesmen, who had advanced training in a principal craft. The agreement also outlined that there would be just four grades, with payment relevant to their primary level of skill and expertise. If an employee (usually when a trade barrier was crossed) worked in an equal or lower grade, then he would receive the same pay. However if a trained employee carried out a higher grade of work for over one week then he would receive additional payment.

Numerical Flexibility

The agreement also stated that, at times of high demand, the unions would not object to the employment of temporary workers or to any work being sub-contracted. If the temporary staff were employed for more than three months, the company would consider making them permanent workers. This gave the company both numerical and financial flexibility over its employees.

Employee Responsibilities

In the light of a changing commercial environment, in which product quality was increasingly important, it was necessary to ensure that the employees were responsible for the quality of their own work. Furthermore, to ensure that the company utilised its resources more effectively and implemented new control systems, the employees would have to cooperate with new work booking and job recording procedures.

Time Management

"In line with the general philosophy that all work should be completed on time, employees undertake to:

i. minimise waiting time and to accept personal responsibility for the speedy completion of all tasks assigned.

ii. be available for work for the full working hours at their place of work.

iii. management and supervision equally accept the responsibility to plan and control work effectively to reduce the impact of lost time.

Work booking and Job Recording

Employees will cooperate fully in the implementation and maintenance of sound work booking and job recording procedures. This will require the acceptance and use on the shop floor, and in offices, of measured or estimated target times and standards, against which work progress and performance will be assessed, to meet the needs of our customers.

Employees will be personally responsible for the accurate recording, and, where practical, the actual input of times spent on jobs where required.

Quality and Inspection

To increase job satisfaction and reduce costs, all employees will assume personal responsibility for the quality and inspection of work they produce. All employees are encouraged to develop pride in their craftsmanship and skills and will be required, where necessary, to sign off completed items of work as meeting the required standards. Inherent in this approach is the concept of "traceability" back to the original employee, or group of employees, which is an essential requirement of eg. general engineering activity."

Joint Monitoring Committee

It was acknowledged that there would be problems and disagreements when implementing "The Future For Employment" agreement, especially in the beginning. For this reason a Joint Monitoring Committee, (JMC), was established, consisting of the Convenor from each of the trade unions, two management personnel, and a chairman. The management believed that it was important for specific objections to be heard, after the job transfer and not before, to limit the disruption to production. The agreement was not a "no strike" agreement but, it was accepted that industrial action would operate only as a measure of last resort, and would be an indication of failure of management and employees to arrive at a satisfactory solution. The terms of reference for the JMC are outlined below.

"i. Review the use of flexibility occurring over the previous week, and its effectiveness.

ii. Discuss and identify any problems arising and make recommendations to management for corrective action if required.

iii. Review the forward forecast of flexibility plans and highlight potential problem areas requiring management attention.

iv. Identify additional opportunities for flexibility to further increase productivity / efficiency and recommend accordingly to management."

"The Future of Employment" was a unique and special document for the company and its employees. It became a platform on which modifications could and have been made, and it has resulted in frequent dialogue and discussion between management and employees on the manufacturing operations.

The document was also unique in that it would not be directly applicable to other companies, although the skeleton outline described could be adopted. Similar agreements were being implemented in the traditional low volume, labour intensive heavy engineering sector, where trade unions have been well established, and where pay and working conditions are poor.

Those companies who had no trade unions, or single AEU representation did not have the restrictive working practices associated with multiple trade unions and often had more modern facilities. These companies were moving forward by providing :

1. manual and production workers the same benefits as those given to staff,
2. improved working environment and facilities, such as less noise, air conditioning and sanitation,
3. common canteen facilities,
4. greater flexibility in staff hours and "Annual Hours" for production workers especially in companies where product demand is seasonal.

5.2.2 Influences of AMT on Management and Employees

Many of the companies visited claimed that the advent of AMT had changed the working environment. By observation it is clear that companies have often improved the working conditions in the area where the AMT is to be installed.

Most AMT is well protected by guards which, when opened, will automatically stop the machine. This has made the machines much safer and in many cases reduced noise levels. For the larger FMS, new facilities have been built, in which the ambient conditions have improved as well as creating a better working environment.

To some workers (particularly the keen and young) the operation of AMT has been seen as progress and a challenge. This has increased the job satisfaction and motivation of the affected employees. In order for employees to maintain a high and consistent level of work over a long period of time, they have to be motivated, and interested, so that their concentration is kept on the job in hand. Companies are now more aware of the necessity of high employee morale, and try to introduce variety through work rotation schemes.

One aspect to coincide with AMT and lower direct labour costs is the reduction in the number of job grades, which used to be a source of much conflict. It is also said that the job descriptions have to be made more specific. This is to ensure that the job is done properly, first time, on time, and can easily be recorded. This is emphasised by AMT, as the opportunity cost due to poor work is high, making the employees more accountable for what they do.

The other major change is that, to justify large investments in AMT, companies have to operate the machines for more than one shift. All twenty companies visited had some part of their production operating more than one shift. This, in itself, can be difficult for personnel departments to manage, as many of the support services also need to be present.

5.2.3 Training and Education in the UK

It was difficult to obtain information about the training that takes place within a company, and how effective it has been. The problems of quantifying the effects of training within a company are given in a feasibility study for the EITB by Elder, (1987). Initially, there are different forms of training required for the different employees. Sometimes, this makes it difficult to distinguish between the job and the training. Since this is the case, it is also difficult to isolate the true cost of training, this being the direct training cost plus the opportunity cost from loss of productive time.

Elder found that some companies, with certain procedures, were unable to quantify their training costs. The majority did not, and could not justify devising a system to find out. This is not to say they did not have training strategies, but that they could not see the benefits of having detailed cost data. One common problem was that the benefits of training are intangible and often subjective. This makes it difficult to correlate the effectiveness of training investment.

It is claimed by the Oxford review of Economic Policy, (Autumn 1988), that public and private employees spend £14.4 Billion a year on training which is around 8% of the UK GDP. This is comparable with other European nations and North America. However, the Economist, (1988), argues that the money is spent by too few companies, and often on the wrong type of training. It is said that companies spend too much time and money on teaching school leavers the basic skills, which should have been covered by the schools.

Companies are keen to take advantage of the limited free training provided by AMT suppliers, but few medium or smaller sized companies will carry out their own. The larger companies will have their own "In-house" training centres, and, to justify the expense, will ensure that it is fully utilised. With the exception of these cases, companies see training as an expense without tangible rewards. Furthermore, employees who are trained, are themselves more marketable and, failing a financial reward, or sense of loyalty, will be lost to another company. Thus the training cost is then to the benefit of the potential competitor.

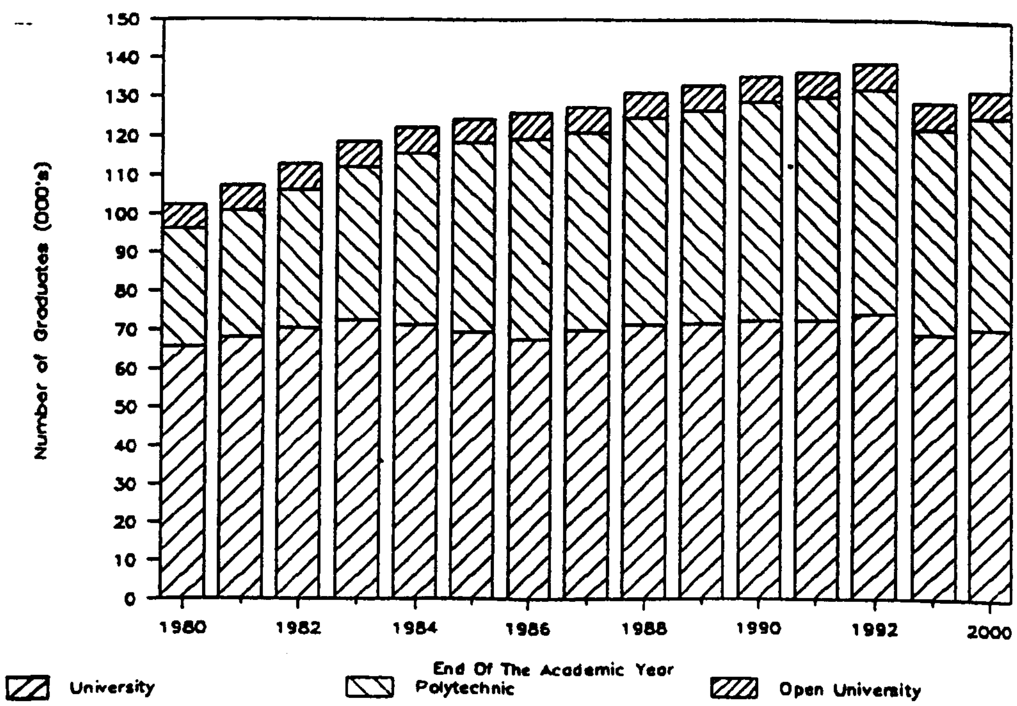
The changing of many working practices and environments are becoming increasingly common. These changes have coincided with easier communication and a greater flow of information. To maintain this trend, the education and training of management and employees has to be improved. Furthermore, with the demographic profile for the existing teenagers set to fall in the UK, this increases the pressure on companies to promote and train existing employees.

University Graduates and Degree Disciplines

The projections of future student numbers are taken from the document "Projections of Demand for Higher Education in Great Britain 1986 - 2000", published by the Department of Education and Science, (DES), (UGC, 1987) and (DES, 1988). These projections show that the numbers of initial entrants to higher education are expected to rise from 165,000 in 1985, to 172,000 in 1989. Thereafter, the numbers are forecast to fall to 154,000 in 1995, before rising again. This trend is shown in figure 5.2(1), with the detailed figures given in Appendix XIII.

Figure 5.2(1)

Actual and Projected Degree Graduates : By Higher Education Sector in Great Britain 1980 to 2000



The University Grants Committee, (UGC), claim that "Engineers" are in short supply. With the recent growth in manufacturing, the demand for Engineers of all types has increased, and is expected to increase by a further 20%, before the year 2000. However, the DES is not going to allow the increase in Engineering graduates to exceed 10%. The problem is compounded by data from the UGC, (1987), which shows that a third of engineering graduates take their first employment position in a different discipline, usually general management, or finance.

The report "Automation in Perspective", published by HMSO in 1956, predicted that their would be future skill shortages in the areas of Management, Science, and Technology. It also highlighted that their would be a change in the distribution of labour and greater unemployment. These predictions were correctly forecast, but successive governments have failed to tackle adequately the problems, as the lead times are often long.

5.2.4 The Japanese System

Since the early 1970's the growth of the Japanese nation to the position of the number one economic power is remarkable. The nation, decimated during the Second World War, has 120 million inhabitants on mountainous islands with few valuable minerals or land for excessive arable farming. So their reliance on imports of basic commodities, such as food and fuel, has to be balanced by the exports of manufactured goods.

Their culture and systems are not a panacea nor a complete role model for the rest of the world. Of the companies surveyed, none would admit to have copied Japanese methods or procedures. However, the continued drive to reduce inventory, build a working relationship with suppliers, introduce harmonising working environments is a reaction to the Japanese competition.

The Japanese characteristics of respect for superiors, loyalty, hard work, and collective responsibility is unlikely to be matched. Their trade unions seek to harmonise relationships between their members and the management. In return companies ensure life employment, and profit sharing.

On a national scale there is an emphasis on long term planning, and obtaining market share before early profits. They study their export markets very carefully. This is assisted by a government that provides an infrastructure and a favourable economic climate for growth. It openly discourages imports, and has a Ministry for International Trade and Industry, (MITI), with trained bureaucrats responsible for promoting and projecting Japanese Industry.

Lee and Schwendiman, (1982), describe all aspects of Japanese Industry systems, whilst Schonberger, (1982), concentrates on manufacturing operations. However, with company products and processes being much different, the human resource management is an area, where most lessons can be learnt. This is clearly described by Wickens, (1987), who became the Director of Personnel at the Nissan car manufacturing plant near Sunderland.

Wickens, (1987), claims that all workers must be treated alike with common terms and conditions. This is one stage to harmonising the workforce, and avoids creating the "Them and Us" syndrome that persists in some British Industries. Flexibility agreements, as outlined in section 5.2.1, alone can increase flexibility in traditional industries by 50%.

The quality of product and system has been a large factor in the success of Japanese companies, "Quality is a hard point on which there can be no compromise" (Wickens 1987). However, Gow, (1988), responds to the concept that every thing in Japan is good by saying :

> "The use of Quality Circles in Japan has been exaggerated and the failure rate ignored. Quality Circles are only introduced as a refinement, once total quality control has been achieved."

Many companies in the UK, and especially the foreign owned ones, are introducing their own quality control systems. The traditional British companies are lagging behind, but they will have to follow Japanese working practices to compete, as it is the philosophy that is important, and not the culture.

5.3 Process Choice and Positioning

The section looks extensively at the theoretical characteristics of manufacturing processes for the span of possibilities from jobbing shops to continuous production. These are then compared with the characteristics observed at ten of the companies surveyed, resulting in a profile analysis.

Discussion is then centered around some of the organisational changes being made on the positioning of the process machinery into a "Group Technology" layout, and into forming groups of people into "Quality Circles". Throughout the work, the inadequacies of company's performance measures are highlighted. These are investigated further in relation to manufacturing systems. The research then shows how the effective use of "Learning Curves" and "Product Life Cycles" can assist a company in its long term strategic decision making.

5.3.1 Manufacturing Process

The problem in many companies is that they have had a rigid departmental and organisational structure, in which the different functions of the business have been isolated from each other. This has created barriers for effective communication between different functions without incentive to break them down. Each function would have its instructions, budgets, procedures and measures of performance, and the less influence, or interaction from external bodies, the better it was supposed to be.

This led to the situation, in the larger companies, where the different functions may have different interests and objectives to pursue. One of the objectives of the present company investigations was to try and establish the degree to which the functions or departments communicate with each other. Direct measurement proved difficult due to the subjective nature of the topic.

It was possible, in half of the companies visited, to complete a comprehensive profile analysis for one particular point in time. The concept, is described in Hill, (1987), classifies the different characteristics of different manufacturing processes, from project to continuous, for various aspects of the company. Table 5.3(1) is a simplified version of that given by Hill, with only the two extreme characteristics recorded. The characteristics of the ten companies studied in greatest detail are given in Appendix XIV.

The detailed research carried out in 10 of the companies aimed to discover :

i. if the process technology of the company matched the theoretical characteristics of the process, and,
ii. how compatible the different aspects of the companies were.

<u>Products and Markets</u>

For a typical jobbing shop there is usually a special product, which has a large number of possible variants. The variants will be constantly changing and therefore require frequent product developments. In general the company will sell products where a competitive price is the first consideration of the market, taking priority over quality and design.

Naturally, the marketing system of the company has to be established so that it is able to identify the type of customers, and the methods it is going to adopt to sell the company's products or services. Companies, with batch production, should have characteristics in between the two extreme cases mentioned above.

Table 5.3(1) Business Implications of Process Choice

Manufacturing Aspects	Characteristics of Manufacturing Process Project	Batch	Line
Products and Markets			
Type of Product	Special		Standard
Product Range	Wide		Narrow
Customer Order Size	Small		Large
Level of Product Change	High		Low
Rate of New Products	High		Low
What does Company Sell	Capability		Products
Market Winning Criteria	Quality		Price
Order Winning Criteria	Price		Quality
Manufacturing			
Process Technology	General		Dedicated
Process Flexibility	High		Low
Production Volumes	Low		High
Dominant Utilisation	Labour		Plant
Key Manufacturing Task	Specification		Cost
Changes in Capacity	Incremental		Stepped
Infrastructure			
Organisational Control	Decentralised		Centralised
Organisational Style	Entrepreneurial		Bureaucratic
Level of SpecialistSupport	Low		High
Investment and Cost			
Level of CapitalInvestment	Low		High
Level of Inventory (WIP)	High		Low
Material Costs	High		High

Source : Hill, (1987).

Three companies could be classed as being consistent on all eight aspects of product and market, as shown in table 5.3(1). Two were jobbing shops and the third a batch producer. The remainder had some inconsistencies, for example:

i. special products and a narrow product range,
ii. standard products and a wide product range,
iii. standard and narrow product range but with a high rate of new product introductions.

The fact that there are so called "inconsistencies" may be a reflection on the commercial environment, in which that company operates. However, it is often the case that some manufacturing aspects of the company's operations are changing quicker than others, resulting in a time delay before the other aspects move in line. This could explain why the most common discrepancy is found in the Market Qualifying Criteria, (MQC), and Order Winning Criteria, (OWC), as they are the aspects that interact most closely with the final customer.

The research shows that the companies surveyed are generally moving away from the characteristics of line production, as they adopt batch processes, in order to gain flexibility and improve their competitiveness.

Manufacturing

The jobbing shops should have the most flexible process, low production volumes, with labour being the dominant utilisation, and with the key manufacturing task being the product "specification". In contrast, production lines are associated with high production volumes, low flexibility, with cost as the key manufacturing criterion, and plant the main utilised resource. These represent the two extremes with the various forms of batch production in between.

One objective of the research was to assess whether the surveyed company's production processes, resources, and capabilities were matched. Only in two of the ten companies, studied in greater detail, was it clear that all the aspects mentioned above were consistent.

The problems of process mismatch arise due to conflicts of interest between business activities. For example, marketing departments may want to increase the product range, whilst production often wish to take advantage of economies of scale and reduce the number of manufacturing operations. However, few companies wish to have traditional dedicated production lines, even if product volumes are high. One reason is outlined below:

> ""Hard Automation" for mass production is vulnerable to changes in the market place."
>
> (Ayres and Miller, 1983)

Few companies are able to dictate terms and conditions to their customers. So the trend is to move away from totally dedicated production, despite the dominance of unit cost as the key manufacturing task.

The general criteria given by Hill, (1987), outlined in Table 5.3(1) are not applicable to all companies. Importantly the process adopted for the manufacturing should complement the objectives of the business and, more particularly, the manufacturing strategy.

<u>Infrastructure</u>

Hill, (1987), Skinner, (1969), and Woodward, (1965), discuss at length the organisational infrastructure of companies. However, all the companies surveyed appear to fall into the same category. They are predominantly centrally controlled and have bureaucratic styles. The advent of computer controlled systems has led companies with all the different processes to build a central database, from which specific instructions are given concerning each task. The aim is for employees to know what they are doing first time, and to eliminate reject work. In general, the companies believe that employees' job descriptions are less rigid, due to flexibility, but that the actual work descriptions are more detailed and specific.

Indeed, there are supposed to be different methods of organisational control and style for the different methods of production. However, the research did not find evidence to substantiate or deny this. In addition, it was difficult to obtain organisational structures of companies in sufficient detail to assess whether they matched the method of production. Therefore, due to the lack of information the research is unable to assess whether the "organisational infrastructure" is in focus with the remainder of the company, and its production strategies.

Appendix XIV shows the type of process which exists for various manufacturing, product and market aspects in the ten companies where sufficient data was collected. It is clear that companies 3, 7, 13 and 20 are in focus, as their manufacturing profile matches the product and market profile. They are companies, whose main line of business has not changed, and where their manufacturing systems have evolved to match closely all the functions of the business.

The remaining six companies have mixed types of process for the various manufacturing, product and market aspects. Hill believes this indicates that the aspects of the company are not in focus. One major problem in conducting this analysis is making generalisations for a company's manufacturing operations as a whole, rather than for different production areas. Therefore companies which have a variety of different characteristic products, markets and production processes are classified as being out of focus. However the achievement of synchronised manufacturing, as described by Mather, (1987), encourages manufacturing operations to have different process characteristics.

5.3.2 Group Technology and Quality Circles

> "Group Technology is a way of putting together machines and operations to simulate assembly line techniques in batch production."
>
> (Ayres and Miller, 1983)

The adoption of group technology is is a further example of Japanese manufacturing systems being applied in British companies. It is a way of increasing employee morale and motivation by encouraging teamwork and, simultaneously, increasing the controllability of the manufacturing system. The system also allows for "quality circle" groups to be implemented, and simplifies the flow of information around the employees.

With products and their sub-assemblies becoming more modular, and the diminishing popularity of traditional line systems, the use of group technology has been promoted. The concept is to have areas designated to carry out specific functions or operations. However, unlike a traditional functional layout their will be a variety of different process machines (eg lathes, mills, drills etc) in the proportion required to manufacture the products.

All the batch producers surveyed had some form of group technology in operation. Often there appears to be inconsistency in the manufacturing layout and operations, as different areas of the larger companies will have vastly different layouts and process technologies. When the system is properly implemented and planned, it can assist in synchronising manufacture. This is where the production volumes of a variety of products can more accurately match the process technologies. The concept is described in greater detail in section 5.4.

Quality Circles

> "A "Quality Circle" is a small group of between 3 and 12 people, who do the same or similar work, voluntarily meeting together regularly for about one hour a week in paid time, usually under the leadership of their own supervisor, and trained to identify, analyze and solve some

of the problems in their work, presenting solutions to management, and where possible, implementing solutions themselves."

(Hutchins, 1985)

There are four phases in the development of quality circles as a means of solving problems. Initially, groups, commonly between 6 and 10, will be trained to identify and solve problems relating to their work area. Often the problems will relate to the factors uppermost in the minds of most employees.

Phase two concerns the training in simple control techniques, which will be adopted to monitor the improvements that have already been made. The progression into phase three involves the group positively making improvements, rather than just solving problems. It is also claimed by Hutchins that no country in Western Europe has achieved phase four "Self Control".

It is easier to establish quality circle groups in areas where there is a group technology layout, and where labour is not intensive. The introduction of AMT throughout manufacturing will promote smaller groups of people needing to work more closely together as a team. When the groups are trained properly then Robson, (1982), believes that the employees will gain the trust of the management. It is also necessary that the group members are truly flexible as outlined in section 5.2.1.

The importance of establishing these harmonious working groups is that they are ideally positioned to inform management of how manufacturing systems and communications can be improved. They are also in a position to highlight areas for new technological and product innovations, and, when properly trained, conduct the implementation of new AMT, as outlined in chapter 4. With full cooperation, they also assist greatly in the collection of shop floor data for analysis in a Management Information System.

One manufacturing company visited claimed that, through the introduction of quality circles amongst the workforce, and quality assurance in the design centre, rejects at the end of final assembly had fallen from 12% in 1982, to 0.5% in 1987. The company's manufacturing manager said that by reducing rejects to a point where they are insignificant, means that they (the company) can concentrate on the positive aspects of quality. However, he says that initially there was a feeling of uneasiness amongst the supervisors that quality circles would undermine their position, an impression that was quickly dismissed.

5.3.3 Performance of Manufacturing Systems

> "More important than attempting to measure monthly or quarterly profits is measuring and reporting a variety of non-financial indicators."
>
> (Johnson and Kaplan, 1987)

This is because the role of short term financial performance measures undermines the changes in technology, product life cycle and innovations, to such an extent that they are almost irrelevant. Johnson and Kaplan, who are both Professors in Management Accounting, and, Primrose and Leonard (whose work on justifying AMT was discussed in section 4.4), believe that greater value should be given to manufacturing performance measures and their trends. In addition, a company wishing to measure quality, must redefine the term as quantifiable indicators such as scrap, rework, defects, reliability, consumer complaints, warranty expenses and service calls.

Therefore strategic decisions have to be taken on the variables that a company wishes to measure and analyze. They must be quantifiable so that the indicators may be used to compute :

1. the variables required to justify investment appraisals,
2. the trends in the company's manufacturing performance,
3. whether the company's operational, business and corporate objectives are being met.

The performance of a manufacturing system has to be measured and monitored consistently. The criteria used will vary considerably, depending on the company, and the position of the contact within the company. However, it is important that the performance indicators used give clear and accurate information.

The research has been unable to extract any formal statement of objectives which can be measured in any way. Too often proposed objectives are vague and use terminology such as "to meet customers' expectations", where no measurement can be made.

Goldratt, (1985), and the EITB believe that there should be three global measures of performance. These are for sales, inventory and cost of production. Production quantities are of limited use if the product cannot be sold. If the correct products are not being made or there are scheduling difficulties, then inventory will accumulate. Finally, concerning the cost of actually manufacturing the product, Goldratt says that the operational "Goal" of a manufacturing system is to increase the throughput, whilst decreasing inventory and unit operating expense. The author agrees, but finds these statements lacking clarity.

It is fine to have global measures of performance, but a company also has performance measures on a smaller scale, which are able to highlight areas of inefficiency and "bottlenecks". Such measurements would also be used to monitor the performance of AMT.

In any company there must be a hierarchical structure of performance measures representing the corporate, business and operational levels. For each level it is critical to know the effectiveness and efficiency of the company against its objectives. The measures will require to monitor the utilisation of all the company's resources, as outlined below:

"Efficient manufacture is the optimum mix of,
(i) conversion of raw material to finished product,
(ii) utilization of capital equipment,
(iii)utilization of productive labour."

(Clews, 1985)

The same three resources of materials, labour and machinery are identified, by Wild, (1985), as the three dominant types of operating system resources. In many ways these can be applied to the three hierarchical levels mentioned above. The problem, in many cases, is that the higher up the management structure the more important the financial considerations and measures become.

When the companies were asked for the performance measures, used by their company, corporate financial measures were given, similar to those given in Appendix VI. The company's profitability was the key measure, followed by sales volume and product lead times. It was known that companies collected a plethora of data for middle managers and production controllers to consume, but they were not classed as being particularly important by production engineers.

Some production performance data was collected by the AMS group (NEDO, 1985), to show the impact of AMT on manufacturing. This research has analyzed the data, and concludes that :

1. The number of employees has been reduced from between one quarter and a half.
2. The number of machine tools required to carry out the same number of operations is halved.
3. With fewer machine tools, the manufacturing area has been reduced by over a quarter.
4. The number of days required to tender for a job has been reduced to a fifth.
5. The delivery lead time has been reduced by at least one half.

Company 1 gave a list of the beneficial impacts, after two years of their FMS on production performance. The list is given below :

1.	Lead Time on Customer Order,	10 Months to 2 Months.
2.	Work in Progress Inventory,	reduced by £1M.
3.	Component 1 Machining Time,	170 Hours to 70 Hours.
4.	Component 2 Machining Time,	286 Hours to 60 Hours.
5.	Inspection Time per Casting,	40 Hours to 10 Hours.
6.	WIP to Sales Value Ratio,	50% to 30%.

5.3.4 Learning Curves

When progress is made in the performance of a variable on a repetitive and predictable basis, it is considered to be as a result of "learning".

> "The learning curve describes the empirical relationship between the performance variable and quantities of certain outputs. It portrays the concept that the cumulative average unit cost decreases systematically by a common percentage each time the volume of production increases geometrically"
>
> (Belkaoui, 1986)

The first empirical observations of the learning curve concept were taken by T. Wright in 1936. He showed that, in the military aircraft industry, the labour requirements decreased by 20% every time output doubled. This is known as the 80% learning factor. The theory is that people learn from experience, so that when workers repeat a task they become more efficient at it.

Henderson, (1972), found that the learning curve phenomenon was just as applicable to the young, high volume industries as it was in the old, low volume ones. The experience, gained by more by more effective operatives, improved methods, scheduling and work organisation. However, the major cause for improvement is "Technological" change.

Every surveyed company's operations are affected by the log linear learning curve, but few are aware of the information that it provides the manager. It is a strategic tool for decision making. There are three main areas for which it is applicable:

1. Productivity.
2. Introduction of new machines (such as AMT).
3. Product operational efficiency.

The productivity curve refers to the improvement to measures, such as labour content and cost per unit output against the units manufactured. When the labour content is plotted on a log scale against quantity (also on a log scale) the result is a straight line as shown in figure 5.3(1).

If the direct labour content falls consistently then the cost of each product falls as well. Knowledge of the learning curve factor gives the decision maker information which allows him to make strategic decisions concerning future target costs and future pricing policy, which, when combined, affect the company's relative position against its competitors.

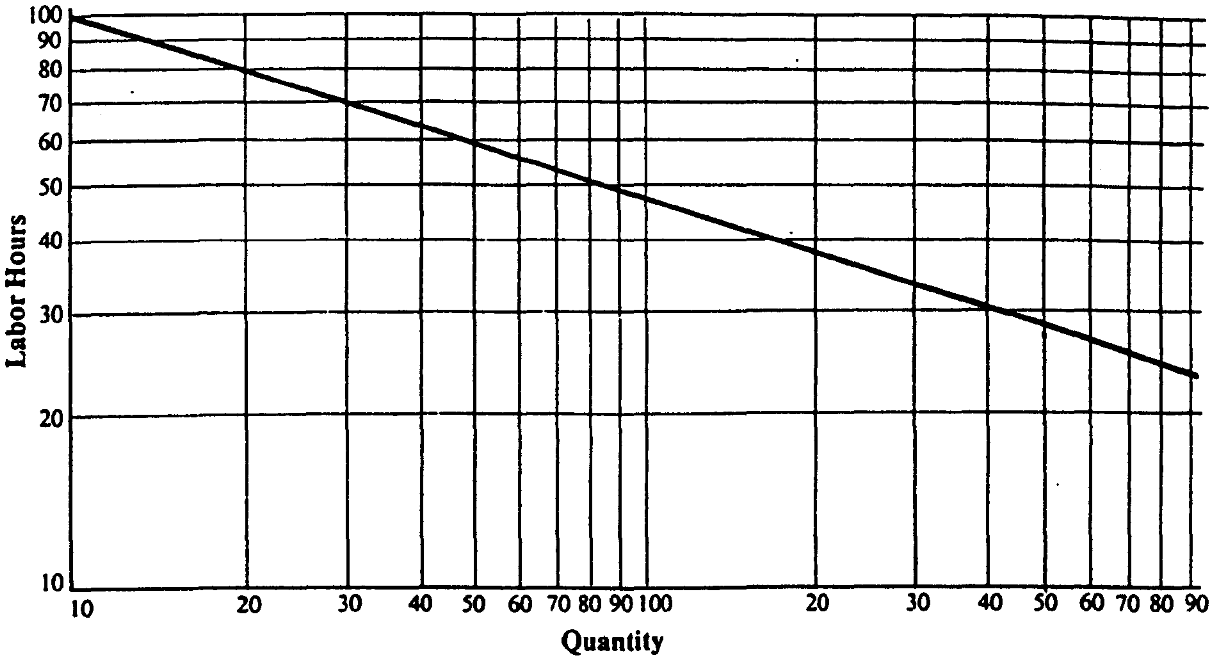
Henderson discusses, in greater detail, the competitive implications for profit and market share that need to be considered.

One method of reducing the unit cost is by adopting new manufacturing methods and technology. However, there is a learning phase involved in the implementation of AMT and systems. The conceptual "S" shaped curve as depicted in figure 5.3(2) is a measure of how quickly the machinery operates optimally. The y axis is a measure of efficiency, such as units manufactured per hour. If this value is expressed as a percentage then the maximum will be 100% capacity. As the company gains experience by adopting new technology, the gradient of the curve will increase, reflecting the reduced time needed to fully implement the system.

Figure 5.3(1)

Log Linear Cost Reduction Curve

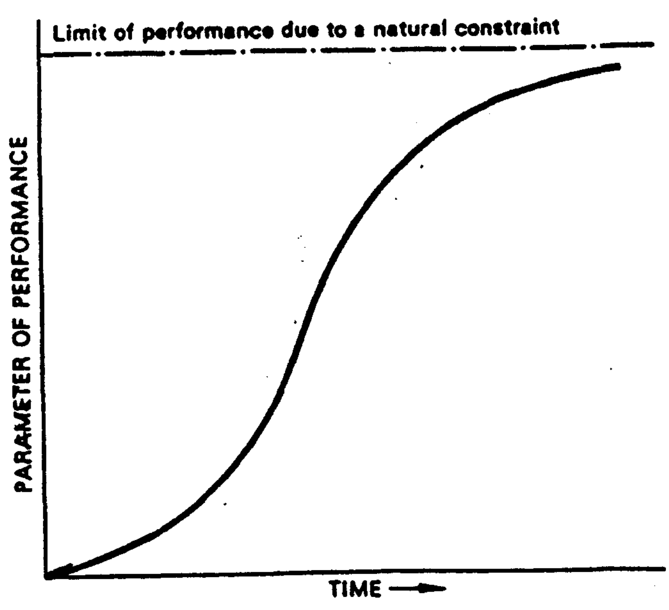
- Cumulative Average Labour Time at 80% Learning Rate



Source : Belkaoui, (1986).

Figure 5.3(2)

Learning Curve for the Implementation of New Technology



Source : Twiss, (1986).

The third perspective of learning curves refers to the performance of certain product characteristics. For instance, over a period of time, product design changes improve the product's operational efficiency.

5.3.5 Process Technology and Product Life Cycle

The characteristics of the Product Life Cycle, (PLC), are outlined in detail by Wasson, (1978). This theory is taken up by Hayes and Wheelwright, (1979), as they link the PLC with various characteristics relating to product volume, variety of models, industrial structure, the form of competition and the learning curve.

The study of the characteristics, (given in table 5.3(2)), gives an indication of the process technology required, along with the other resources needed for the company's production line. Therefore, the combination of product variety, volume, and OWC will determine the technology to be adopted. This would suggest that, as the product matures, it is necessary for the process flexibility to decrease and the productivity to increase. If this is correlated with figure 2.2(1), then the process of automation would begin with CNC machining, and gradually move towards dedicated transfer lines.

The difficulty with this simplistic approach is that there are uncertainties, many of which are outlined by Wasson. Other drawbacks on the nature of the product are given by Dhalla and Yuseph, (1976). They cite many examples, where companies have closely monitored and analyzed the PLC's, leading to a premature product death. They conclude that less emphasis should be placed on the value of PLC forecasts.

Table 5.3(2)

Production Process Characteristics and the Product Life Cycle

Product Life Cycle	Launch	Growth	Maturity
Unit Product Cost	High		Decreasing
Process Flexibility	High		Decreasing
Process Productivity	Low		Increasing
Product Variety	Large		Decreasing
Industry Structure	Many Small		Few Large
Order Winning Criteria	Product Features		Price
Level of Automation	Low		Increasing

It can be seen that, for long term products, their basic characteristics are going to change, indicating that changes in the process technology and operational systems may be required. Prior knowledge of this will be of strategic importance to management in formulating their future corporate plans.

5.4 Manufacturing Systems

The section draws together the three resources of materials, labour, and process machinery. The research looked at the involvement of the resources in the concepts of synchronised manufacture, flexible manufacture and focused manufacture. Finally, the study examines whether the principles of the three concepts are compatible with each other.

5.4.1 Synchronised Manufacturing

The concept of synchronised manufacturing is a planning and control function, which combines the operating process and batch quantities with the inventory and quality control systems. Each machine and functional area, within the manufacturing plant, will have an EBQ, which may not necessarily be the same. Indeed there are likely to be large differences in the production speeds between different machines.

Therefore, if all the machines are fully utilised, inventory builds up between the machines where a slow machine succeeds a quicker one. This costs the company money in WIP and lost opportunity in floor space. However, this practice, where machine utilisation is used as an objective measure of performance, and where labour bonus incentive schemes promote high utilisation rates, is encouraged.

The aim of synchronised manufacture is to allow the right quantity of materials to enter the system to manufacture the order. This is similar to the "kanban" inventory control system outlined in section 5.1.4. If the system is extended throughout the business system, then it will ultimately involve the goods suppliers and retail outlets.

The companies surveyed all have different variations, due to their products and position held in the industry. However, two companies claimed that they were implementing synchronised manufacture, and their first task was to identify patterns in their production. For instance on a three model line (with products coded A, B and C) there could be a permutation of AABCC. Although this sequence may not be the same as the order sequence, analysis of demand patterns showed that demand for models A and C are equal, but twice that of B. It is then claimed that the employees familiarise themselves with the pattern, which is consistent throughout the sub-assemblies and system as a whole.

5.4.2 Flexible Manufacturing

Many companies are purchasing AMT, as they believe it will make their manufacturing operations more flexible. However, it is rare that the manufacturing operations are made more flexible under the criteria adopted by Browne, (1984). They are undoubtedly more machine flexible, in that they are adaptable in making tool changes. In many instances AMT machinery is being used as a replacement for several previous functions. Without exception AMT is more complex and sophisticated, with a broader variety of options available to it.

The problem, in many cases, is that the additional sophistication leads to greater reliance on the whole system to be operational. In addition, the impracticality of dual purchasing, means that "routing" flexibility is often restricted. Furthermore, with a greater number of critical operations in series rather than parallel, there is an increasing probability of failure. The counter argument is to say that the machinery is more reliable, and therefore the whole system is available more of the time.

The extent to which AMT can be "expanded" varies enormously. Engineers are more concerned with the present system than for any future expansion plans. However, Managers are also left unclear as to future expenditure, which makes the planning of, or allowance for expansion more difficult, especially when it requires capital expenditure, or it is likely to be superseded by even more sophisticated machines. Only three of the companies surveyed had technologies which had grown incrementally over time. The remainder were "islands", where the AMT was purchased to do a specific task.

"Operational" flexibility is the ability to interchange the ordering of several operations. Due to routing inflexibility, then, once an order is being processed, it would be difficult to stop it in preference for a later one.

The reason for many AMT installations is to manufacture at a consistent rate for a longer time. Many implementations are only justified on the basis of two or three shift working. This means that the AMT is having to work for longer hours, which would suggest that few systems have "volume" flexibility, as they are not profitable at different production volumes. However, the counter argument to this, is that AMT is only implemented in those areas where volumes are high and steady.

In conclusion, most AMT is purchased for sophisticated but dedicated tasks. This is what is required for high volume, single product production operations. The problem arises for manufacturing operations, which have to serve multi-product companies, where new launches are frequent. The tendency here is to automate the dedicated parts, and utilise manual labour for the flexible, changeable parts.

5.4.3 Focused Manufacturing

Many companies are failing to compete because their manufacturing operations are not focused. Skinner, (1974), Hill, (1987), and, Hayes and Wheelwright, (1984), all discuss the concepts and characteristics of having focused facilities.

> "Focused manufacturing involves linking an organisation's manufacturing facilities to the appropriate competitive factors of its business(es), with the aim of enabling that company to gain a greater control of its competitive position."
>
> (Hill, 1987)

The companies have all witnessed major commercial changes to their product design and product mix over the last two decades, and have all adopted new AMT systems. The problem, in the short term is that companies are more concerned with reducing costs and improving efficiency and productivity, rather than "competing". This often arises because companies have preconceived ideas to reduce labour costs, even when their proportion of total costs is low (See section 5.1.5). Skinner, (1974), identified two other changes that companies had to undertake to restore the competitive balance, and treat the company as a whole system.

1. "learning to focus each plant on a limited, concise manageable set of products, technologies, volumes and markets."

2. "Learning to structure basic manufacturing policies and supporting services, so that they focus on one explicit manufacturing task instead of on many inconsistent, conflicting, implicit tasks."

The key to focused manufacturing is tuning the whole business system from manufacturing, design, maintenance, marketing to procurement that all are operating in conjunction with the overall corporate strategy. The evolution of an Integrated Business Information System (IBIS), if based on sound objectives can be a way of achieving focused manufacturing.

> "The whole economy has moved towards an area of more advanced technologies and shorter product lives, the concepts of production have not been readjusted to keep up these changes. Instead productivity and economies of scale have continued to be guiding objectives."
>
> (Skinner, 1974)

The trend, observed in the surveyed companies, is for them to become more focused. This is because of the general movement where :

i. a lower proportion of the product is manufactured "In-House",
ii. greater emphasis is placed on increasing quality,

iii. the cost attributable to direct labour is decreasing,
iv. the cost attributable to materials is increasing,
v. plant layouts are becoming more functional and smaller,
vi. there is greater control on inventory at all stages of the manufacturing process,
vii. there is a greater intensity of support services for manufacturing.

However, the three aspects, which are repressing the move towards focused manufacturing, are:

i. the diversification of product mixes,
ii. greater variety within the product range,
iii. differing manufacturing processes within the whole production system.

Over a period of time the desired focus of a company changes, due to the modification of one particular aspect. In order for the company to remain in focus, it must make complementary changes to all the other aspects. Such changes may be due to:

i. customer demand for a change in product mix and range,
ii. customer demand for a change in product volumes,
iii. different working practices and flexibility agreements,
iv. new process technology being implemented,
v. the business control systems measurements taken and analysis conducted,
vi. the corporate strategy of the company.

The only way a company, once focused, can maintain its position is by ensuring that the company's manufacturing strategy is formulated to meet the mission of the business. This, in turn, will require the business to work as a system which manages its activities and resources within a commercial environment to achieve specified objectives.

New AMT is no longer alien to many large manufacturing companies. Their experience and knowledge of the systems have made the new adoptions more manageable. Furthermore, the smaller companies, in particular, purchase what is now becoming more proven technology. The major direct impact of AMT is to reduce the optimum batch size, by reducing set up costs through reducing set up times. The major indirect impact of AMT is to promote the planning for the systems required for the successful adoption.

Requirements of a Focused Factory - some Conclusions

Focused factories are rare, not only because companies have adopted incompatible strategies, but also due to constant change to critical variables. Once a critical variable of a focused factory changes, or is changed, then the whole system is out of phase. Therefore, to achieve a focused factory there have to be many trade-offs, since the time taken to change each variable is different from the next one.

The key variable is sales volume. This, to a large extent, determines the nature of the business methods used, and the choice of process. The illustration would be a true representation for a single product company. However, with multi-product companies, a second variable is introduced, that is the number of types of products manufactured.

From appropriate information the volume per product can be calculated and matched against figure 2.2(1). This, too, is over simplified because the number of sales for each product are not equal giving a company the problem of having to manufacture several products to different volumes and production campaigns.

Furthermore, the different types of products may have common parts, indicating that the volumes in the sub-assemblies may be different from the main assembly volumes. Then, when one takes into account the fluctuations in sales volumes due to unpredictable demand, product life cycles, and changes to product design, it is easily understood how companies loose "focus".

For those companies not involved in continuous methods of production, the critical variable is batch size. This will iron out some of the absolute volume variations highlighted. Without exception, each company surveyed had batch production, the batch size of which was determined by the volume of sales for each product.

For every machine and production system there is an optimum economic batch quantity. Hill, (1987), illustrates the type of equipment appropriate to different volumes of production. The type of equipment adopted will have optimum batch sizes. The focused factory will ensure that the equipment purchased has an optimum batch quantity, within a given tolerance, to coincide with the batch size calculated from total volumes.

The equipment has also to be matched to the functional layout of plant facilities. Most of the companies visited had a functional layout, within which areas of "group technology" were being introduced. Those companies, with higher volume products, would have a distinct line layout within a functional area. This is not necessarily out of focus, as long as the facilities layout matches the batch size for that function, and it is in phase with the rest of the manufacturing facilities.

The factors mentioned above illustrate the necessity for batch production companies to become more flexible, and thus more responsive to the changes in the market. However, it is important to realise that, with more unpredictable demand, flexibility in equipment and batch size broadens the scope for focused manufacture. It also means that changes in capacity can be met incrementally, although there will be a capacity limit, beyond which a major step will have to be taken.

Summary

The chapter has studied the detailed implications for the manufacturing resources and operations, as a result of companies adopting AMT. This began with an investigation into the trends that have taken place in manufacturing companies, especially over the last five years. It has been shown how there have been significant changes to the proportion of products manufactured "in-house", the quality of products manufactured, and the inventory control system. The combination of all the changes have resulted in the material cost becoming a greater proportion of the total than direct labour.

The chapter then studied the changes that have taken place in the management of labour required for AMT. This included an insight into the modern "flexibility agreements". The importance of training and education were also discussed along with the supply and demand of university graduates.

The third major resource, process machinery, was investigated and the effects that AMT has had on characteristics of manufacturing processes. These were compared with the process profiles of ten of the companies surveyed, which highlight some inconsistencies. The research also looked into the trends in "group technology", facilities layout, "quality circles", performance measures, learning curves, and product life cycles.

Finally, the chapter took an overview of the implications on the changes to the manufacturing resources and operations, as a result of implementing AMT. Discussion into synchronised, flexible, and focused manufacture revealed the individuality of every company's production systems.

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CHAPTER 6

INTEGRATING BUSINESS ACTIVITIES

Chapter 6

Integrating Business Activities

6.0 Introduction

The strength of a company is determined by the cohesiveness and compatibility of the overall business system. Manufacturing is not the only activity that is affected by the implementation of AMT. This chapter investigates five other activities of a commercial business, and assesses how they are affected by new technologies, and how well the companies operate as an integrated system. The systems activities are Product Design, Procurement, Sales & Marketing, Maintenance and Management Information Systems.

These five non-manufacturing activities were highlighted at the beginning of the research as having a bearing on the success of any automation. Consequently, some of the questions asked focussed on the surveyed companies' strategies towards each of the activities and how they had been affected by AMT. The sections on maintenance and product design were also supported by questionnaire surveys to a broader sample of UK engineering industry.

6.1 Design and Computer Aided Engineering

Product design is a key factor in the success of a company. However, too often the design functions have been isolated from production and engineering. To fully utilise AMT the three activities have to collaborate and communicate to provide an optimal solution. It is essential for Designers to know the capabilities of the manufacturing facilities so that they are able to "design for manufacture".

Initially, the section looks at two different interpretations of "design", and how CAD, CAE and CAM has assisted the process of product design. This is followed by two case studies into the justification of CAE and CAD systems, and discussion on the importance of linking the design activity with AMT.

6.1.1 Different Interpretations of "Design"

There appear to be different opinions on the meaning of "design", and consequently it was a natural question to ask of design engineers. The OED defines "design" as

> "a preliminary plan for future building", and a designer or draughtsman as "someone who makes plans for manufacturers".

From the 50 responses, no two answers to the open question were the same, making analysis and deductions difficult. It seems that design may be split into two categories. One envisages design as a final product whilst the others see it as a process. Those who believed that design is the actual drawing are closer to the dictionary definition, which defines it as a "plan" from which something will be made.

The design, as a set of drawings, is a restricted and closed view of a process, where designers, in collaboration with engineers, are responsible for the development of new ideas and concepts and making them into a workable solution. The output of the design process is an actual plan that should meet all the specifications and constraints imposed. It will also contain scheme drawings with all the necessary dimensions and calculations. The design process itself should continue by taking the actual plan through pre-production prototype, testing and development, to monitoring the final product. This is because modifications may have to be made to the original design. However, the systematic process should be cyclical, as the product in full production, when properly assessed, will yield new concepts which provide a "feedback loop" into creative design modifications.

Whatever interpretation is used it will be necessary for a design to have, or involve the need to :

i. recognise a customer or market need,
ii. conform to predetermined functional specifications,
iii. synthesise experience, ideas and manufacturing technology,
iv. evaluate all possible scenarios to achieve the objective, which is usually to develop a working product that produces the most cost effective solution.

The end product of a design process is both a product and production design. In the past it was usually up to the design and product engineers to decide on the optimum method of producing the design. However, sophisticated CAD/CAE systems now allow the two functions to be carried out simultaneously. This naturally means that engineers are being forced to work along side draughtsmen at computer terminals, and that the design process itself is becoming more dynamic and interactive.

6.1.2 Computer Aided Design and Engineering

When CAD was initially marketed, in 1968, the machines required the use of mainframe computers. In the 1980's CAD systems can be based on personal computers, due to the growth and development of microcomputers. Indeed the personal computer is credited with much of the recent growth, and will account for 90% of the market by 1990 (Design Graphics World, 1985).

The most common reasons for introducing CAD appear to be:

"i. improved productivity of designers and draughtsmen,

ii. shortening the lead time from order to delivery, or from conception to production,

iii. performing work which is too complex for manual design and drawing."

(Edquist and Jacobsson, 1988)

Some companies, especially in the electronics and aerospace industries, find that CAD is necessary to deal with the required detail and accuracy. Other large engineering industries use CAD to shorten lead times and improve product design. Indeed, to some companies, the cost of using CAD is insignificant in relation to the total production cost (Giertz, 1983).

The introduction and development of CAD has parallelled that of CNC machining centres. Arnold and Senker, (1982), who researched the UK automotive and aerospace industries in 1982, "identified little activity to date" in linking CAD and CAM, and believe that "...the process of developing CADCAM applications on a wide scale may take quite a long time." This research has also shown that this is still the case.

In total, 70% of the questionnaire respondents belonged to companies who had CAD facilities, and every company surveyed had systems, often with many work stations. The figure may have been even higher, if those respondents, who were in certain service industries and non-engineering industries, were eliminated. Indeed nearly 17% of the companies had over 10 work stations. The mean figure of 13.9 is high due to two very large users of CAD. However the median number of two reflects a more realistic situation in which the smaller companies are gradually introducing themselves to CAD.

CAD is capable of giving more than simple geometrical information, as data can also be obtained on the characteristics and properties of the materials in use. It can also be used to optimise factory layouts. On average each company, who has CAD, carries out over 2.8 different functions on them. Therefore many data banks are needed to build up the CAD system, which in itself is a simple integrated computer system.

The integration of CAD with other areas of a company, such as manufacturing, is more limited. Over two thirds of the companies, in the questionnaire and those surveyed, had isolated CAD systems. Of those who did have links, very few had direct links involving no human interface or physical tapes. This illustrates that the CADCAM vision suggested by Arnold and Senker, (1982), is still in the future for most companies.

Furthermore, with 70.8% of respondents indicating that they believe CAD is a prerequisite to AMT, then the integration of CADCAM can only take place when the CAD system has been properly implemented, understood and operated.

Case Study - Computer Aided Design and Engineering

One of the companies surveyed knew that they would have to implement some form of CAD/CAE system. Their two main reasons were : an antiquated drawing office with its inefficiencies becoming a burden on the company, and the visible attributes of systems seen in other manufacturing plants. The company was able to obtain finance for an independent consultant to carry out a feasibility study. The report, which was concluded in November 1980, gave the following recommendations.

1. The most feasible type of CAE equipment for your business is the turnkey minicomputer type of system which would increase substantially the engineering productivity.
2. Senior management should make a policy decision to acquire a CAE system and give the project whole hearted support.

3. A working party should be set up with firm terms of reference and a timescale for reporting.
4. A drawing coding system should be developed.
5. The proposals of the working party should be accepted.
6. The drawing offices should be reorganised where appropriate.
7. Install the system.

The report only confirmed what the company knew was inevitable. Table 6.4(1) gives a brief outline of the costs and benefits of the proposed "turnkey" system.

Table 6.1(1)

Investment Appraisal Model for a CAE System

	(£000's)	
Initial Costs		
Three graphic work stations and a plotter.	200	
Installation	10	
Development and Training	10	
		220
Annual Costs		
Supervision	10	
Power	8	
Consumables	4	
Maintenance	24	
		46
Annual Quantifiable Benefits		
Overtime in the drawing office	28	
Reduction in Draughtsmen Employed	90	
Savings due to fewer drawings	11	
		129

The six year investment appraisal analysis is carried out in Appendix XVII, and only includes the costs and quantifiable benefits outlined above. The feasibility study calculated that the accounting payback period would be two years. However, this study calculates, that on the data given, the payback period is over three years, with an IRR of 27.4%, and a NPV of £79,480 at 1980's value of money. The consultant's study did not take into account the time value of money, and failed to allow for non-optimum use of the facilities at the beginning, due to learning and training, which the report claimed would happen.

The consultants believed that the long term unquantifiable benefits, (listed below), would outweigh the quantifiable benefits.

1. Without such a system the company would not remain competitive in the industry.
2. Estimated productivity gains for the three main engineering functions would improve (turbine and mechanical by a ratio of 5 : 1 and electrical by 8 : 1).
3. CAE will reduce the lead time and produce an improved quality of drawing when tendering for a contract, since the present quality is dependent upon the time that is available.
4. Once contracts have been won, the company will be able to process design and draughting content with fewer men and in less time.
5. The market standing and esteem of the company will be increased by improved quality tenders, technical excellence and demonstrate a forward looking approach.
6. The quality of the drawings through accuracy, detail and consistency will improve and be produced to the desired scale.
7. Properly constructed design database will eliminate the need for redrawing that which cannot be found, and also allow for quick retrieval of drawings.
8. The system will make it easier for the company to introduce strategies regarding the standardisation of parts, and consistent units of measurement.

The factors mentioned above all relate to benefits attributable to the design and engineering departments alone. Although this is often the initial intention for most companies, it should not be seen as an "island of computerisation" in the long term. Further productivity gains can be obtained by using the CAD/CAE system to generate computer code, which can be transferred directly to CNC machine code through a graphics terminal.

Top management approved the report and set up a working party, which included representatives from senior management, all the engineering functions and the trade unions. The easiest decision was choosing the system, because they chose the system that was identical to the system used by their licensing company in America. This would ensure that the two systems would be compatible, and that communication between the two companies would be made easier. Work could be conveyed directly through existing telecommunication networks, or by disk, and would reduce the quantity of paper work.

The working party, having visited the licensor, were satisfied with the system, and the suppliers were willing to offer generous discounts, as they were wishing to establish a European base in the UK.

The more contentious issues for the working party involved working and operational practices, the position of the graphics terminals and the layout of the drawing offices, which were described as being "poor". It was finally agreed that there should be a separate air conditioned room, with subdued lighting, for the system.

The major logistical problem was that the company had just three terminals for 75 designers. The trade unions insisted that, for their cooperation, all the designers had to be trained to use the system, and receive additional payment for their skills. The compromise situation was that all the appropriate designers would be trained and those that passed a test would receive the additional payment for their skills. In addition, the company introduced a three shift operation to utilise the terminals, but this was unpopular and had to be reduced to a double day shift.

The research has also obtained a cost justification for a second CAD system. A copy of the investment appraisal is shown in Appendix XVIII. It, too, did not take into account the time value of money, but included different justification criteria, outlined below :

1. Savings in travel and communication form the company's various sites in the UK.

2. The reduction in circulation of drawings and material lists.

3. Moldflow, stress and temperature analysis.

4. Additional profit from products produced on time.

5. Additional profit from additional work created as a result of having CAD.

The inclusion of allowances for the generation of additional future profit made the project appear most attractive, with an IRR of nearly 75% and a NPV over £1.2M for a six year time period. This confirms the desirability of much fuller accounting assessments in innovative situations.

6.1.3 Design of New Products

One of the questions in the design questionnaire asked the respondents to rank their company's products against seven design features. The results are shown in Table 6.3(4). This shows that the company designers' primary interest is in designing a quality product, which will be of practical use to the customer. It is interesting to note that a greater proportion of those companies, who had some AMT, ranked quality first in priority. However there is insufficient evidence (at the 5% significance level, chi-square test), to reject the null hypothesis that the adoption of AMT did not affect the importance of product quality.

Therefore, it appears that those companies, who have adopted AMT (for which all have CAD), appreciate and acknowledge the additional quality such technology gives. It also illustrates the nature of international competition, in which quality and functional value are the market qualifying criteria, whilst cost is one of the order winning criteria.

Those companies, who have achieved the market qualifying criteria, then look towards winning orders. One of the methods now being used is the concept of "designing for manufacture", which aims to simplify the manufacturing of the product, and utilise more cost effective materials. The effect is to reduce operating costs, with the more advanced companies implementing design for manufacture techniques prior to the introduction of new products. In many companies this is not feasible and a more gradualistic approach is required.

In relation to the above points, it is understandable why appearance, and original or novel features are ranked as least important. They are simply not a top priority for most UK engineering products at this time.

Most companies require to design new products. The questionnaire asked respondents for the reasons why their company designed new products. Since there may be more than one reason the question asked for the rank of six different factors on a scale from 1 to 5 (1= Very important, 5= Not Important). The results are shown in Table 6.1(2).

Companies' main reason for designing new products is to open up new markets. This is achieved in several ways, of which the most popular is to diversify the product range. Companies generally advance their product ranges when there is some new scientific or technological development. Indeed, those companies directly involved will have to take advantage of the developments.

It is noticeable that companies prefer to diversify, in preference to focusing on developing existing product ranges, through the use of more cost effective materials or production methods and replacing existing products. Companies rarely wish to specialise within a restricted product range.

The effective use of CAD and AMT enables modifications of the product ranges to be made easily and quickly. The flexibility of equipment allows companies to diversify product ranges, whilst retaining their existing products.

An attempt was made to establish which group of people were the inspiration behind new products, and which group of people actually decided on whether development should take place. Tables 6.1(3) and 6.1(4) display the respective responses on the project initiators and innovators.

Table 6.1(2)

Reasons for Designing New Products

Rank	Reason for New Product Design	Mean Score
1	Developments in Science and Technology	2.2
2 =	Diversification in Product Range	2.5
2 =	Use More Cost Effective Materials	2.5
2 =	Use More Cost Effective Production Method	2.5
5	Replacement of Existing Products	2.7
6	More Specialisation	3.4

The results from the tables show that the two most important sources for new product designs are the designers themselves, and the customer. These are the two groups of people who know most about the product, and who are using it. Together they should be in the position of deciding what needs to be developed.

However, the authority for developing such products comes from the higher management or director level. The spread, within the table, probably shows how different company structures are, with different procedures resulting in critical decisions being made by different people at different levels.

Table 6.1(5) displays the responses to a question aimed to ascertain which group of people have greatest influence on the company's product design. This clearly shows the importance that companies place on the customers. It is a little surprising that companies do not give more prominence in the design team to manufacturing, where staff are usually in the best position to decide on how existing products could be better manufactured to meet these customer requirements.

The research also tried to establish the reasons why new products are designed, and the people responsible for their initiation and development. The answers to these questions reflected the strategies and organisational system within the company, and are not directly influenced by the level of automation adopted. However there are going to be constraints and restrictions placed on designers. These are shown in Table 6.1(6).

Table 6.1(3)

Source of Ideas for New Product Design

Rank	Source of New Ideas	Mean Score
1	Product Designers	2.5
2	Customers	2.8
3	Management	3.1
4	Sales Personnel	3.2
5	Other Employees	4.5
6	Other Consultants	4.7

Table 6.1(4)

Authorization for the Development of New Designs

Rank	Level of Authority Needed	Frequency	Percent
1	General Management	20	23.9
2	Director / Board Level	16	27.1
3 =	Marketing / Sales	8	13.6
3 =	Others (eg R&D)	8	13.6
5	Product / Project Management	7	11.9

Table 6.1(5)

People Most Influential in Instigating Product Design

Rank	Most Influential Factor	Frequency	Percent
1	Customers	36	73.5
2	Management	8	16.3
3	Manufacturing	5	10.2

Table 6.1(6)

Constraints and Restrictions Placed on the Designer

Rank	Constraint or Restriction	Mean Score
1 =	Product Cost	2.3
1 =	Market Need	2.3
3 =	Manufacturing Capability	3.1
3 =	Management Specifications	3.1
5	Traditional Practices and Methods	3.7

There are three distinct sections within this table. Firstly there is the internal belief that traditional design practices and procedures are no longer a major constraint. The advent of CAD systems has resulted in much more flexibility within a design department.

The two major constraints are : meeting the market need, and with a product at the designated cost. This response is not surprising, as this is critical to the survival of a business. However, the product can only be manufactured at the right cost if the company has the manufacturing capability and has been given carefully prepared guidelines and specifications for product development.

These factors are all constraints to a designer. However, it is claimed that the opportunities for creative design have increased. This is probably due to the fact that companies selling consumable products to a market gives their designers more scope, within specified guidelines, to attract potential customers.

6.1.4 Design For Manufacture

One of the open questions on the questionnaire tried to solicit how design departments made themselves more responsive to the changing commercial environment, in which they were operating. Many of the respondents outlined the changes that were taking place within their company and industry. It is indeed important to identify the changes and trends, which are taking place, before formulating plans and strategies to deal with them. The most common response was that the industry was becoming more competitive and customers more cost conscious. In some industries the companies are having to respond to changes in legislation, like on safety, product and defect liability and British Standards.

The methods of achieving greater competition, or responding to the changes, were primarily improved communication with, and better awareness of :

1. the customer to ascertain the market needs (this may be channelled through salesmen and / or marketeers),
2. production with the aim of simplifying manufacture and eliminating unnecessaryly expensive facilities,
3. goods suppliers to ensure quality is maintained, and
4. other areas of the organisation and particularly Engineering Directors and Chairmen to ensure design departments were given sufficient attention.

In addition design departments have to become more aware of :

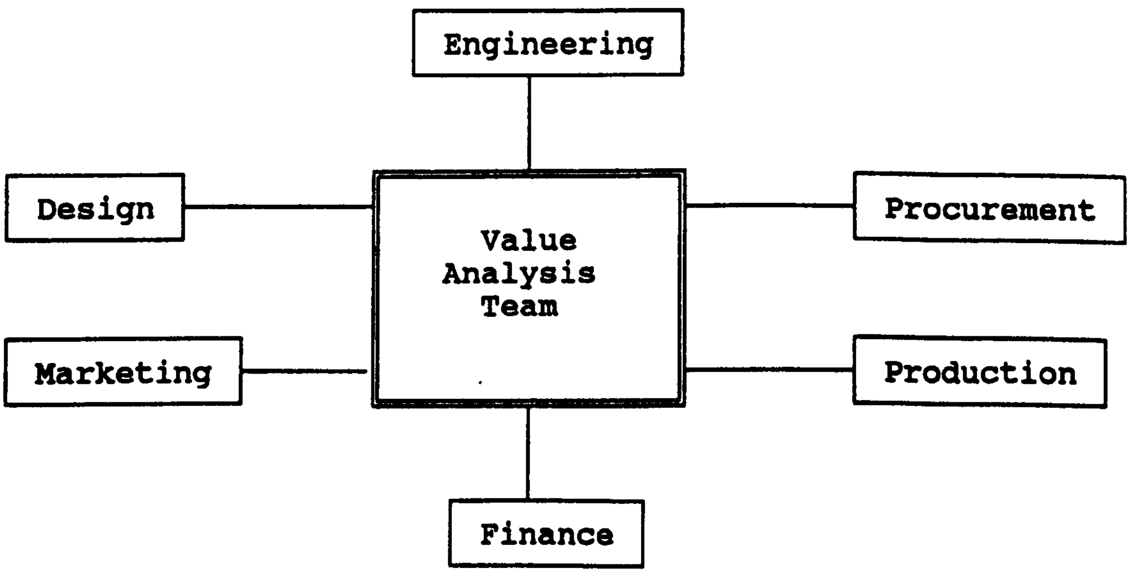
1. competitors products so as to appreciate the standards that had to be achieved,
2. new materials, production techniques and technology so they are able to produce designs appropriately, and
3. the need to have better communication with all the affected departments.

The idea that design departments could become more responsive, by adopting CAD to produce more accurate drawings more quickly, and by better appreciation of what can be produced on a drawing board, was only mentioned by two respondents. Furthermore, no respondent mentioned that "designing for manufacture" or conducting "value analysis" would allow the design department to become more responsive to change. However, these technical terms may be hidden behind the screen of improved communication and awareness.

To conduct value analysis (Value engineering for the development of new products), a company has to establish a team with representatives from design, procurement, production, engineering, marketing and finance. See figure 6.1.

Figure 6.1

Activity Members in a Value Analysis Team



The team has to evaluate everything about the product to determine the most cost effective solution. Wild, (1984), describes the process as :

> "an organised and systematic effort to provide the required function at the lowest cost consistent with specified performance and reliability".

With the change to the cost structure of many products, (see section 5.1.5), the emphasis is moving away from reducing direct labour and directed more towards materials and overheads. Material sciences are becoming a critical part of future product strategies, as new materials and improved use of existing ones such as plastic, metal and ceramics make products more cost effective.

The accuracy and consistency of AMT allows for tighter tolerances and less scrap to minimise material usage. This, to many companies, is an unquantifiable benefit of AMT. However, to attain better results from AMT, changes in the design will almost certainly be necessary. This process is known as "designing for manufacture" and is spearheading companies' drive for further cost effectiveness and improved competitiveness.

One further consideration to be made is with regard to the European directive on "Product Liability" and the Consumer Protection Act 1987. Together, they make manufacturers strictly liable for the products they produce, which cause harm to consumers. This emphasises the need for a well designed product, which is accurately manufactured to specification.

6.2 Procurement and AMT

> "The big three American car manufacturers have realised the importance of having a close relationship with their suppliers. Despite being leaders in their country they have been forced into action by the success of the Japanese car manufacturers in imposing their systems in every country in which they manufacture."
>
> (Economist, 1989)

Building long lasting relationships means a move away from having to have multiple suppliers for each component. There has to be trust and unity, so that component suppliers and manufacturers work together in developing a better strategy, where the synergy acts to give the final product a competitive advantage.

6.2.1 The Evolution of Company and Supplier Partnerships

Prior to 1970, the component suppliers were considered totally independent of their customers creating a divisive and hostile relationship. Battles would constantly be fought on cost, quality and delivery. The result was to encourage manufacturers to produce as much as possible "in-house", and build a network of component suppliers for each part to be purchased. This was a strategic attempt, by the larger company, to pressurise the smaller sub-contractor to manufacture a more competitively priced product.

The British trading systems had many problems creating inconsistency of component parts, as a broad range of suppliers were unable to produce parts to the same tolerances. Consequently, when these parts filtered to the production line some components would fit well, and others less so. Furthermore the low component price reduced supplier's profit margins, and restricted their ability to reinvest, creating a vicious circle of diminishing quality. The circle was only broken when the quantity of trade was threatened by overseas competitors to the larger companies.

The emergence of the Japanese nation, and particularly their industrial practices, has promoted the building of relationships between manufacturers and the goods supplier.

Some of the sample companies surveyed have reduced the number of component suppliers. Even though they may be fewer in number, due to merger or closure, there has been a distinct movement, since the 1970's, in strategy towards single source suppliers. In the other cases, the increase in the number of components supplied to a company is because the product being manufactured is more sophisticated and complex. This results in additional features requiring more components, such as electronic or computerised components.

The advantages of single source supply are numerous. Initially, it allows the two companies to build a partnership, so that personnel representing the different companies can communicate and collaborate. It also means that if the supplier is able to manufacture the product to the right quality, and deliver it to the agreed schedule, then he will be guaranteed the business.

When consumers purchase a product they expect it to be good and work first time. Therefore, with consumer expectations consistently rising it is vital that minimal numbers of rejects pass through the system. Thus, the goods supplier are being made responsible for the quality of the products they make. They are also responsible for ensuring that the correct quantity is delivered on time. The important factor is that the final product is not manufactured by the assembling company, but by a whole chain of companies, working as a team.

Making the goods supplier responsible for the products they manufacture prevents the need for duplication of quality control inspections. However, the goods receiving company often had random quality checks on suppliers to ensure the quality specifications are being maintained. With fewer goods suppliers, any faults that occur can easily be traced to the defective part and then to the supplier, or the production operation.

Penalty clauses in the contracts for reject parts means that it is essential for the quality of every component to be consistent. If any problems persist then it is in the interests of both parties to work to a satisfactory solution. On the whole the process makes the goods suppliers more accountable for the work that they produce, and assists in building a partnership.

Companies do not like to hold excess quantities of inventory because it is unproductive working capital, and takes up space, which could be used for other functions. Therefore, with increased inventory turnover and space, there is less need to hold stock. Pressure is put on the goods supplier to hold the stock, in the knowledge that it will be released sometime, or to have a production system that is able to manufacture the component sufficiently quickly that it, too, can minimise the finished goods inventory. This is the extension of the JIT stock control system and philosophy, (discussed in section 5.1.4), from the main manufacturer to the goods suppliers.

The link with AMT is an extension to section 5.1.3, on the quality of products manufactured. Often AMT will only accept consistent parts, which may require special design features. These can only be achieved if there is a harmonious relationship between the manufacturer and the goods supplier.

6.2.2 British Standard 5750

The other major change during the last decade is company's awareness, knowledge and implementation of the British Standard 5750, titled "Quality Systems". This standard is "a basis for evaluating the capability of a supplier's quality management system ... to provide assurance to interested parties". The standard is divided into three basic parts, which represent the levels of the system for the assurance of quality of material.

A similar European Standard is being directed as part of the negotiations between the twelve member states, in preparation for the 1992 "Single European Act".

The standard makes the supplier responsible for the design, development, manufacture and installation of a product so that it meets the specified technical requirements. It is also responsible for carrying out appropriate inspection and testing of the product.

The advantage to a company, whose suppliers operate BS 5750, is that the company can check that the supplier is operating a specified quality management system, and is conforming to it. It has become so widespread that many companies are now insisting that their suppliers operate BS 5750, which will form part of any business contract. This is further evidence that companies are reacting to quality issues and putting additional pressure on goods suppliers, by making them more accountable for the components they produce.

6.2.3 Communication Between the Company and the Supplier

For the whole system to operate well, all the companies, from the initial component suppliers through to the retail outlets, have to function effectively. This requires a high level of understanding and communication between the different links in the chain. In some cases, the major company in the chain may take a lead, set the example, and assist their suppliers to implement AMT and associated systems.

Assistance could come in various forms. Initially, companies may wish for their personnel to have an understanding of each others operating systems, so that they may appreciate the difficulties and problems to be overcome. The process is helpful in agreeing deadlines and quantities, and in establishing "points of contact" within the company, where problems can be discussed, perhaps in the modification of a component for a new product.

The partnership could be extended further by sharing and collaborating on new investments in AMT, CAD and computerisation in general. This would be a transfer of "experience" to improve the system as a whole. One company visited has asked all its suppliers to purchase the same CAD system, so that drawings could be passed quickly without the delay and inconvenience of obtaining and posting printouts.

One other company has gone a stage further than this. Its suppliers (and retail outlets) have compatible computing systems, but it has also introduced its computer integrated business system, so that its sales men and retail outlets can record actual sales using British Telecom's Electronic Data Interchange (EDI) system, "TRADANET". Thus it can automatically inform not only the main manufacturer that a sale has taken place, but also their suppliers. With the JIT concept in operation, the supplier knows that, (unless otherwise instructed), the company will require one further component.

The research has observed that companies often make detailed plans for the actual installation of AMT. However, they rarely pay sufficient attention to the business as a whole. For AMT, and all the production equipment to perform optimally, there has to be a change to the traditional perceptions and attitudes on inter-business relationships. This section highlights the need for consistent components, not only for AMT to operate more efficiently, but also in assisting the company to meet its objectives.

6.3 Impact of AMT on Marketing

The section discusses how some marketing departments have been able to use the attributes of AMT to promote the sales of their products. In most companies AMT is used to manufacture a product (or give a service), which is more marketable to potential customers.

The product life cycles, (PLC), are then analyzed to see how the intelligence attained can be used by manufacturing departments, when deciding on the most appropriate form of process technology. In addition, the need for close communication between marketing, manufacturing and design are highlighted, as they all need to work towards common goals.

6.3.1 Marketing and AMT

Some companies have actually used AMT to promote the sales of their products, (one of the first being the television advertisement for Fiat cars, in the early 1980's). In these instances the corporate image they wished to portray was complemented by the esteem value of AMT. Companies, whose products require vigorous testing, and where consistency and reliability are order winning criteria, are also in this category.

For the majority of companies, AMT is not used as a direct selling function. However, potential customers can only be impressed if they visit a manufacturing plant that appears to be well managed and organised with sound investment in AMT. This once again indicates that AMT alone is of limited use, but, when included as a package of measures, it becomes highly effective.

When customers purchase a product, the precise details of how it is manufactured is not usually of direct concern. However, companies naturally use the advantages given to them by AMT to promote their product. Such advantages are in quality, (via user guarantees), batch size, shorter delivery times and lower cost. The actual size of the benefits to be gained will depend on the success of the implementation.

Even though few companies use AMT as part of their marketing strategy directly, a greater proportion use its attributes to promote their products. Half the companies surveyed have adopted AMT for the simple replacement of existing manufacturing machines. The other half have implemented AMT in a specific attempt to broaden market diversification, and increase production.

The research observed that the marketing departments had little direct input into the selection of any new technology. However, those companies, who had established "steering" committees, usually had a marketing representative, responsible for providing vital information on sales, product life cycles, future sales forecasts and of proposed new product ranges. These factors emphasise the vital role to be played by marketing personnel, in ensuring the most appropriate equipment is purchased for the forecasted product ranges and volumes.

It appears that only those companies, who manufacture large volumes of standard products, have been able to utilise AMT to their advantage when entering new markets and increasing volumes. The remainder have generally used AMT as an internal tool to reduce costs. However, those companies whose competitors are from overseas or who need to export, have additional problems with the relative prices of products, due to currency fluctuations.

6.3.2 Product Trends and Product Life Cycles

Irrespective of the volume of manufacture and of forecasted future sales, all the sample companies are broadening their product ranges. This is mainly achieved by increasing the number of variants possible on a fixed set of basic products, as observed when purchasing products such as motor vehicles and tractors. Mather, (1985), described this as the "funnel effect", since many of the variants were added late in the production process, and usually in final assembly. Those companies, who were broadening their product range, were seeking to expand their businesses.

Due to the consumer demand for greater variation in product, the product life cycles have, in general, been declining. This has been made possible by the more responsive manufacturing methods, such as AMT, which allow changes to be made more easily, and reduce product lead times at minimal cost. Furthermore, the shortening lead times in developing new technologies also add to an increase in the rate of change of new product introductions. In seven out of the 20 companies surveyed, AMT could be highlighted as being a contributory factor in the development of new products.

In contrast, the "life span" of the products manufactured have lengthened. This is due to the combined effect of improved design, use of materials and manufacturing techniques. Section 5.1.3 described how new manufacturing systems and AMT have increased the quality, consistency and reliability of product and consequently lengthening their life.

Most products exhibit a similar pattern when their profit and volume histories are plotted. Initial high costs and low volumes reflect development and launch costs along with production inexperience. Then, in time, volumes increase, unit costs fall and profit margins rise. Once competition has been established, prices and profit margins are lowered to maintain sales. In addition, as volumes begin to fall, overheads have to be spread over a smaller range. This was illustrated in figure 4.4.

Every company's sales and marketing departments monitor the product life cycles. They also try and forecast future sales volumes. This is naturally complicated by any predictable seasonal and cyclical variations, and by unexpected variations. Thus any forecasting model, predicting future demand, has to have a range of values or possibilities to account for variability and uncertainty.

The major problem, within companies, is the communication of this intelligence and information to other functions of the business. Production engineers and controllers persistently complain about the inaccuracy of short and long term production forecasts. This, naturally, makes the planning and selection of new AMT more difficult.

It is therefore critical to forecast accurately future demand changes, so that production may change its operations to match the forecast. Optimistic predictions, plus a contingency, leads to poor, inadequate forecasting and over compensation by production for process facilities. Work by Freeman, (1982), and Duijn, (1983), show that product life cycles can have four scenarios as shown in figure 6.3(1). These are i. Abolition, ii. Substitution, iii. Extension of Maturity and iv. Extended Life cycle.

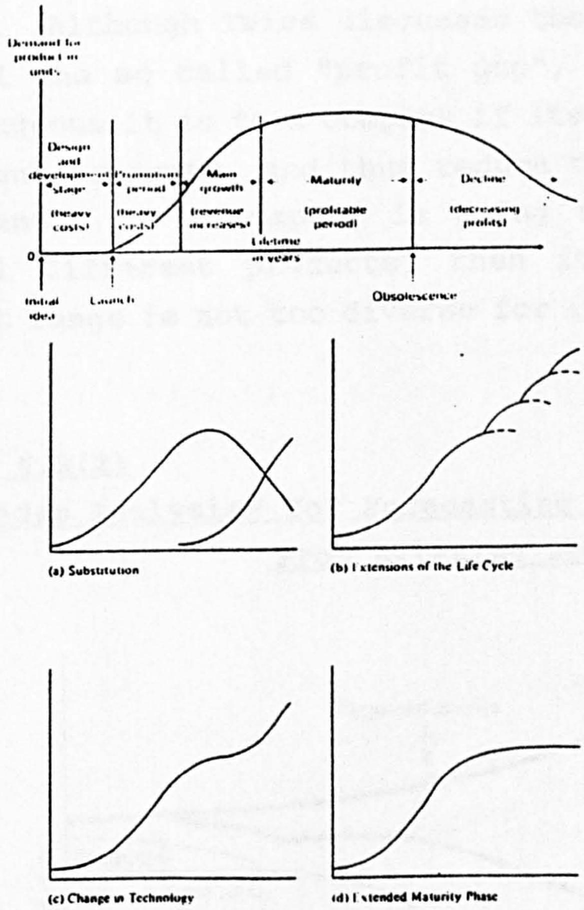
It is important to try and predict the changes to the PLC, so that the company is able to plan and manage the change. One has to :

i. anticipate the introduction of new technologies,
ii. estimate the rate that new products are likely to appear,
iii. estimate the rate at which new products are likely to reach the market,
iv. decide when to enter the market with a competitive new product.

When a new product is to be launched it is necessary to decide which stage of the process should be automated (if at all). It is believed that the "infancy" stage is one, where manual production is used and teething product problems are solved. New advanced manufacturing technologies are only fully utilised during the "maturity" stage, as described in section 5.3.5.

Figure 6.3(1)

Four Variations to the Product Life Cycle



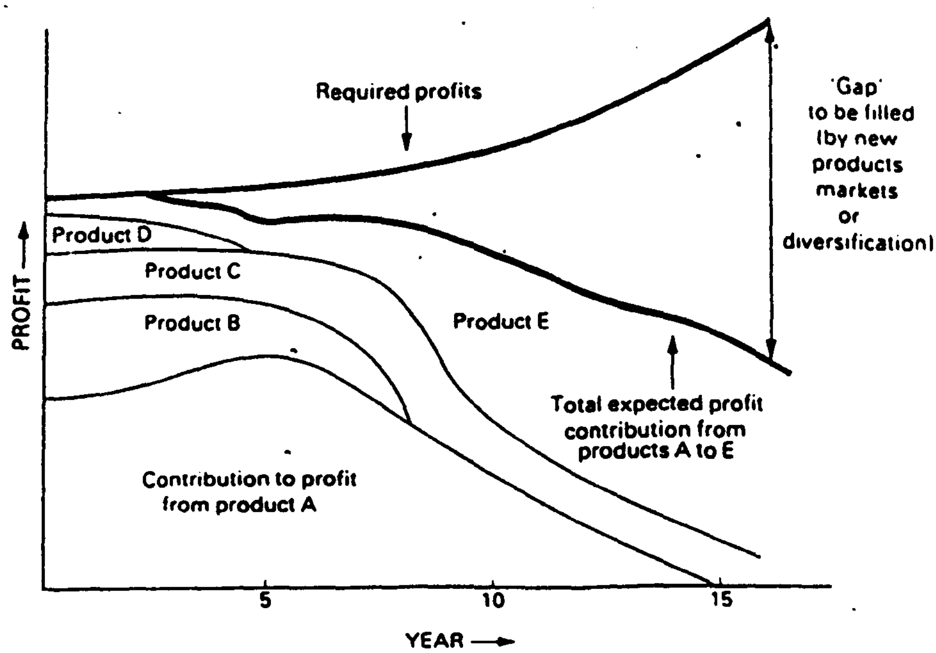
Source : Duijn, (1983), and Evans and Ford, (1984).

This link, between the PLC and new technology, could not be established, since all of the sample companies surveyed had established products. New products result from any one of the four factors concerning the extension of product lives. This research observed that AMT was being adopted at different stages of a product life cycle and that it was beneficial to a company, if it was able to convert its technologies, to produce more than one product.

Few companies (and none of those surveyed) were single product companies. Therefore, the companies' sales and profits were generated from several products, each of which may be at different stages of their PLC. The corporate strategy of the company should identify the required mix as shown in figure 6.3(2). Although Twiss discusses the R & D strategies required to fill the so called "profit gap", it can be easily seen how advantageous it is to a company if its AMT is able to manufacture different products, and thus reduce the need for duplication of equipment. If a company is going to use its AMT to produce several different products, then it has to ensure that the product range is not too diverse for its chosen equipment to cope with.

Figure 6.3(2)

"Gap Analysis" for Forecasting Profit Contributions From Existing Products



Source : Twiss, (1986).

From the "Design" questionnaire, (see Appendix I), there were three questions relating to PLC's. The first asked for the average product life cycle for their company, and the responses are shown in table 6.3(1). The information clearly shows that there is an even distribution across each of the categories with a mean time of 13.4 years. There was a question to try and establish whether PLC's were increasing, not changing or decreasing. Table 6.3(2) shows that, in half the companies, the PLC's are not changing. The research then tried to see if those companies, who had automated, were different from those, who had not. However, the chi-square test score of 2.00 resulted in accepting the null hypothesis that AMT has no significant effect on the PLC.

Table 6.3(3) shows the responses for the frequency of new product introductions. Here there is a distinct peak in the 2-4 year range, where 43.5% of the responses fell. The mean time for a company to introduce a new product is 3.3 years. Therefore the mean number of products per company is 13.4 / 3.3 = 4.1. With the mean number of models manufactured being 55.3, the mean number of models per product is 55.3 / 4.1 = 13.5.

In addition, the mean time companies plan into the future is 7.2 years (median and mode being 5 years). This would suggest that the average planning cycle lasts a little under half a PLC (13.4 years), or two product introductions (3.3 years each). However, in the majority of cases, where a 5 year plan exists, the planning cycle lasts for a third of a PLC, or 1.5 product introductions.

The mean time for respondent companies to design and manufacture their last product was 2.5 years. This is 0.8 years less than the mean frequency for new product introductions, and may indicate that companies are becoming more efficient at introducing new products.

Table 6.3(1)

Product Life Cycle Durations

Range (years)	Frequency	Percent %
Less than 5	8	15.4
5 < x < 10	14	26.9
10 < x < 15	8	15.4
15 < x < 20	6	11.5
20 < x < 25	9	17.3
More than 25	7	13.4

Mean = 13.4 years

Table 6.3(2)

Changes to the Product Life Cycle Durations

Response	Frequency AMT	Frequency No AMT	Frequency Total	Percent %
Decreasing	7	7	14	26.4
No Change	18	9	27	50.9
Increasing	10	2	10	22.6

Table 6.3(3)

Frequency of New Product Innovations

Range (years)	Frequency	Percent %
Less than 2	13	28.3
2 < x < 4	20	43.5
4 < x < 6	9	19.6
More Than 6	4	8.6

Mean = 3.3 years

6.3.3 Compatibility Between Design and Marketing

There were two further questions designed to see if the design features of the companies products matched their perceptions of why the customers bought them. Respondents were asked to rank seven design features and the same number of similar market features. The results are shown in table 6.3(4).

The primary market feature (ie what the respondents believe their customers look for) is that of price and is followed by quality and functional value. However, the respondents (mostly design engineers) ranked quality as the primary design feature, followed by practicality, and cost. With the exception of cost and price, the rank of the other design and market features were identically matched.

Table 6.3(4)

Compatibility of Product Design and Market Features

Design Feature	Rank	Mean Score	Mean Score	Rank	Market Feature
Cost	3	3.4	2.4	1	Price
Quality	1	2.4	2.5	2	Quality
Practicality	2	3.3	2.8	3	Functionality
Manufacturability	4	3.8	3.5	4	Availability
Material Used	5	4.7	4.5	5	Material Used
Appearance	6	5.0	4.9	6	Aesthetics
Novelty/Original	7	5.2	5.9	7	Novelty/New

This would indicate that the company designers and engineers design for what they call quality, and not for what they perceive their customers want, which is cheapest price. This potential conflict between cost and quality is an important issue. The dilemma, (as described in section 5.1.3), is that the addition of quality features, such as reliability, usually adds to the cost.

It is important for companies to distinguish clearly between market qualifying criteria, and order winning criteria. The balance between quality and cost could be referred to as being "value for money". To qualify for a market, the product has to have a quality level equivalent to other competitor products. By achieving this level, Hill, (1987), believes that orders will not be lost. To win additional orders the companies must compete on price, delivery and other factors, such as the company's esteem value or extra product functions.

The problem often arises when a competitor company raises the quality of its product, and increases the "value for money" concept for the customer. In order for the other companies to remain in the market, they will have to raise their quality level. This is prior to competing for actual orders.

The 20 companies surveyed had difficulty in identifying their market qualifying criteria and order winning criteria. Since 19 of the 20 companies were actually manufacturing a product, their qualifying criteria was to manufacture a functional product to the necessary specifications for dimensions, performance and reliability that gave "value for money", as they themselves perceived it. The 20th company was a sub-contract engineer, where the above criteria can be related to the services offered to their customers.

The order winning criteria mainly revolved around the price and delivery deadlines. However, it seemed that many of the staff were oblivious to the style of visual products, reputation, image and the service the company may offer. Without clear, precise statements of a company's market qualifying criteria and order winning criteria, the designers and marketeers are likely to be incompatible and working towards different goals.

Appendices IV and V describe the characteristics of the companies surveyed, and the products or services they sell. There seems to be a difference in the marketing strategies adopted depending upon whether their products are sold to a specific company or to a market in general. The heavy engineering industries, with their jobbing shops, where products are made to a specific customer order, are likely to use the high precision qualities of AMT in promoting their products. In contrast the higher volume lighter engineering companies will give AMT a higher profile in promoting its consistency and flexibility.

This section has illustrated the need for marketing departments to communicate with production, to ensure that the most appropriate process technology is purchased for the intended product range. Once again the departmental strategies and tactics have to complement each other in order for the objectives of the company to be met.

6.4 Maintenance and AMT

Often the importance of maintenance costs and strategies are overlooked in many companies. One definition of maintenance for a manufacturing company is given below.

> "That set of activities, the aim of which is to ensure that the buildings, plant and machinery of an organisation are kept in such a condition that they can continue to carry out their required functions satisfactorily"
>
> (Evans and Ford, 1984)

This section discusses the maintenance dilemma faced by manufacturing companies and is followed by a discussion on the opinions of the suppliers of computerised maintenance systems. The maintenance strategies are then studied to see whether the key issues have been adopted by the companies surveyed. Finally the research looks at the impact of AMT on maintenance strategy and how it affects the dilemma.

The objective of preventative maintenance, as described by one of the suppliers of computerised maintenance systems, is :

> "to ensure that the correct inspections are carried out at the right time, and that appropriate actions are taken by the correct personnel, so that developing faults can be detected early enough to avoid secondary damage, with its associated long down time and high repair costs."
>
> (Idhammar Management Systems Ltd)

The equipment has also become less standardized and more technically complicated. It requires multi-skilled engineers to service it, since any problems may require a combination of electrical, mechanical and electronic expertise to solve them. The standard, stand alone AMT machines are more reliable, and require less provision for maintenance than conventional equipment, although, in this latter situation, companies often try to extend the life of their conventional machines beyond their intended limits.

Some larger AMT installations, and the early FMS in particular, have had many teething problems. This reflects the Weibull distribution model, (described by Bestwick and Lockyer, (1982)), for the frequency of breakdowns. There are other complications to add to a maintenance strategy. Companies need to distinguish maintenance of the actual AMT machinery from the general maintenance of the production line and factory facilities.

6.4.1 Questionnaire Responses on Maintenance

In addition to the questions asked of the 20 companies surveyed concerning their maintenance strategy, the Pemec'87 exhibition (NEC Birmingham, September 1987) provided the opportunity for similar questions to be asked of the suppliers of computer maintenance systems. The questionnaire displayed in Appendix III, and the results from the 17 (from a possible sample of about 25) respondents are summarised in Table 6.1.

The most important factor in any company's maintenance strategy is to operate production at the lowest overall cost. This was rated the primary priority by 70% of the respondents, which corresponds to a mean score of 1.41. There was only a slightly lower mean rating, of 1.65, to the priority of minimising the down time of the machinery (1= Important, and 5= No Importance).

The remaining three factors of safeguarding the firms assets, prolonging the life of the asset and reducing accidents had an average level of importance of around 2.5. This shows that there appears to be a distinct short term emphasis on company's maintenance strategies. It may also indicate that companies tend to use machine utilisation rates and enforced down time as the main measures of maintenance performance.

The importance of the maintenance strategy, within an overall corporate strategy, resulted in a mean score of 3.18 , with half the respondents electing 4. This would appear to show that maintenance is not rated as highly as other functions such as finance, sales, marketing and manufacturing. The reason is probably due to the fact that maintenance is not perceived to have a direct impact upon the company's trading position or operations. Indeed, in the short term, it will sometimes appear as an unnecessary and over resourced cost. However, its undoubted value must be in the long term a reduction in down time costs. Many respondents did comment that maintenance was becoming more important as companies took a longer term outlook, and a systems view.

The importance placed on maintenance in the design of automation and AMT was given a mean score of 3.12. This is below the average, and indicates that the functional design of the machine is of greater importance than its maintainability.

It was claimed that 50% of companies adopt a policy of repair only when the machine breaks down, with 30% having "stand by" or replacement machinery. However, 50% of respondents said that preventative maintenance should be adopted in the future, whilst a further 37% said that greater flexibility of production lines, such as "extra routes", would alleviate some of the maintenance problems. This would suggest that nearly all respondents expected changes to be made to maintenance strategies some time in the future. Questionnaire respondents claimed that:

1. 16% over maintained their equipment,
2. 65% did not conduct systematic training programmes,
3. 39% gave complete job descriptions to their employees,
4. 77% under estimate the value of a comprehensive maintenance strategy.

The above information gives a clear indication that companies give maintenance a low priority and that systematic training programmes, complete job descriptions and a comprehensive strategy might have helped to redress the balance.

The major problems in maintaining automation and AMT drew a large and varied response (see Appendix XV). These could be divided into five categories: Manpower, Information, Resources, Management and Equipment. The major problems were that of managing the maintenance team and the implementation of the equipment. Then there were the problems of having the manpower available, of the required skill level to maintain the equipment. Finally, another problem related to the lack of information and documentation required to maintain the equipment.

Other problems relating to resources and equipment, such as the compatibility of the systems, were less frequently mentioned. However they would have to be considered as part of an overall maintenance strategy. This may suggest that the failure of automation is due to the peripheral and accessory equipment, and not the AMT itself.

Good maintenance engineers must be technically competent. This will require them to be well trained and multi-skilled. In addition they must be able to diagnose faults quickly, communicate with other people, and, where possible, solve the problem. The individual responses to the questionnaire are given in Appendix XVI.

Respondents felt that the training of a maintenance engineer should be more practical and with less emphasis on theory. The mean score was 2.4 (1 = Practical, 5 = Theoretical), with an even distribution of responses across the scale. This implies that there are different strategies adopted for the theoretical content in training courses.

The respondents believed that about half of the training should be carried out "in-house", and a third at the equipment supplier's. Only occasionally were educational establishments and professional institutions mentioned as possible places for training. This clearly reflects the belief that a greater proportion of the training should be practical, as suppliers courses are often more theoretically based.

It is claimed that, on average, it takes 5 years to train a maintenance engineer and that the annual training time per year should be more than 16 days spread over the whole year. On average, £1,600 is spent annually on an engineer's training courses each year. This amounts to a daily cost of about £100 but the real cost, when lost production, expenses and wages are considered, is much greater.

The proportion of men trained to be maintenance engineers varied considerably. Some respondents felt that every employee should be trained, whilst others believed that, with greater equipment reliability, a lower proportion was needed. From the sample of companies surveyed, it was observed that some companies expected the machine operators to carry out routine maintenance, leaving a smaller maintenance team to concentrate on the main breakdowns and special service tasks.

Table 6.4
Summary of Response to the Maintenance Questionnaire

Description of the Question	Response
1. *Components of the Maintenance Strategy:	
i. Operate at lowest total cost	1.41
ii. Minimise down time	1.65
iii. Prolong the life of the assets	2.41
iv. Reduce accidents	2.76
v. Safeguard the firms assets	2.76
2. *Corporate Importance of Maintenance	3.18
3. *Maintenance considerations in the design of AMT	3.12
4. Past Maintenance Strategies:	
i. "Breakdown"	50.0%
ii. Planned or Preventative	15.4%
iii. Other	34.6%
Future Maintenance Strategies:	
i. "Breakdown"	3.8%
ii. Planned or Preventative	46.2%
iii. Other	42.3%
5. Problems in Maintaining Automation and AMT:	
i. Management	29.2%
ii. Manpower	25.0%
iii. Information	20.8%
iv. Resources	12.5%
v. Equipment	12.5%
6. Characteristics of a "Good" Maintenance Engineer:	
i. Technical Expertise	40.7%
ii. Managerial Skills	22.2%
iii. Equipment Diagnostics	14.8%
iv. Communication	14.8%
v. Business Understanding	7.4%
7. Proportion of Engineer's Training takes Place:	
i. "In-house"	51.6%
ii. Equipment Suppliers	31.3%
iii. Educational Establishments	10.9%
iv. Professional Institutions	9.4%
8. Mean Time to Train a Maintenance Engineer	5 years
9. Number of Days spent each year on Training	16 days
10. Money spent each year on Training each Engineer	£1,600

* Questions where the Mean Score scale is from
1 = Important, to 5 = Not Important

6.4.2 Companies Maintenance Strategies for AMT

The majority of companies would describe their maintenance operations, prior to the 1980's, as being over staffed, and where the engineers would only attend an actual breakdown. Restrictive practices and demarcation lead to single skilled engineers, who would only carry out one set of tasks leading to an excess of manpower resources.

Large redundancies, especially within the labour intensive industries, and more cross trade working have significantly reduced the size of maintenance teams. However, the "breakdown" strategy still remains, where machines are only maintained when they have actually broken down. This line of thought existed in half the companies surveyed.

For the actual AMT cells, the number of companies operating a planned preventative maintenance strategy was 75%. This is a further example of investment in AMT leading companies to review their manufacturing operations. One consequence has been the new labour agreements ,as described in section (5.2.1), in which the machine operators do routine cleaning and checking. The introduction of "quality circles" has made operators more aware of the need for the machinery to operate optimally. In addition, by taking more care of the work done, and with a greater flow of information, the employees know when a machine is not performing to specification.

Many AMT suppliers give the company detailed programmes on what routine maintenance needs to be carried out and on the frequency. They will also train the maintenance engineers to carry out these tasks, since it is in the interests of the suppliers and the users not to keep large task forces on stand by in order to conduct routine jobs. However, the suppliers have to make engineers available for the more difficult jobs, and usually guarantee a 24 hour attendance service.

Companies now appreciate that their key machines have to be kept running to tighter schedules. This is emphasised by the need to reduce lead times, and penalty clauses for late work. It is then critical to maintain the machines when they are not actually being productive, usually in the evenings or at weekends.

Some AMT, especially the FMS, requires the constant attention of well trained personnel. However, in general, with the increased reliability of AMT, there is less need for large maintenance teams. Indeed some companies claim that more maintenance work is needed on the factory services than on the machines.

This often leads to distinctions being made within the maintenance departments. Those staff, who wish to be highly trained and multi-skilled, are designated tasks concerning the machinery. The remainder will be employed on factory facilities. Every maintenance engineer will have there programme to carry out routine maintenance. However, there has to be a contingency for the unexpected breakdown, and a capability for staff to give such breakdowns a higher priority than routine work of a preventative type.

The impact of AMT has been to focus the attention of management on :

i. increased reliability of machinery, which requires less attention and maintenance,
ii. increased opportunity cost of non-productive time, especially when the manufacturing operations work around the clock,
iii. increased cost of calling out the machine suppliers,
iv. maintenance training, despite the varied interpretations.

It is important for companies to have a flexible maintenance strategy that does not have over rigid rules. The strategy has to be formulated, so that the maintenance resources applied to each machine match the failure profile of it. Therefore, each machine has to have its allocation of resources, and the size of the maintenance team should match the adoption rate of the new technology. It is inevitable that companies will have to make provisions for "breakdown" maintenance.

Some companies are now using the computerised maintenance systems in their manufacturing operations. They have enabled the maintenance personnel to focus their attention on the existing procedures and practices, and how they should be carried out in the future. The more comprehensive software packages cost around £15,000, and include modules on the following :

i. Schedule maintenance.
ii. Management of stock control for holdings and purchase ordering.
iii. Maintenance statistics and staffing levels.
iv. Logging of the existing tool machines and plant histories.
v. Forecasting future maintenance events and staff workload.
vi. Compiling and updating a comprehensive asset register.
vii. Costing all aspects of maintenance and providing budgetary information.
viii. Allowance for breakdown and unplanned events.

6.5 Integrating Business Information Systems

The resources available to a business have to be managed, through a number of activities, to manufacture the product, and meet the company's objectives. The two previous chapters have discussed the resources and the activities of a business system respectively (also see section 2.3), and have concentrated on how they affect, or are influenced by automation.

The development of an Integrated Business Information System, (IBIS), has been assisted, through the capability of computer technology, to collect and process large quantities of information quickly and accurately, and by commercial pressures to become more competitive.

The introduction of an integrated business system, within a company, has to be addressed at a strategic level by the highest management. When implemented, the system will encompass the whole business allowing management to control and plan the resources and activities. It is therefore critical that there is a consistent approach, understanding, philosophy and culture throughout the organisation.

A.T. Kearney's recent survey, (1989), shows that, in spite of the great interest in IBIS (sometimes confused with Computer Integrated Manufacture (CIM)), few companies have addressed the issue at a strategic level. Consequently, implementations have been limited in scope and scale, and have failed to deliver the benefits in those areas judged to be most important for competitive advantage.

6.5.1 Components of an Integrated Business System

In business, products are always sold to a customer whether it is the final consumer directly, or through an intermediary. The output of one system is the input to a succeeding system. Many see their customers as being the strategic end point of their system. The description given below of an IBIS has been modified from a system that was in operation at surveyed company 4.

The link with the customer is usually a salesman, who takes the orders and relays them back to the central planners. Information from many salesmen and orders then initiate the integrated marketing system. The orders are processed so that the quantity of each product is known. This information is then passed to three other centres, namely distribution, forecasting and marketing intelligence planning.

The distribution system controls all products that are kept in stock and, with knowledge of what is being manufactured, can give the salesman an immediate answer on the delivery date to a customer order request. Key factors in delivery are the geographical location, the customer type and the availability of transport.

The market intelligence and planning systems included three years of historical data on customer orders and competitors. This data goes into a central database which monitors the trends to individual products and the market, and have to ensure that the company has the right products in the right place at the right time.

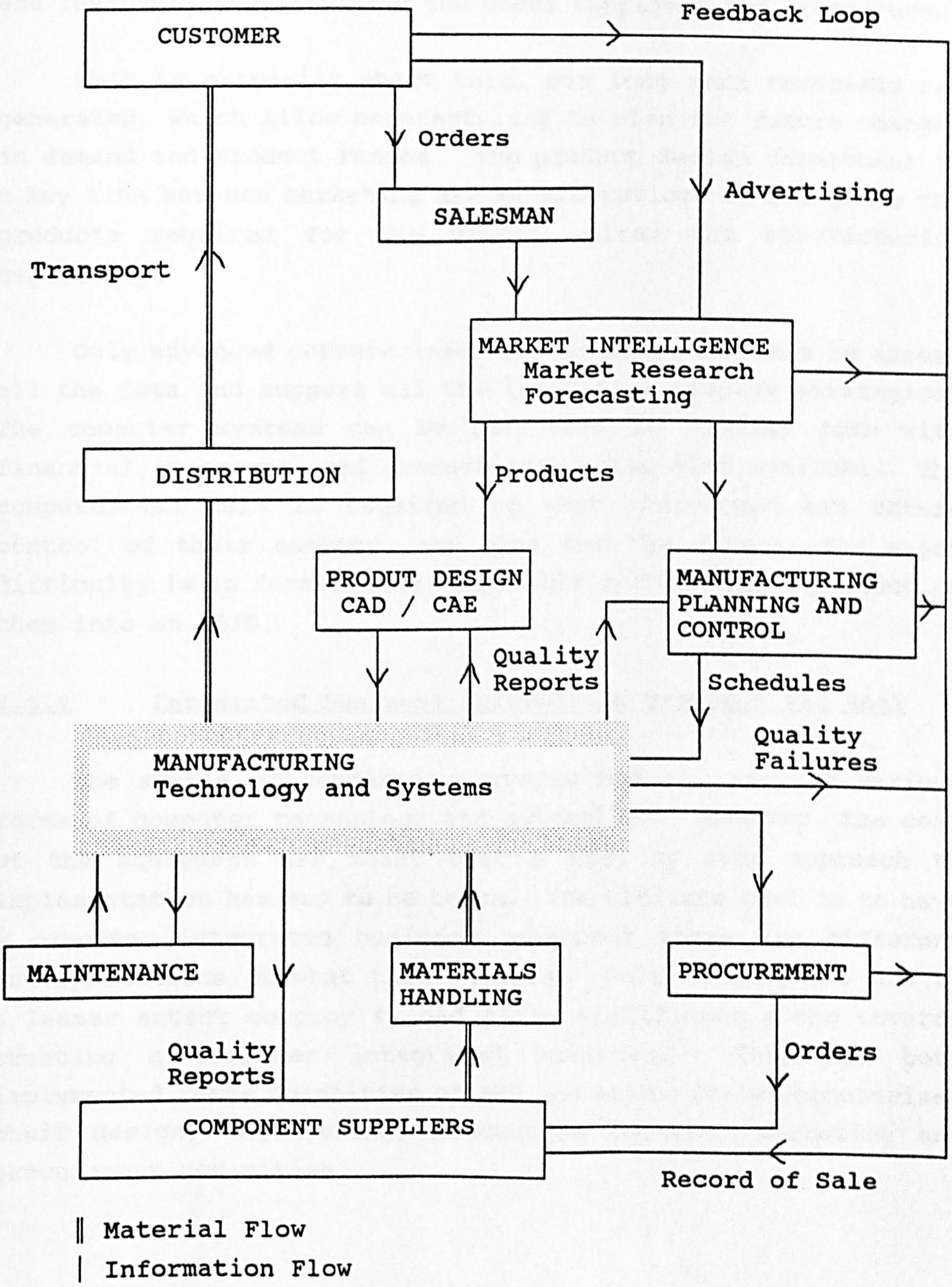
The planning and control activities are at the core of business operations. Computer Aided Production Management (CAPM) systems are capable of providing the informational link between production, component suppliers and customers (see figure 6.5(1)). Communication of delivery dates, quotations and production schedules are provided by EDI systems such as "TRADANET".

The third destination of the order information is to forecasting and inventory control that calculates the flow of products required to satisfy demand. This information is used

Figure 6.5(1)

Integrated Business Information System

Material and Information Flows



by the manufacturing planner who decided on the production schedules. This now starts the integrated manufacturing system. Using the information processed in the marketing system and a common data base, manufacturing is able to decide on batch sizes and inventory required from the goods suppliers and stock rooms.

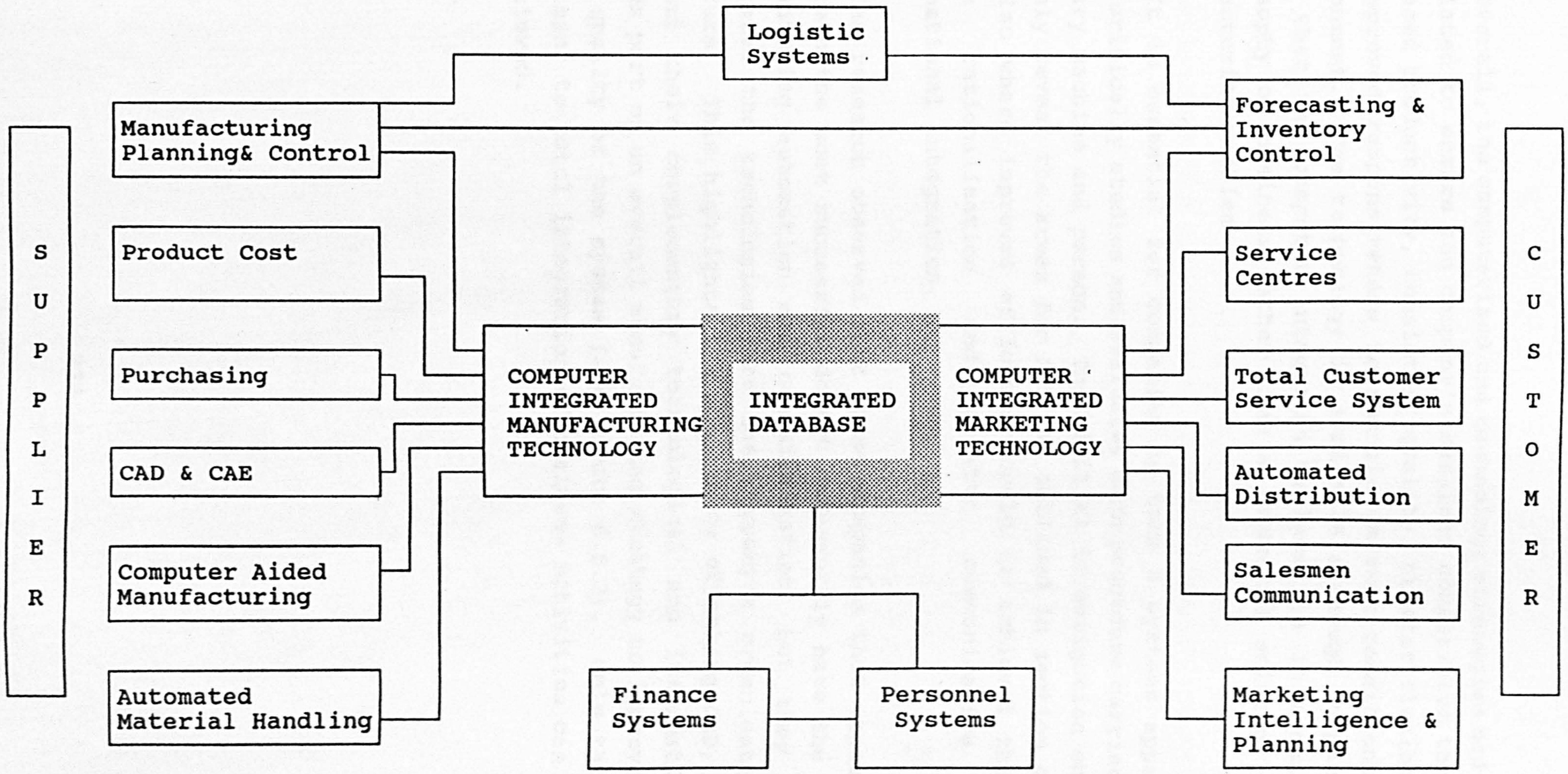
This is primarily short term, but long term forecasts are generated, which allow manufacturing to plan for future changes in demand and product ranges. The product design department is a key link between marketing and manufacturing, by designing the products required for the market, given the manufacturing capability.

Only advanced computerised systems have been able to assess all the data and support all the individual company strategies. The computer systems can be purchased in modular form with financial, personnel and product cost units also available. The computerised IBIS is required so that management can obtain control of their company, and plan for the future. The major difficulty is in formulating compatible systems and implementing them into an IBIS.

6.5.2 Integrated Business Information System - The Goal

The sample of companies surveyed had all adopted various forms of computer technology and automation. However, the cost of the equipment has meant that a step by step approach to implementation has had to be taken. The ultimate goal is to have a computer integrated business, although there are different interpretations of what this entails. Only company 11, and to a lesser extent company 4, had taken significant steps towards creating a computer integrated business. They had both implemented large quantities of AMT and extensively computerised their design, engineering, production control, marketing and procurement activities.

Figure 6.5(2) Components of a Computer Integrated Business System - Company 4



Overall, the computerised and technology strategies had been formulated to ensure the company's remained competitive through increased productivity, consistent quality, greater flexibility and improved responsiveness to changing market conditions and environment. The technology is available although company 11 claim that the computer integrated business is in essence a philosophy of business rather than a technical solution to a manufacturing problem.

It is essential for companies to take a systems approach which critically studies and evaluates each procedure carried out by every machine and person. This initial investigation should not only reveal the areas for AMT (as outlined in section 4.1), but also where improved efficiency could be achieved through simple rationalisation and greater communicative and informational integration.

The research observed that those companies that appear to have been the most successful do not necessarily have the most manufacturing automation and computerisation, but they have integrated the techologies into the company's organisational structure. This highlights the importance of making CAD, CAE, AMT and their complementary technological and informational systems part of an overall manufacturing strategy to improve the total quality of the system (see figure 6.5.2). Only through commitment to total integration of business activities can this be achieved.

Summary

The adoption of AMT and CAD are only two parts of a business's drive for improved effectiveness and competitiveness. However, they are frequently central to company's objective of achieving "Total Quality" and obtaining customer satisfaction.

Chapter 6 has focused on four non-manufacturing activities of a business, which are affected by the implementation of AMT. The implications for maintenance, procurement, marketing and product design illustrates the breadth of the impact, which large quantities of AMT have on a business. It is important for individual activity's strategies to complement the overall business strategies to optimise the system as a whole, and not its sub-systems. This process has been assisted by the development of computerised Integrated Business Information Systems, which are capable of collating and analyzing large quantities of data, quickly and accurately.

The adoption of AMT has often resulted in the simultaneous development and rationalization of product designand simplified the manufacturing processes. This advance in manufacturing has directly benefited the marketing activity. In addition the combined affect of the existing competitive environment and computerisation has resulted in greater collaboration with component suppliers and higher machine utilization.

Chapter 6 References

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CHAPTER 7

EXTERNAL INFLUENCES ON THE SYSTEM

Chapter 7

External Influences on the System

7.0 Introduction

The preceding chapters discussed the activities, resources and their relationships, within a company adopting AMT. These factors are all functions that are within the control of the management and their employees. Together, they manage and operate the internal objects of the system.

However, as mentioned in chapter 2, there are factors, such as global competitors and the national economy, which are out of the control of the individual company, yet can influence management decisions. These features will be referred to as the "Environment". The research identified four business environment issues that affect each of the 20 companies surveyed.

Firstly, there are the manufacturers and suppliers of the AMT equipment. The relationship, that is developed, is a key criterion for the successful implementation of AMT. The opinions of both the suppliers and the users are critically examined.

Finance is a key factor for every company. The study concentrates on the forms and sources of finance that are available to both AMT manufacturers, and users, and not on the financial structures of the sample companies. Consideration is also given to the internal accounting systems and the validity of corporate reports, as these measures are used to justify projects and determine the suitability of a company for funds.

Investigations were also conducted into the role of the Trade Unions, who can be influential both within and outside the company's boundary. On a national level, opinions of the regional Trade Union officials are collected; and the impact of this Government's actions are also reviewed briefly.

Finally, the government's related fiscal measures are reviewed, since political administrations are usually blamed for anything and everything that goes wrong. The research focuses on the industrial grants, and support that is available for both the AMT suppliers and users.

7.1 The Suppliers of AMT Equipment

The role played by the suppliers of AMT equipment is naturally of importance in the development, implementation, and success of such technology. Although it was not intended to carry out detailed research into the AMT supply industry, its critical nature meant that some study was inevitable.

First contact with personnel from the supply industry was made at the biannual "Automan" Exhibition, Birmingham in 1987. This was sponsored by the BRA and had over 450 exhibitors. Most of the world's suppliers of AMT were represented, along with consultants, integrators, the professional institutions and the manufacturers of accessory equipment.

The aim of the four day visit was to :

1. gain an understanding of the industry,
2. witness the capabilities of some of the AMT equipment,
3. discuss the various strategies adopted when implementing AMT,
4. establish the problems that a potential user has in choosing and selecting the equipment suppliers,
5. understand the limitations of the different types of equipment.

The initial survey of 45 exhibitors covered a cross-section of the different types of supplier. Discussions with them were informal and the following opinions expressed represented more than two thirds of the respondents, unless stated otherwise. Following the exhibition five suppliers of AMT were visited. The purpose was to discuss, in greater detail, the findings from the exhibition and to pilot a questionnaire, which would be targeted at the AMT manufacturers and integrators.

7.1.1 The Structure of the Industry

Research, by White, (1984), showed that 13 UK based robotic equipment suppliers employed a total of 476 people. The proportions engaged in the categories of R&D, manufacturing and others were 27%, 36% and 37% respectively. The R&D personnel for the whole of British industry is only 2.5% of all staff, so this emphasises the early stage of robotic development. The research questions the length of time robotic companies can carry on spending large sums of money on R&D without increasing sales.

White also shows that all but one of the UK's large companies have benefited from licence agreements with at least one foreign company. The immaturity of the industry is also illustrated by the number of company takeovers that have occurred. In addition, with such a broad area to cover, many of the smaller companies chose to specialise in applications where the competition is less severe, but where expertise is still at a premium. One such example is Lamberton Robotics, who also follow the Japanese approach, by working closely with their customers to develop systems for specific applications.

Prior to 1987 there were turbulent times for the world's robot manufacturers, as Dainichi Kiko (Japanese) went bankrupt, GM Fanuc reduced its workforce, Thorn EMI stopped its robot division, whilst Westinghouse reorganised Unimation, and Welding Robotics and Automation were only saved when they were bought out by Cloos, (Automation, 1987).

Information from the BRA shows that there are around 100 manufacturers of robotic systems and their accessory equipment in the UK. In addition, there are nearly 150 agents and integrators, with approximately 50 involved in education, or research, and a further 40 companies classed as robotics consultants.

When matched with the official information published each year in "Robot Facts", (BRA, 1986, and 1987), regarding the cost of systems purchased, it is clear that most of the UK manufacturers only produce the small robots (ie valued less than £20,000, as outlined in section 2.2).

This research has identified four categories of supplier.

1. The large suppliers, who have generally grown from large electronic or automotive companies, and who are concerned primarily with supplying the large industrial robots (which tend to be relatively slow). These companies have the financial and R&D resources, and expertise to develop their equipment, usually at high cost.
2. Smaller suppliers of AMT, who have less financial backing, and who offer proven, simple and modular systems.
3. Companies that manufacture AMT under licence from a large overseas supplier.
4. The companies who adapt basic systems from a variety of suppliers, in order to build to a specific system.

Companies rarely have the ability to provide complete systems, and often need to collaborate with fellow suppliers. However, there are intermediaries often known as integrators, who will act as a "go between", and organise several suppliers to provide a complete system. They will usually obtain commission on the equipment they sell and organise the service contracts. Clearly there is much potential for design error and cost enhancement in these arrangements.

7.1.2 Opinions of the AMT Suppliers

The suppliers thought that their primary role was to provide the AMT equipment to the required specification and delivery date, agreed with the user. In general, they would give advice to the user on the suitability of AMT for the intended application, but felt in no way obliged to assist in the formulation of the specification. This is despite the difficulties the smaller inexperienced companies have in knowing exactly what they want, and accurately matching this with what is available, as described in section 4.2.

The key to any successful implementation of AMT is in the "equipment specification". This is primarily the responsibility of the adopting company and not the supplier. Companies, in general, do not have the in-depth plans needed to give a proper comprehensive equipment specification.

It is claimed that companies rarely automate the easiest applications first, and suffer from the so-called "Car Syndrome". This is the concept which questions the purpose of a luxury car, with all the accessories, when a basic car will achieve the fundamental objectives, usually of travelling between two places. The suppliers believed that the user company usually insisted on the equipment being either too complex or sophisticated for the intended application. Where possible it is thought that companies should join the learning curve by adopting dedicated equipment, prior to experimenting with more flexible AMT.

The performance of the suppliers is measured initially by the company's ability to have the right system operational on the agreed delivery date. However, the ultimate success is measured on the company's ability to obtain repeat orders, and make profit.

The Integrators claim to have a much closer working relationship with the customer, and to assist in the selection process for the equipment. Even in this case, the application has to be identified beforehand by the adopting company. Furthermore, the management, and the responsibility for the project, remains with the adopting company. This was emphasised because the suppliers felt the companies stood back to allow the equipment to be installed, expected it to operate successfully, and were not prepared to take further "design" responsibilities. This also illustrates the lack of planning by some companies.

Training for operatives, maintenance, and technical engineers will always be available from either the supplier, or the agent, and can be conducted on the company's premises. The training programmes are flexible and can be easily adapted to meet the requirements of the individual customer. Initial training programmes would be included as part of the cost, with additional courses, on more detailed electronics and advanced programming, having to be paid for. However, few companies are prepared to commit additional expenditure to learn the more intricate details of programming and equipment capabilities.

Training generally, in UK industry, was seen to be given a low priority by many companies. Therefore, insufficient resources are put aside to prepare the company's employees for AMT. This is particularly relevant for those companies, who do not have the in-house expertise or experience. Two suppliers advise companies intending to use AMT on a wide scale to purchase cheaper training systems on which to teach and practice. There are at least five companies that manufacture systems specifically for training, whose major markets, to date, have been the higher education and research establishments.

Using this training strategy, the management and engineers would be able to understand equipment capabilities and plan for the future, prior to making the final commitment on large investment decisions. It would also give the company the opportunity to assess, and develop the interests and enthusiasm of the existing workforce.

The suppliers favour providing "Turnkey" systems, in which they are solely responsible for the commissioning and operation of the equipment to the agreed specification. The company has negligible involvement in the development of the physical system, other than in the planning and management of the project. In addition, it is believed that modifications should be carried out by "suppliers", as they are the only people, who fully understand the equipment. However, it is strongly denied that suppliers would force their products onto the client, or that the management and control of the project would be lost to the company.

It is claimed that too many companies wish the suppliers to adapt their equipment unnecessarily, in order to provide a solution specifically for their manufacturing system. This is because modifications to basic models are expensive, time consuming and take longer to commission, as the software system "bugs" have to be identified and removed.

Non-adopting companies, in general, fail to appreciate the need for a change in the attitudes for accepting, and the criteria used for appraising AMT investments. The problem, as discussed in section 4.3, relates to an exaggeration of the costs, and the under estimation of the benefits.

Expensive imports, high UK interest rates, insufficient profit generation for investment and uncertainty over future product markets were the most frequently mentioned reasons for the slow diffusion of AMT in UK companies. In addition, it was felt that there was insufficient promotion and assistance from central government. Section 7.4 explains the aid that is provided by the UK government to both the suppliers and potential users of AMT.

Initially, AMT was slow to be adopted because the companies were frightened by the technology; they thought it was inappropriate, too complex and expensive. This resulted in a lack of commitment to raise the finance for a high risk investment.

For those companies, who were adopting it, it was felt that many additional problems arose because they did not :

1. appreciate the time involved in developing a system,
2. sufficiently modify their products and production processes,
3. have total management commitment,
4. properly inform their employees of developments,
5. stick to a system they could afford,
6. have a plan that extended beyond the existing phase of AMT.

One of the common themes in the supplier discussions was that AMT would be much more successful within companies, if there was greater collaboration between the design and production departments.

7.1.3 Opinions of the AMT Users

The impressions gained from the sample of over 20 companies surveyed, concerning the AMT suppliers, varied enormously. The larger companies, who had adopted much AMT, and attained experience, were familiar with the equipment that was available, and the service they could expect from the suppliers. These companies knew what was required to formulate a specification and a contract.

The smaller, less knowledgeable companies, in terms of the AMT adoption, were much more sceptical of the suppliers. They treated them with suspicion, and felt that the equipment was expensive. These people were often overwhelmed by the technical literature produced by the different suppliers.

There was little concern that most of the machine tools now came from other European countries. Indeed, it was often said that this was probably a good indication of a better quality product. In addition, the European-based companies have just as good, if not better after sales services available than the

British companies. The users felt that the Single European Act (described in section 7.4), to be introduced in 1992, would have no influence on the global AMT equipment industry in general.

7.1.4 Analysis of the Supplier Questionnaire

Having analyzed the responses from the 45 suppliers at the Automan'87 exhibition, and the five manufacturers that were questioned in greater detail, a short questionnaire was designed, (see Appendix II). The purpose of the questionnaire was to investigate , in greater detail the thoughts of the AMT equipment suppliers, and to obtain more quantitative data. It would expand on the published work by Fleck, (1984) and White, (1984), at the University of Aston, and the Economic Commission of Europe, (1985), who were primarily concerned with the actual numbers and underlying reasons behind the trends. This research questionnaire focused more on disclosing management strategies and decision making processes.

Three hundred questionnaires were despatched in September 1988, to named manufacturers and integrators of AMT, with the assistance from the British Robot Association. The 33 completed replies represented an 11% response rate, and the results were summarised in Table 7.1.

There appears to be an overriding belief that the main reason behind a company's decision to automate is to remain competitive. Without investment into new technologies, it is not possible to continue the downward trend of real costs, (as described in section 5.3.4, regarding learning curves). This naturally assumes that the new technology is bought to reduce relative product costs for the existing range, and not for other reasons, such as product enhancement and quality.

The two other parts to the question yielded a response of 25% each. They were to provide a solution to problems with existing machinery, and meeting future demand respectively.

These reasons, too, have an underlying competitive nature of either cost reduction or increasing market share.

44% of automation suppliers believe that companies, in general, do not adequately look to improve their present operating systems before automating. This gives rise to the opinion that companies believe that automation is a panacea that leads directly to greater competitiveness. However, some 25% of companies do consider improving products, manufacturing techniques, and using materials more cost effectively.

62% of the interviewed suppliers believe that any consultancy advice should be carried out by independent companies, in preference to the equipment suppliers and expertise from within the company. This is so that a second opinion can be obtained, as many of the suppliers, (or their agents), claim to conduct their own consultancy prior to selling the automation.

It was felt, by the suppliers, that the most successful approach to automating was to select one main supplier who either was able to manufacture all the equipment, or subcontract some of the work, but remain in control. They would remain responsible for the technical aspects of the project until all the work was complete.

56% of the suppliers believe that companies should invest continually in new technology, by taking a gradualistic and evolutionary approach. Inexperienced users should wait until they have seen their technology operate in a similar application. There are too many potential problems, and costs inherent with "taking a lead"; this also resulted in many delays, in which competitive advantage could be lost.

It was strongly believed that only proven technology should be adopted, although, in many cases the equipment may have to be adapted or modified for individual applications. These two responses accumulated over 80% of the replies, whereas the remainder thought that specially built automation was necessary to obtain precisely what a company wanted, but expressed caution in adopting this approach.

Automation should not be implemented in a single step. It should be introduced more gradually, with 75% opting for the "step by step" approach, in preference to by product or production line. There are numerous reasons for this, such as the availability of financial resources, uncertainty of future sales and the acknowledged learning curve effects. However, there are a number of examples where it is only feasible to implement AMT in one step, mainly due to the disturbance caused, and lost production during installation work and commissioning.

On deciding what automation to choose, 55% of the suppliers believe that it is important that the equipment bought should be as flexible as possible. They believe that starting with dedicated machines, and building in flexibility later, is unnecessary.

The requirements of the potential user are obtained by talking and discussing the problems with the supplier or integrator, and by carrying out market research. However, it is often noted that customers do not know what they want and therefore suppliers are in a responsible position. This perhaps explains why independent consultants are recommended in such instances.

An impression of the suppliers and their thoughts on their own industry, was gained from question 13. They think that over 80% always put their customers first, but 30% are unwilling to adapt their products to meet the needs of the end user. Similarly, it was felt that 30% of suppliers have too much control over the management of the project, and 38% agreed that the after sales service was not efficient. However, the most significant figure was that 43% of suppliers thought that they forced their products onto the customer even though these may not have been optimal for the user.

One of the striking features of this series of questions, regarding suppliers thoughts of manufacturing companies, was the broad range of responses that were given, which resulted in all the mean results falling in the range from 30% to 60%. The suppliers believed that nearly 60% of the automating companies fail to match the skills of their employees with those required by the technology. In addition, it was thought that less than 40% of companies buy in personnel with the required expertise. This appears to highlight the area of education and training, as one which could be improved in the automating companies. One supplier claimed that companies were interested only in operating the machines, and not diagnostics or programming to achieve control.

It is also claimed that only 30% of companies formulate and implement a cohesive manufacturing strategy, whilst about half take a systems view of the company. It is felt that just 35% plan beyond the present phase of automation, and only half make full use of the automation which is installed. Additionally, the suppliers think that 60% of companies do not design their products specially for automated manufacture.

Table 7.1
Tabulated Summary of the Supplier Questionnaire

Question Description	Score
Reasons for Automating :	
i. Solve a problem with existing machinery.	25%
ii. To meet the forecasted future demand.	25%
iii. Take advantage of advances in AMT.	0%
iv. To remain competitive.	42%
v. Because the company feels that it has to.	8%
Considering Alternative Improvements to :	
i. Present products on existing technology.	25%
ii. Present manufacturing techniques.	44%
iii. The cost effectiveness of the materials.	25%
iv. Existing machinery.	6%
Place where consultancy advice should be taken :	
i. Independent Consultants.	50%
ii. AMT equipment suppliers.	20%
iii. Expertise from within the adopting company.	30%
AMT Equipment should be Purchased from :	
i. Many small suppliers.	11%
ii. One main supplier, responsible for all work.	33%
iii. Integrator or "systems house".	56%
The Installation should be Timed so that the company	
i. Leads the rest of the industry.	10%
ii. Invests continually in AMT.	50%
iii. Waits until the technology has been proven.	40%
iv. Waits until it can "leapfrog" competitors.	0%
Purchases AMT which has :	
i. Already been proven.	60%
ii. To be adopted or modified.	20%
iii. To be custom built for the operational task.	20%
The Development of an Automatic System should be :	
i. Introduced "step by step".	56%
ii. By product or production line.	44%
iii. Completed all at once.	0%

Question Description	Score
When Developing an Automated System, should start :	
i. Dedicated and build in flexibility.	11%
ii. With the most flexible equipment.	56%
iii. Rationalising existing systems.	33%
The Proportion of AMT Equipment Suppliers that :	
i. Fail to put their customers first.	20%
ii. Are unwilling to modify their products.	33%
iii. Take over the management of the project.	27%
iv. Provide an insufficient after sales service.	40%
v. Force their products onto customers.	39%
The Proportion of Automating Companies that :	
i. Fail to match the skills of their employees with that required by the technology.	55%
ii. Employ personnel with required expertise.	29%
iii. Do not formulate corporate and manufacturing strategies that complement each other.	72%
iv. Do not take a "systems approach".	53%
v. Do not plan beyond the present AMT project.	40%
vi. Do not fully utilise the existing AMT.	55%
vii. Do not redesign products for manufacture.	63%

Summary

The equipment suppliers believe that the most successful automation implementations are achieved when independent consultancy companies and single responsibility suppliers are employed to introduce proven technology "step by step", which is the most flexible at the time, and in a modular form. This is the action that has to be taken to remain competitive, but must follow and be linked to improvements to the overall systems efficiency, such as products, marketing, materials and techniques.

The equipment suppliers also think that their own performance could be improved by providing a more effective after sales service, and not forcing their own products on to the customers if they are not optimal. However, they do believe that there is more room for improvement, within companies wishing to automate, in their planning and formulation of corporate and manufacturing strategies.

7.2 Financing Advanced Manufacturing Technology

"The Money is available for financing AMT, but much of the art of getting it lies in the preparation of your case."
(Rees, 1985)

Lloyds Business Advisory Service claim that the financial institutions are cultivating a better understanding of the needs of manufacturing industry. Both Investors in Industry, and ACARD, (1983), claim that the financial institutions are reluctant to give companies the support they need, and fail to take a long term view of AMT proposals. This accords with the observation of short term accountancy attitudes within companies, as described in sections 4.4 and 7.2.2.

During the research, four commercial clearing banks and two development capital financing companies were visited. The original aim was to obtain an understanding for the types of finance that are available to both the suppliers, and users, of AMT, and the conditions which are attached. Discussions followed a semi structured question format which raised issues about company suitability, relationships, point of contact, and the accounting information system which operated within the company.

Below is a review of the five different forms of finance available to the manufacturers of AMT, accessory equipment and the users. The comments made are based on the seven interviews carried out in the summer of 1988.

7.2.1 Forms and Source of Finance

The representatives from the four clearing banks said that they did not differentiate between companies, or have any prejudices. They also insisted that money was given (mainly in loan form) to a company primarily on assessment of the borrower's capability to service the debt.

One of the interviewees claimed that, in the past (prior to 1980), these assessments were based on the companies' historical financial performance. However, the bank, in general, was moving towards placing greater emphasis on the company's "Business Plan or Proposal" for the future. This is a general requirement, rather than applying to specific claims about the new incremental investment in AMT. The selection process is subjective, as the banks have no firm criteria for assessing a company's suitability for a loan, except on the basis of their historical financial accounts.

Loans from the clearing banks are given to almost any project, whether they are for new AMT equipment, a new building or a company car. The banks give no special consideration for AMT, as they admit to not fully understanding the technical aspects, or the economic benefits. Neither do they wish to interfere with the internal operations of a client.

The clearing banks form their assessment on four main criteria :

1. The company's financial state and performance.
2. The future "Business Plan or Proposal" of the company.
3. Assessment of the management team, company operation and structure.
4. The company's point of contact with the bank.

The clearing banks, being commercial lending institutions, have to make profit, to enable them to pay dividends to their shareholders. In addition, the banks have to protect the money of their depositors, who invest in the bank. This, naturally, leads to a prudent, conservative strategy, and consequently the banks will only lend money to "safe" clients. This applies to both suppliers, and users of AMT. Therefore, the borrower has to convince the bank that they can honour the loan. This process is made easier if the borrower has been a "good" customer of the bank for a number of years.

None of the banks have any formal guidelines or lists of criteria, which a company must include in its "Business Plan". The length of a "Business Plan" is expected to cover all aspects of the company's business for at least the succeeding five years, and taking into account the product range, projected sales volume, markets and profit margins.

The main form of finance given by the clearing banks is "Term Loans" which are commonly up to 10 years in length. Interest charged on the loan is at the banks base lending rate (alternatively the London Inter Bank Offer Rate), plus an additional margin typically between 2-9%, which represents the contingency for profit and the risk of the loan.

The legally binding agreement known as a "Loan Structure" outlines :

1. The interest rates to be used.
2. Conditions for the overdraft facilities allowed to compensate for short term changes in working capital.
3. The financial performance criteria (such as the debt/equity ratio) to be maintained, failure of which may lead to termination of the loan.

The role of some merchant banks, such as "Charterhouse", is to invest in so called "Mature", unquoted companies that are making significant profits (ie in the region of £0.1M - £0.2M a year). The development capital is not a loan, but an investment to enable the company to make a "quantum leap", for the building of a new factory, product, or production line.

The criteria for assessing the suitability of a potential client are the same as for those companies, who wish to have a loan from the clearing banks. However, greater emphasis is placed on the "Management Team" and assessment of their ability to implement and manage this "quantum leap". Because the investment is made into unquoted companies, the risk is greater and the merchant bank may insist on representation on the board of directors, and could insist on changes to certain personnel.

It is rare for the merchant bank to become involved in the detailed operation of a company, its accounting and information systems. The belief is that, once the bank has confidence in the "top" person, then he will ensure that the correct codes of practice are followed.

This form of finance could be appropriate to a manufacturing company, who wishes to automate a section of its production line to maintain competitiveness. In return, the merchant bank will take a minority equity stake in the company, for which it will receive an annual dividend, and potential growth on its capital. However, this can only be realised when the company is bought, or floated on the stock exchange.

Lease Purchase, (commonly known as Hire Purchase), is a form of finance where the bank will purchase the fixed asset, and give it to the company, in return for predetermined instalments. When the contract is terminated the company will own the asset. The difference from straight leasing is that the ownership of the "goods" never passes from the lessor to the lessee.

The banks are able to tailor the repayment profile to suit the customer's cash flow. However, it was said that only 5% of customers take advantage of tailored packages, which can take account of their seasonal and cyclical cash flow fluctuations. It is claimed that this reflects insufficient planning and attention to detail made by the companies prior to making the investment.

Lease purchase and leasing are competitive businesses, and companies will frequently obtain quotations from several financial institutions. This means that there is insufficient time to study the company, its investment, and all the consequences. Consequently, assessment of a customer's suitability is made on the impressions obtained from the "point of contact", and his knowledge concerning the proposed investment, and the company's financial accounts for the previous 2-3 years. Lease and lease purchase are generally short term finance options, and, as a result, it is rare for a company to have a long term strategy to lease.

In leasing, the bank owns the asset and claims the capital allowance that accrues from ownership, which, in turn, reduces the corporation tax paid. The benefits of capital allowances can be passed back down to the customer. When a company leases a piece of machinery, the bank has to ensure that it is able to recall the asset. Therefore, a common proven asset is more likely to be leased, than a unique asset. The actual saleability of the asset is often reflected in the interest rate charged. No AMT had been leased although some computer controlled equipment had been. Despite being feasible, under the existing banking "culture", large AMT investments are unlikely.

Venture Capital companies will invest in companies who are inventive, and wish to develop their ideas into new products. They are usually small manufacturers, with opportunities for quick growth. However, there is also a high risk of failure. Where possible, venture capital companies try to concentrate on developing an image in a particular area, or sector of an industry. Thus, Baillie Gifford Technology invest exclusively in high technology including Software (such as TOP, MAP, AI) and various hardware. This form of finance could be appropriate for the manufacturers of advanced manufacturing technology.

The process of assessing a company's suitability for venture capital is very similar to that of the merchant bank, where the emphasis is put on the ability of the management team to manage change, and achieve quick growth. Venture capital is usually long term and invariably costs considerably more than the initial proposal.

7.2.2 Company's Accounting Practices

> "Most companies still use the same cost accounting and management control systems developed decades ago for a competitive environment drastically different from that of today."
>
> (Kaplan, 1984)

The major problem is that accounting conventions refer to allocating overheads to direct labour hours. Section 5.1 illustrated how the diminishing number of direct labour hours undermines the traditional accounting practice and procedures. In addition, Kaplan believes that the accounting systems have not evolved in relation to the changes in manufacturing industry. This means that the exclusion of critical, non-financial aspects of manufacturing leads to an inadequate reflection of the value of a company.

In chapter 5 discussion centred on the changes that are taking place to the resources within a manufacturing system, illustrating many of Kaplan's points. In his conclusion, Kaplan states that :

> "Today's global competition requires that non-financial measures - on quality, inventory levels, productivity, flexibility, innovation, deliverability, and employees - be used in the evaluation of a company's manufacturing performance."

The problem with the existing accounting systems is that they are entrenched within a company's culture, and that the cost of implementing a new system would outweigh the benefits. Therefore, Anson, (1985), believes that the best way to tackle the problem is to educate the users of the accounting information into the limitations of the data and systems. This way, managers are able to use the information as a "tool" for decision preparation and not for actually making decisions. However, this does not overcome the fundamental flaws in the accounting systems, and further increases the resistance to change, as referred to in section 4.4.

The quality of any report depends upon the quality of the information available at the time. The financiers will not interfere with the company's own internal accounting system, as long as they have confidence in the "point of contact".

Therefore, to a large extent the financiers do not appear to worry about the methods adopted for calculating the value of assets, (which can be greatly affected by the company's approach to valuing AMT and its software). What is vital, is that the company, (with the agreement of the auditors), are consistent in the methods and procedures they adopt. It is felt by the financiers that the quality of the Accounting Information System (AIS) is influenced by the management team and finance director, and that they will determine how factors such as intangible assets are accounted in investment appraisals.

7.2.3 The Validity of Corporate Reports

The present day methods of accounting have evolved over the last century and are based on rigid rules, procedures and conventions. They were most appropriate to large labour intensive companies, which were prevalent at the beginning of this century. The vast difference in company structures and accounting methods has led McMonnies, (1988), to conclude that the balance sheet and profit & loss statement are outdated and do not portray economic reality.

The methods used to derive the corporate accounts, and the information shown in financial performance indicators, will determine the validity of the data. In the preparation of company accounts there is no consistency in the valuation of a company's assets. Furthermore, there is no indication given on the economic environment or performance relative to other companies. This, along with the fact that private companies do not have to publish their accounts within 10 months (7 months for public limited companies, 1976 Companies Act) from the end of their accounting period, means that the corporate accounts are historical. This, along with dubious methods for recording other information, means that corporate accounts are generally secretive, and do not portray an accurate picture of a company's trading position or worth, or of particular technological changes and achievements, such as the development of AMT systems.

A representative of the EITB believed that the quality of corporate accounts depended to a large extent on the quality of the MIS in operation. Concerning the three performance measures for production (outlined by Goldratt, (1985)), throughput should be increased, whilst inventory and operating costs are reduced. The dilemma is that, although the aim of production is to decrease inventory, there is no incentive in the accounts, as inventory is classed as an asset. Similarly, management accountants may wish to calculate and monitor machine utilization. The problem is that high utilization is often associated with high efficiency by taking advantage of economies of scale, but may also increase inventory.

Therefore, companies have to decide which method of accounting best suits their business and manufacturing process. Of the four accepted methods for valuing assets and liabilities of historical cost, current replacement cost, economic value and current Net Realisable Value, (NRV), Chamber & Sterling favour the latter (McMonnies, 1988). The reason is that it has the additivity property, and uses current selling price, which the historical cost method does not.

In investment appraisal, both accountants and engineers accept that, on balance, the net present value is the most appropriate method. However, the subjectivity of estimating future costs and benefits, and uncertainty due to the risks involved, means that it cannot pass the so called "reality" test. The net realisable value does not involve estimating future costs of replacement equipment, which may not be required, and is subjective at the time of the accounts.

It has been shown that the accounting procedure adopted can influence, to varying degrees the figures incorporated in financial accounts. However, the information is of some value, if not consistent from one company to another. It is for this reason the research did not place too much emphasis on published financial data to assess the relative position of each of the surveyed companies (see Appendices VI, VII and VIII).

Summary

The research has highlighted the importance of financial managers becoming aware of the cash flow requirements of AMT, and the free flow of information. There also needs to be a much more flexible approach, especially within the more rigid organisations, to capital expenditure budgets. This is because most integrated manufacturing systems are often inter-departmental.

It is therefore important for budgetary systems not to departmentalises the company and maintain barriers between them. For effective use of company financial resources, capital expenditure programmes should be allocated on a company wide scale. This will aim to optimise the whole system rather than optimising the sub-systems.

The implementation and operation of AMT into British manufacturing industries must remain in the control of the individual company. The company management must maintain all responsibility for its payment, and ensure that the correct form of finance is obtained. It has been illustrated that there are many forms of external finance available, but the most appropriate one for a company is unique and will depend mainly on the financial structure of the company.

To some companies the attraction of one form of finance over another is the tax implication. It is the role of the company accountant to decide on the most appropriate form of finance.

For instance, it may be profitable for a company to lease in the early part of the year, and lease purchase in the latter part of the year. This is because there are different tax allowance arrangements for the different forms of finance.

The key features, which require special attention by suppliers and users of AMT, are :

1. Company's suitability for funds.
2. Company's point of contact with the financiers.
3. Company's past performance.
4. Company's accounting and management information system.
5. Financier's attitudes towards automation.
6. Financier's attitudes towards the validity of corporate reports.

It would seem that the lack of long term management by some financiers (with the exception of Development Capitalists and Merchant Banks) merely compounds short term thinking in the company.

7.3 The Trade Unions and AMT

People and their skills (as shown in section 5.2) are an important attribute to any company and, ultimately, it can be argued, determine the success of the business. They are the resource that plans, installs, commissions and operates any change, whether it is in the form of advanced manufacturing technology (AMT), or JIT stock control systems. People provide the vital interface between the production plan and the operation of the machinery.

It has been regarded as natural for the employees of a company to group together to form Trade Unions. Traditionally, in large labour intensive manufacturing industry, this was encouraged by the management, inorder to separate the workforce into smaller and more manageable units. In much of British Industry, the Trade Unions were established to improve, or at least protect, the "pay and conditions" of their members. Furthermore, the Trade Unions have been the only formal negotiating link between the employees and the management of the company.

Therefore, any implementation of AMT has to have the acceptance of the company employees, and the trade union. The potential importance of this link in the eventual success of AMT warranted further investigation. Consequently, four interviews were arranged with regional, and national trade union officials, who represented employees from companies adopting AMT. The aims of the interviews were to establish :

1. How the trade union members were affected by the introduction of new technology.
2. What guidelines were given to the trade union representatives by their union when negotiating for the introduction of new technology.
3. How the trade unions communicated and collaborated with management, in these circumstances.

4. What the trade union's could offer the management of a company willing to develop automated plants.
5. How the role of trade unions is going to change in the future.
6. What the trade unions opinions are towards the government, redeployment, job losses, and the services it provides to its members.

7.3.1 The British Trade Unions

The most quantitative data available on trade unions concerns total "payed up" membership and the total number of Trade Unions affiliated to the TUC. Data from 1895 to 1986 is displayed in Appendix XIX. The notable features are discussed in Appendix XIX along with the general public's impressions of the Trade Unions.

The trade unions officially welcome the introduction of AMT as it illustrates a company's willingness to invest in its future. Indeed the TUC has persistently argued in its "Alternative Economic Strategy" published in the late 1970's of the low level of UK investment relative to our overseas competitors, (see figure 2.4(8)). The trade unionists believe that Manufacturing Industry is critical to the wealth of the nation, and that a high level of investment is required.

The position of the STUC is that new technology should enhance the working conditions of its members. It should, initially, be implemented to replace the most hazardous jobs, even though these may not necessarily be in the areas of greatest operational benefit or profit to the company. In automating, the trade unions accept that, in most cases, the number of direct workers employed on a particular job may fall. This is an acceptance that AMT and operating systems are innovations, which extend the utility of the resources discussed in chapter 5. Therefore, in representing their members, the trade unions would like the manpower resources to be transferred by one of two mechanisms :

1. the company should retain the employees and deploy them in a different job, or
2. the government, on a national basis, should take on the responsibility to create new jobs in the remaining labour intensive industries to counter balance those lost in manufacturing industries as a result of automation.

The trade unions would like their members to benefit directly from the introduction of new technology and procedures, but in the acknowledgement of severe competitive pressures their fall back position is that nobody should be worse off. The actual negotiations are left to the individual trade unions and, indeed, to the union representative within the company. It is on this level, where there are differences between the trade unions.

The introduction of automation has had little influence on trade union policy. It is usually categorised under "changes" due to the introduction of "new technology", which have been ongoing. The precise "changes" or the technical aspects of "new technology" are not of primary importance.

The trade unions had little common ground with the present Conservative government, who, since 1979, have introduced five "Acts of Parliament". This was an attempt to make the trade unions more democratic, less politically active, collectively less powerful and more accountable to their members.

The first was the "Employment Act 1980", which provided payment for secret ballots on the company's premises, and outlawed secondary picketing. This was broadened in the "Employment Act 1982", which referred to the issues of "unfair dismissal", and "trade disputes". The main Trade Union Act came in 1984, which compelled the individual unions to hold secret ballots prior to taking industrial action, and for election of certain office bearers. This was further amended in the "Employment Act, 1988".

Too often, in recent times, trade unions have been more interested in stubbornly protecting the positions of their existing members, rather than increasing their overall membership by finding new employees. This was highlighted, by Ford's decision in 1988, not to build an electronics components plant in Dundee, which would not only have created 500 jobs directly, but also a further 500 in associated industries, most of whom would have become trade union members. The products to have been manufactured were the new electronic gadgets that a more affluent European consumer is requesting in its motor vehicles. This illustrates some of the difficulties for multinational companies, who are thinking of developing new manufacturing sites, based on advanced machining and production methods, in the UK.

Many trade unions have signed so called "single union agreements" with companies, who have built new manufacturing plants in the UK. This is in conflict with traditional trade union rules, which state that any trade union is free to have representation within a company. If there are any conflicts then these are to be resolved by the respective TUC or STUC arbitration committees. This procedure was agreed by the trade union affiliates at Bridlington in 1938. The failure of the EETPU to abide by the jurisdiction of this committee's recommendations ultimately lead to their expulsion from the TUC in 1988.

The EETPU claim that the TUC rules are outdated and restrictive, and that they have not modernised their policies, (Beresford, 1988). Many of the traditional trade unionists claim that the EETPU has abandoned members' fundamental rights to withdraw their labour (Harris, 1988). The Economist, (1988), and Wickens, (1987), support the EETPU in believing that single union representation, as adopted at Nissan in Sunderland, is "setting the example and the pace for the remainder of British industry".

7.3.2 Trade Union Representation in the Companies Surveyed

Three of the twenty companies surveyed during the research did not have trade union representation. These companies were light engineering manufacturing plants owned by N. American companies, and had personnel departments which carried out the functions of a conventional, non-political trade union. One other overseas owned company had a single union agreement, whilst the remainder all had multiple union representation.

No trade union leader interviewed disputed the importance of the relationship between their local representatives and the company management. They all said that each company management was different, and covered the whole spectrum from "good" to "poor". The trade unions believe that they should be given more information more often. To secure their understanding and long term support, management must be more forthcoming in revealing their short, medium and long term plans. Then, when there is a specific development such as the introduction of new technology, there should be separate consultations covering the reasons for automating, along with the economic and manpower implications. Meetings should also take place to discuss quality (eg "quality circles"), performance measures, business updates and forecasts.

With this level of consultation and information, the management should prepare their employees for perceived changes to working hours, working practices and manpower levels. The EETPU called this process "Attitude Training", and it is now common in "high tech" and overseas controlled companies. It is also said that a good union/management relationship enhances employee satisfaction, and gives them a sense of "belonging", and being an integral part of the company.

The dilemma for the management team is that they know industrial relations is a tactical key to the success of any project. They realise that information is the way forward, but that too much information can rebound, and have repercussions on morale and possibly lead to further demands. This is due to trade union officials trying to probe management, looking for areas of unpreparedness and ignorance, which can be exploited. The management also believe that many trade union meetings are time consuming and bureaucratic.

7.3.3 Trade Union Issues and AMT

Lord Murray, the former General Secretary of the TUC, summarised the issue of new technology with the following statement :

> "The impact of new technology on employment in the 1980's is one of the biggest challenges facing not only trade unions, but our industry and society as a whole. But in some respects our message is a simple one. It is not just a question of accepting the new technology or of fighting it. The issue is how we can maximise its benefits and minimise its costs, and ensure that its benefits are equitably shared."
>
> (TUC, 1981)

The "TUC Education" department sees the introduction of new technology as being inevitable, and the trade unions would be "luddite", if they tried to resist it. This, naturally leads, the trade unions into a dilemma. If companies do not invest in new technology, then there is a chance that all jobs will be lost in the highly competitive international environment.

One of the main policy issues between the trade unions is that of their members' trade-training. The AEU, along with most other unions, believe that it is the responsibility of the government to provide the financial resources and facilities for training. They would like to see an the expansion of the Engineering Industry Training Board, (EITB), and for training boards to be established for every industrial sector.

Presently, the EITB directs its modular training courses towards young and inexperienced people. The unions, in general, feel that private and commercially operated training centres could receive government financial support, but would fail to meet adequate standards, and not give "value for money".

In contrast the EETPU recognised that electricians' training was not being properly conducted, and, in the late 1970's, decided to set up their own training centre. They felt that, as a trade union they had a responsibility and an obligation to keep their members up to date. There are now three training centres, which are run on a non-profit making basis. The courses offered are progressive, and will all lead to a recognised qualification, such as "City and Guilds".

The national trade union administrators recognise that many traditional trade skills will be made obsolete and therefore representatives must negotiate strongly for new jobs and retraining. Trade Unions are having to adjust to the changing training patterns, away from industry-wide training, towards company-specific training. This development according to Cross, (1985) :

> "is an attempt to move towards more cross trade craftsmen which has for example increased merging of mechanical and electrical jobs".

The companies, in which there were multiple unions, would usually negotiate jointly as one committee (as illustrated in section 5.2.1). This has created the situation, in which the inter-union disputes and conflicts are settled first, which then strengthens the unions' bargaining power as a whole.

Trade unions, who are not against change, or new technology in principle, want to influence the way in which it is implemented and managed. This is to ensure that "pay and conditions" are at least maintained and that the workers have not foregone previously obtained "rights", for example, visits to doctors and dentists in company time, due to the adoption of "flexitime" and "annual hours".

Trade unions are very wary of the so called "multi-skilling" practices required for the efficient use of AMT. They are worried that employees will be given responsibilities, for which they have not been adequately trained, and financially rewarded. The unions also see the employee flexibility agreements, as described in section 5.2.1, as an attempt to break down skill barriers and demarcation lines. These problems of companies trying to control their unions are not new, as similar campaigns were known as "productivity agreements", (in the 1960's and 1970's). Today, these situations are known as "flexibility agreements".

The trade unions, in general, do not like the creation of small elite groups of workers to be formed, within larger groups of employees, as this is said to create jealousy and resentment. To this extent, union leaders try to persuade the management to train a whole department or area, and to reward them financially, even if there are only a few machines. The main difficulty is to find an agreeable performance measure.

The trade unions claim that employee training is inadequate, and that they are constantly taking the initiative to inform management of such deficiencies. In addition trade unions have "health and Safety" representatives, who draw the company's attention to any dangers. However, AMT is accepted to be much safer, cleaner, and less noisy, as it often has its own safety guards and protection shields, which cannot be easily over-ridden.

This could be a role of the individual trade union, as, in many cases, especially in the smaller companies, the trade unions may be more aware of the training opportunities available than the management. In addition the trade unions may also be more aware of the specific problems of using machinery and visual display units, (VDU's). They are also in a better position to learn from the experience of their fellow trade unionists on the introduction, implementation and implications of AMT.

The trade unions, and particularly the Manufacturing, Science and Finance Union, (MSFU), are wary of the additional stress placed on their members by the use of computer technology, and office automation. This point is also made by (Morgan, 1984), who bases the reasons on the greater workload and accountability measures applied to each individual employee.

Summary

The management and the employees (whether represented by a trade union or not) of a company should communicate regularly, on a general basis concerning company business, with a view to fuller participation in proposed changes to operational practices.

Management has to convince the employees of their creative roles,so that they feel part of the company and share in its strategic aims and objectives. The implementation of a project network should include time scales for the introduction of new working rotas, working practices and training.

Brown, (1986), foresees the 1984 Trades Union Act as bringing more formality and discipline to union activities. He also believes that sustained economic growth is unlikely to alter the fragmentation of the union movement born of changed employment practices.

The recent trends in payment methods by salary systems, training, and job evaluation schemes, which focus attention on initial pay differentials, rather than on external pay comparisons and employment structures, pose major organizational problems for trade unionists. Individual members, who are more enterprise orientated, endorse company packages of working practices and technological innovation in return for job security. This attitudinal change of some trade unions and their members will exacerbate inter-union rivalry especially around the manual / non-manual divide.

In the last decade there have been three distinct factors which have affected the trades union movement on a national basis. These are :

1. Government Employment Acts since 1979.
2. Single Union Agreements.
3. Expulsion of the EETPU from the TUC in 1988.

7.4 Government Involvement in AMT

The most influential factor on the business system is the position and stability of the nations' economy and government. Politically there are many different aspects, in which the government can influence a business' trading position. The state of the UK economy was described in section 2.4, whilst the general governmental issues are discussed below.

This section looks in detail at the government legislation, and industrial support schemes which are applicable to the users and suppliers of AMT equipment. There is also discussion on the role of financial and AMT consultants.

7.4.1 Government Legislation

The DTI and the grant distributing authorities have to work within the guidelines of government legislation. The Science and Technology Act 1965, and revised in 1978 allowed:

> "further provision with respect to the responsibility and powers in relation to scientific research and related matters of the Secretary of State, the Minister of Technology and certain chartered bodies and other organisations..."

This charter established the Research Councils with the Science Research Council responsible for:

> "the carrying out of scientific research, the facilitating, encouragement and support of scientific research by other bodies, and of instruction in the sciences and technology."

The Industrial Development Act 1982, allowed the Secretary of State to designate areas with particular employment, population migration, and regional problems for special assistance. There were two categories:

(a) a development area,

and (b) an intermediate area.

The significance of the development area was that the companies were eligible for a 22% Regional Development Grant, for providing new machinery (such as AMT) or plant, for use in qualifying premises. Those in an intermediate area were eligible for a 15% grant. The surveyed companies, within the assisted areas, had taken advantage of the scheme. However, as a result of greater investment since 1984, (see section 2.4) the government has imposed greater constraints on the "qualifying premises".

Furthermore, there could be additional financial assistance for industry if the Secretary of State believes :

"(a) the financial assistance is likely to provide, maintain or safeguard employment in any part of the assisted areas, and,

(b) the undertakings for which the assistance is provided are, or will be wholy or mainly in the assisted areas."

The purpose of giving selective financial assistance for industry in assisted areas is to :

"i. promote the development or modernisation of an industry.

ii. promote the efficiency of an industry.

iii. create, expand or sustain productive capacity in an industry, or in undertakings in an industry.

iv. encourage the growth of, or the proper distribution of undertakings in an industry.

v. encourage arrangements for ensuring that any contraction of an industry proceeds in an orderly way."

It is clear that the motives and intentions are aimed at improving British industry, especially in the assisted areas. However, grave problems remain, as government assistance to British and overseas companies has not prevented their closure or maintained workforce levels, (including sample company 19). Indeed, special financial assistance given to large multinational companies to establish manufacturing bases in Britain's assisted areas, has serious implications on the indigenous companies.

The assistance will only be given on the basis that :

"(a) the financial assistance is likely to benefit the economy of the UK, or of any part of the UK.

(b) it is in the national interest that the financial assistance should be provided on the scale, and in the form and manner proposed, and,

(c) the financial assistance cannot, or cannot appropriately be so provided otherwise, than by the Secretary of State."

However, comparative analysis on the regional variations in unemployment between 1975 and 1987, show that there has been little change. The correlation figure in excess of 0.9 illustrates that those areas granted "Development Area" status in 1975, remain the regions in need of greatest assistance. This is in contrast to the US. which had a correlation coefficient of -0.2 (Economist, 1989).

7.4.2 Government Support Schemes

The consequence of the Industrial Development Act 1982, was the "Support for Business" scheme from the DTI, which ceased in 1986. There were four sections to the scheme :

i. Support for Business and Technical Advisory Services.
ii. Support for Innovation.
iii. Support for National and Regional Investment.
iv. Support for Export.

The Support for Business and Technical Advisory Services allowed companies to have 15 days of consultancy in products and processes, and new technology feasibility studies, for which the DTI would pay 75%, up to a maximum of £2,500. By the end of the scheme over 3,600 studies had been completed at a total value of £9M.

Under the Support for National and Regional Investment there were three schemes, where assistance could be given to those companies adopting AMT.

1. Grants for Major Projects : given for selected major projects of an exceptional nature involving new investment of at least £500,000.
2. Grants for New Technology Implementation Studies and Demonstrator Projects : 50% grants given for studies into the implementation of AMT.
3. Grants for New Technology Investment Projects : 20% of capital investment given to projects involving production and design of advanced electronic products, which possibly require CAD systems.

In addition, companies in the special assisted areas could obtain Regional Investment Support and grants from the European Community. Those companies (88 in total when the aid ceased in 1988), who obtained the grants for the major projects became "Demonstration Firms". The IMechE coordinated a scheme of arranging visits and seminars at each of the sites to promote the awareness of AMT to other industrialists. The AMT feasibility studies and implementation studies were coordinated by the NEL in East Kilbride.

The "Support for Business" programme was replaced in January 1988 by the "Enterprise Initiative", which gives particular emphasis to the small company (less than 200 employees), and to the single European market in 1992.

The scheme begins with a DTI Enterprise Counsellor discussing the business with the contact, who mutually agree a consultant to conduct a "Business Review". The Business Review will identify a particular problem area of the company, which will fall into one of the following categories.

Table 7.4

Coordinators for the Government's "Enterprise Initiative"

Initiative	Coordinator
1. Marketing	Institute of Marketing.
2. Design	The Design Council.
3. Quality	Salford University Business Services Ltd
4. Manufacturing	PERA.
5. Business Planning	3I Enterprise Support Ltd.
6. Financial and Information Systems	3I Enterprise Support Ltd.
7. Regional	DTI.
8. Export	British Overseas Board of Trade
9. Research and Technology	Universities, Polytechnic, and Research Laboratories.
10. Business Education	Regional Technology Centres. SERC Teaching Company Scheme.

The DTI will pay half the cost of up to 15 man days consultancy, and two thirds for those located in assisted areas. Its purpose is to encourage small companies to use the consultancy services, and collaborate with educational and research establishments. In addition, the DTI is providing companies with a range of "Support Services", where information can be attained on Business, Companies, Technology and Science, and Patents.

One of the projects undertaken by the Science and Engineering Research Council, (SERC), in 1974 was the "Teaching Company Scheme". Five of the surveyed companies had participated in the scheme and all held it in high esteem. The scheme is funded jointly by the SERC and the DTI, and aimed to facilitate the transfer of expertise from educational institutions to industrial firms, and the transfer of experience of industry to the lecture theatre.

In 1981, a £2M budget funded 46 programmes and, by 1988, support of £11M was provided for 345 programmes. Dalrymple, (1988), outlines one such scheme, which developed a computerised Manufacturing Contract Planning and Information System, at a jobbing contractor in the heavy engineering sector, which lasted four years. The projects have covered a broad spectrum of areas, from the development of Management Information Systems to the implementation of all forms of AMT.

In most cases the objectives of the scheme (outlined below) have been achieved, but Dalrymple believes the work undertaken must constitute an integral part of the company's strategic development plan, and therefore enjoy the support of top management.

The objectives of the scheme are :

i. to raise the level of industrial performance by effective use of academic resources,
ii. to improve manufacturing and industrial methods by the effective implementation of AMT,
iii. to train graduates for careers in industry,
iv. to develop and retrain existing company and academic staff,
v. to give academic staff broad and direct involvement with industry to benefit research and enhance the relevance of teaching.

In 1948, the National Research Development Corporation, (NRDC), was established to commercialise ideas and inventions from British Universities. The NRDC was to bridge the gap, and, by the 1960's, was funding projects within industry. This form of finance, more commonly known as venture capital, is discussed in section 7.2. Then, in 1980, the NRDC was merged with the

National Enterprise Board, (NEB), to form the British Technology Group, (BTG).

The BTG is the largest technology transfer organisation in the world. It takes ideas from research establishments and protects them, usually by patent on a world wide basis. It then exploits the ideas by licensing them to industry. Their unique role could be attractive to the suppliers of AMT equipment, who do not have the resources to manufacture their product.

In addition, the BTG may provide finance to the manufacturing company, in order to purchase the equipment necessary to produce the product. This may be investment into AMT.

7.4.3 National Government Policies

It is inevitable that government policies will influence British companies and the rate of technological diffusion. Section 2.4 discussed the trends of some of the main national economic indicators. Since government policies have a direct impact on the indicators, then they have an indirect influence on the manufacturing industry. The government can assist companies more directly by providing grants and subsidies to companies, as described in the previous section.

Section 4.4, showed that, given the standard criteria for accepting investment appraisals for projects, most of the eight models in the NEDO report would not have been carried out. They were implemented only with the assistance of the government, through an AMT initiative sponsored by the DTI. From 1982 through to 1985, the DTI provided up to 33% of the cost. Since 1985, applications for grants became so high that tighter constraints on eligibility were imposed, and the grant reduced to 20%.

The initial benefactors were the larger companies who were more aware of the technologies at the time. One of the conditions of the grant aid was for the adopting company to assist the equipment suppliers with the development of the AMT. Then, when the AMT had been implemented, the so-called "Demonstration Firms" were obliged to allow potential purchases to look at, and discuss the installation and implementation problems.

Most of the companies surveyed believe that, without government assistance, many AMT projects would not have been installed. In addition, they believe that the government should have continued with the AMT initiative, especially to assist the smaller companies. Indeed, the overall assistance given to industry per employee is small compared with the support given to agriculture. The ratio of government support to the GDP for the sectors of manufacturing and agriculture are 0.021% and 0.65% respectively ACARD, (1983).

One other common theme to be expressed by the top managers of the companies was the notion that the government should assist and coordinate a national Research and Development centre. The reason is that R&D is an increasingly expensive resource, and companies spend too much time duplicating work. Therefore, "UK R&D Ltd" would be responsible for :

1. development of new materials,
2. identification of the needs of industry,
3. assistance in developing new markets,
4. incorporating knowledge from industry, universities, and research laboratories etc,
5. development of new manufacturing equipment,
6. promoting common standards (eg electrical),
7. encouraging the Manufacturing Automation Protocol, (MAP), to promote and ensure machine compatibility between equipment suppliers.

7.4.4 European Single Market

The European Economic Community, (EEC), in 1957, established what has commonly been known as the "Treaty of Rome". This foresaw Europe becoming a single trading unit. The Single European Act, (SEA), was signed, on the 1 July 1987, by the twelve member nations and will become operational on 31 December 1992.

The SEA will allow the free movement of goods and equal competition by :

i. eliminating all trade tariffs,
ii. eliminating quota restrictions,
iii. imposing common technical standards.

The EEC will have a total population of 320 million, nearly the same number as the US and Japan combined. It is hoped that the single market for goods and services will reduce business costs and stimulate increased efficiency, and therefore encourage the creation of wealth and jobs.

The EEC is by far the UK's largest export market. Its importance is increasing. In 1972, the eleven other countries took 33% of UK exports, ten years later the figure had increased to 44%. In all, UK exports of goods to the community totalled £39 Billion in 1987. Other member states now account for 54% of imports, compared with 36% in 1972. Further details are given in DTI publications.

The SEA will provide an opportunity for British companies to export their products more easily and reduce the number of variants they have to make. However, they will have to meet the EEC technical standards and compete on an equal basis with the other eleven nations. This emphasises the need for companies to be competitive through cohesive strategies and efficient manufacturing systems.

7.4.5 Consultants

In December 1986, eight AMT consultancy companies were approached to see if they were interested and willing to cooperate in the research. Five replies were received, each expressing an interest, but only two were willing to cooperate. General discussions took place, with a transfer of ideas, but without any quantitative data. Both the consultants said that they were under obligation not to reveal their clients names, or financial and operational details.

The consultants believe that there is a so-called "Technology Fix" in much of British industry. This is the situation where the company believes that the solution to any of its problems is to automate. The consultants are sceptical of AMT because of the large number of problems they cause.

This work has shown that AMT alone is not the solution and that a broader systems approach is needed. The consultants think that many British companies are unable to formulate cohesive corporate strategies, which encompass their business as a whole. They also believe that there must be more pressure from the larger companies to enforce the MAP and for the national government to provide more direct grant aid for AMT installations.

The government is prepared to pay 50%, up to a maximum of £2,500 for an AMT feasibility study to be carried out in a company. Companies take advantage of the scheme for second opinions and additional advice gained on the cheap.

The problem of businesses' scepticism arises from the fact that companies expect too much from the consultants, who are rarely familiar with the industry, company's products, processes and procedures. The difficulties are exacerbated because consultants are not responsible for the advice they give, although they have a reputation to build and maintain.

Summary

Company management are sceptical of :

1. AMT equipment suppliers, to whom much trust must be given, because they are purchasing new, sometimes revolutionary systems.
2. Financiers, who preserve their own traditions, procedures and systems, and are more intent on insuring themselves against "bad debtors" than with positively assisting manufacturing industry.
3. Trade Unionists, because of the uncertainty of the actions they may take. However, recently their power has been diminishing, as a result of government legislation, and a sense of realism, as both managers and employees see the necessity of partnership.
4. The Government, attempting to tell the managers how to run their business. To this extent, the government should confine itself to politics, and provide the economic and social conditions, in which a company is able to compete fairly.

The chapter has highlighted the need for management to employ a systemic and scientific approach to their business as outlined in chapter 2.3. It shows how management have to be involved in, and aware of both the internal and external influences affecting the business.

Chapter 7 References

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CHAPTER 8

RESEARCH FINDING AND EMPIRICAL MODEL

Chapter 8

Research Findings and Empirical Model

Initially, the main research findings are reviewed. This is followed by a concluding section, in which each of the original hypotheses is assessed and commented upon individually. As a result of the research findings and conclusions, a 10 point model for the strategic and tactical management of AMS has been constructed. These points provide the thesis recommendations. Finally, ideas for further research, to follow on from this thesis, are discussed.

The research findings have been divided up into sixty four paragraphs. Each individually numbered paragraph has been categorised into one of thirteen sections. The sections relate to the thirteen non-general hypotheses. Furthermore, each paragraph is cross-referenced to the appropriate setion or sub-section in the main text. Appendix XXV gives a summary matrix of the link between each summary paragraph in the main text of the thesis.

8.1 Summary of Research Findings

Justifying and Financing of AMT

1. The largest single obstacle to the diffusion of AMT seems to be traditional company investment appraisal techniques. Restrictive criteria and methods are adopted that are unrepresentative of the true costs and benefits of the project to the company as a whole. Antiquated accounting procedures are one reason, along with the unsuitability of many management information systems to provide reliable, timely and accurate data.
[Sections : 4.4.4, 7.2.2]

2. In appraising investments the costs are always over-estimated, whilst the benefits have usually been under-estimated.
[Sections : 4.4.2, 4.4.3]

3. The financial institutions, not surprisingly, were most prudent in their assessment of a company's overall suitability for finance. They insist on all potential clients submitting a "business plan" for assessment by the institutions. This, in some respects, forced companies to think of the future, but the banks' final assessment is based on traditional historical information obtained in the annual accounts, and the ability of the company to repay the loan. However, the specific assessment of AMT was not a priority for the loan institutions.
[Section : 7.2]

4. The employees and analysts of the financial institutions were generally unaware of how the benefits of AMT could influence the company's performance. This accords with one of the reasons why it is difficult for a company to persuade financial institutions to invest in high capital projects, which have long payback periods. However, there are many forms of finance available, and each company has to analyze the most appropriate for the investment, and the company overall. External finance is only considered when a comprehensive "business plan" is produced, and the bank is convinced that there is a competent management team capable of implementing the plan.
[Section : 7.2]

5. One of the main deterrents to the diffusion of AMT in UK manufacturing industries are the archaic accounting practices and procedures. Those companies, who have adopted large quantities of automation, have taken strategic decisions that, in many cases, have over-ruled the results of formal investment appraisals. The research has also found that the criteria included, and methods adopted, were frequently inappropriate for the investments being proposed.
[Sections : 4.4, 7.2.2]

6. In addition, corporate reports do not portray an accurate picture of a company's trading position. The value of assets are not adequately reflected, and work in progress is not discouraged as it is classed as an asset in the balance sheet. Together the accounting practices and reporting procedures undermine the true value of AMT to a company. The annual accounts have no obligation to incorporate a statement on the aims and objectives of the company. This promotes short term thinking at the cost of strategic planning and full system re-design.
[Sections : 7.2.2, 7.2.3]

Planning for the Implementation of AMT

7. Comprehensive development plans, which have clear and measurable aims and objectives, and are accessible to all the employees, appear infrequently. The contents of the plans do not include all investments and proposed changes, including AMT, and are not updated an a regular basis. The plans are usually devised for isolated installations, and not for a linked series of investments. This is because managements have underestimated the time and resources required to formulate them, and sometimes believe that they are unnecessary.
[Sections : 4.1.1, 4.1.2, 4.2.1, 5.3.3]

8. For the larger investments, project leaders have been appointed from within the company. The size of the project team is dependent upon the investment, and the effect it has on the other business activities. Team meetings are most frequent in the early stages of the project; this is a reflection of the number of problems, and procedures that have to be solved. In practice, problems have arisen due to the lack of "in-house" technical expertise, and inexperience of implementing AMT and complementary systems. However, on subsequent projects, the time taken, and the number of meetings, has been reduced.
[Sections : 4.1.2, 5.2.3, 5.3.4]

9. The project team discusses, and provides solutions to a number of strategic and tactical problems, regarding the implementation of AMT. The team may discuss the operational tasks raised independently, but rarely in terms of an over riding cohesive strategic and tactical plan. Those companies, who have undertaken several AMT projects, now recognise the need for a strategic plan or policy, which can be applied to successful investments.
[Section : 4.1]

10. The key strategic decisions regarding AMT include :
   i. Timing of the implementation.
   ii. Quantity of Automation to be installed.
   iii. Choice of supplier (or integrator).
   iv. Number of modifications or adaptations.
   v. Purchase of a "Turnkey" system.
   vi. Role to be played by outsiders such as consultants.

[Sections : 4.1, 4.3]

11. The key tactical decisions regarding AMT include:
   i. Who will be trained.
   ii. How much training will be carried out.
   iii. Where the training will take place.
   iv. Who will operate the equipment.
   v. When will the system be installed.
   vi. What additional facilities will be required.
   vii. What service contracts need to be negotiated.
   viii. What back up services need to be maintained.

[Sections : 4.1, 4.3]

12. The rate of technological diffusion and successful adoption can be improved by learning from the pitfalls and difficulties experienced in previous installations, and from other users. Few companies analyze other company's investments, or the experiences and implications these companies had encountered. Thus the lessons and consequences of the production systems are not

properly relayed to their own business activities, prior to any implementation.
[Section : 5.1]

13. The formation of strategic plans is essential, if investment into AMT is going to be a success. The sample companies are beginning to understand the need for business strategies that focus on the strengths and resources of the company. Only a few people within the organisation are aware of the future plans for their company. Quantifiable aims and objectives, for the sample companies, were also rare and not known to all the management and employees.
[Sections : 4.1.1, 5.3.3]

Managing the Process of Selecting the most Appropriate AMT

14. The adoption of formal scientific management techniques, such as method study and value analysis, for the identification of those areas in need of change for automation is uncommon.
[Sections : 2.3, 4.1.3, 4.1.4, 4.1.5]

15. Writing an AMT equipment specification is not an easy task for a small company, especially when the machinery required is an adaptation of a basic model, designed elsewhere, and with which the company is unfamiliar.
[Section : 4.3.2]

16. Often companies adopting AMT for the first time, have not fully appreciated the capabilities, implications, costs and benefits of AMT until they have actually experienced the implementation. This is because each company has its own unique combination of activities, inter-functional relationships, and attributes. However, in subsequent investments, the implications are better understood, even though the actual accounting appraisals remain the same.
[Section : 4.4]

17. There is some evidence to suggest that the level of automation adopted depends upon the position the production has reached on the product life cycle curve.
[Section : 6.3.2]

18. The research has been unable to provide quantitative evidence to support the idea that actual generic product lives are lengthening, whilst the product life cycle of the model is shortening.
[Sections : 5.1.1, 6.3.2]

Accounting for the Implications of Previous AMT Installations

19. There are also few formal procedures for selecting the operating areas most in need of change. Those employees, who have experienced the production systems for a number of years, are able to identify the parts which are inefficient and the source of continuous problems and bottlenecks. However, in larger and more complex manufacturing processes, intuition has been used rather than analysis, and has been inadequate in isolating the area for change, which would provide greatest benefit to the company as a whole. Often the reason for the lack of applied scientific management techniques is related to poor management practices, and the low reliability and accuracy of data acquired in the early stages.
[Sections : 4.1.3, 4.1.4, 4.1.5]

20. In general, companies purchased over-sophisticated, multi-purpose equipment that was never used to its full potential. This is due to the initial attractiveness of additional features, unnecessarily high contingency allowances, inaccurate demand forecasts, and undeveloped schemes to modify product design.
[Sections : 4.2.2, 5.4]

21. Few companies actually consider rationalising their business systems before they automate. It is usually only after AMT has been implemented for the first time that the company thinks of

adopting any additional systems and procedures, or realises the potential for rationalization.
[Section : 5.1.1]

22. The major overt reason for implementing AMT has been to reduce production costs, whereas the main explicit benefit has been in the "quality" of the product achievable. This quality improvement has been the primary intangible benefit of AMT, due to the greater consistency and reliability of the equipment to carry out repetitive tasks. Furthermore, the evolution of "quality circles" has focused employee attitudes on improving the overall quality of the product and the production system. The potential benefits of AMT to improve quality have given companies the incentive to manufacture better products, and increase their competitive advantage.
[Sections : 5.1.3, 5.3.2]

23. Companies who have the objective of reducing costs are having to focus on costs other than direct labour, (which in many companies no longer dominate).
[Sections : 5.4.3, 5.1.1]

<u>Implications of AMT on Human Resourse Management</u>

24. Japanese production systems and principles have been adopted by some UK companies, even though they usually deny the influence of external bodies.
[Sections : 5.1.4, 5.2.4]

25. One of the main influences of the Japanese approach has been to improve the management of human resources within a company. This is necessary to introduce, smoothly, the complementary changes caused through the rationalisation of production systems. Since AMT requires less direct labour and greater skill levels,

it is important to maintain, and look after, a well trained workforce. These features have been the trademark of many Japanese companies.
[Section : 5.2.4]

26. The research (through a case study), highlighted the need for "flexibility" agreements with the workforce. Such agreements have to incorporate functional, numerical and financial flexibility, along with requirements to carry out training, and shift working. However, the company's management have to be skilful in seeking the approval, from the employees, to participate actively in "flexibility agreements", "Group Technology" and "Quality Circles".
[Sections : 5.2.1, 5.3.2]

27. Most companies prefer a mixed training programme for their operators, which involves both education, to be carried out away from the pressures of the company, and "hands on" experience with the actual machinery. With the reported difficulty in obtaining adequately trained graduates, companies are placing greater emphasis on re-training their existing personnel.
[Sections : 5.2.3, 7.1.4]

28. Too often the cost of maintaining manufacturing facilities is overlooked, when companies purchase AMT. Some companies failed to account for the additional cost involved in increasing the training and skill level of the existing engineers. However, some companies have found that the overall maintenance budget has fallen, due to the increased reliability of the equipment (relative to their old conventional machinery), and a reduced need to maintain a large team of engineers.
[Section : 6.4.2]

29. A large proportion of companies persist with a "breakdown" maintenance strategy, although more care and attention is given to the AMT investments. This is achieved by implementing specific preventative, or planned, maintenance programmes.

Operators are given more responsibility to carry out routine maintenance, in an attempt to keep the equipment clean, tidy and available for work.
[Sections : 6.4.1, 6.4.2]

Implications of Adopting AMT on Production Operations and Incorporating the Technology into a Manufacturing Strategy

30. The significant trends in other production operations are listed below, but they may not be specifically caused by AMT in every case:

   i. Number of components per product has decreased.
   ii. Products are more technically sophisticated.
   iii. Proportion of standard parts per product has increased.
   iv. Number of production quality checks has increased.
   v. Proportion of products manufactured "in-house" has decreased.

[Section : 5.1]

31. Inventory control is highlighted by consultants, (conducting the DTI's AMT feasibility studies), as the operating area most in need of attention in UK industry. This research has observed that those companies, who had given consideration to work in progress and other inventory problems, were in a better position to identify the areas in need of change. The review of Toyota's "Kanban" inventory control system, which was adopted twenty years ago, illustrates how they initially rationalised their production processes to obtain a competitive advantage.
[Sections : 5.1.4, 5.2.4, 7.4.5]

32. The adopyion of systems that complement AMT, such as improvements in stock control, and the implementation of CAD, are usually adopted in parallel to the main investments. This is because operating systems and product designs need to be simplified, prior to the adoption of AMT, but a lack of forward planning prevents this.
[Sections : 5.3.1, 5.4]

33. There is a drive towards lower batch sizes, greater product variety, and more flexible group technology manufacturing "cells". This has resulted in a shift in some aspects of a company's manufacturing profile, altering the focus equilibrium. The balance can only be restored when there is a complementary shift in the other manufacturing, marketing, product, and organisational factors.
[Sections : 5.3, 5.4]

34. One of the reasons for the inadequate emphasis on strategy formulation and development planning has been the poor communication between the different departments of the business. Often the different departments have conflicting objectives and targets. The primary concern of designers has been to create a product at a price which will satisfy a market demand, without adequate links to production planning. Production functions have concentrated on maximising output at minimum cost. The introduction of CAD and AMT has led to a marked increase in the level of communication, and common objectives, but there is still much room for improvement.
[Sections : 6.3.3, 6.5]

35. CAD and CAE are acknowledged to be prerequisites for AMT, and are often justified separately from other business functions, to which they may be linked, such as engineering, and manufacturing. Therefore they are initially used as tools for designers. They are capable of speeding up the design process, making design modifications quickly, and promoting a modular and standardised approach to design. This can greatly assist the work of the production process engineering departments.
[Section : 6.1]

36. There are numerous changes taking place within manufacturing companies. However, it is difficult to distinguish whether these changes have occurred as a result of commercial pressures, or through introductions of AMT. The picture is further complicated, as many cost savings and efficiencies can be made

through the development, simplification and control of systems, (such as production, process, and data processing), without recourse to automation per se.
[Section : 5.4]

Measuring the Performance of AMT

37. The suppliers of AMT equipment measure their performance on providing the machinery to an agreed specification on time, and obtaining repeat orders. This does not necessarily ensure that the user adopts the most appropriate system or monitors the long term success of the implementation.
[Sections : 4.3.1, 5.3.3, 7.1.2]

38. It has often been difficult to gauge the success of any AMT because :

i. it only forms a small part of the total production operations,
ii. no post implementation audits are formally carried out,
iii. there were many additional changes taking place within the manufacturing activity,
iv. specific information has not been made available.

[Sections : 5.3.1, 5.3.3]

39. There was evidence of a significant learning curve as successive adoptions of AMT ran more smoothly, cutting down the time period for the implementation process. The companies were also gaining experience of managing the equipment suppliers, whose level of after sales service was found to be acceptable, although expensive.
[Sections : 4.1.4, 4.3.4, 7.1.3]

Finding the most Suitable Technology to Integrate into the Manufacturing System

40. In the early stages of the automating process, companies try to automate the production of existing products by adopting AMT, as a simple replacement for manual operations or old machines. This is because these companies expect AMT to operate with the same functions as a human. However, proven AMT equipment does not posses any of the sensory and intelligent attributes of humans. The result is an over-complicated system. This illustrates that significant explicit new planning approaches are required to implement the new methods and procedures for manufacturing the product.
[Sections : 5.3.1, 5.4]

41. The manufacture of computer numerical control machine tools is at a more developed and mature stage than that of robotics. Although, some applications of robots such as painting and moulding, are now well established.
[Section : 5.3.5]

42. In the initial stages companies try to keep projects small and simple, but they often evolve into larger, and more complex projects as additional features are added. This often occurs when the company's project team lose control of the investment to the equipment suppliers or integrator.
[Sections : 4.3.3, 7.1.3]

43. The technical and operational capabilities of the equipment were rarely made available to all the business activities within the company in an easily comprehensible explicit form. This made it difficult for the other business activities to take account of these capabilities, when contributing to strategic planning.
[Sections : 6.5.1, 6.5.2]

44. The adopting companies were not worried about placing AMT investments on critical path activities, where they are more

easily justifiable in directly demonstrable financial terms. This is because these critical activities, were primarily production bottlenecks, and by automating, the bottleneck would be transferred to some other operating task or department.
[Sections : 4.2, 4.4]

45. The placing of AMT on critical activities without alternative routing, is a high risk strategy, and companies usually do not have appropriate guarantees of the reliability and availability of the technology.
[Sections : 4.2.1, 4.3.1]

46. The successful introduction and utilisation of AMT and CAD and other complementary systems have undoubtedly made companies more competitive. On a manufacturing operations level, the companies are more flexible, corrigible and responsive to limited changes in the product ranges and volumes. However, there is a danger that those companies, who automate existing product designs, and copy production methods (without prior assessment), could be in danger of allowing their products to become more entrenched.
[Sections : 5.4, 6.1]

The Effects of AMT on the Marketing Strategies

47. For some companies the adoption of AMT has been used to promote product sales. However, in the majority of cases it is the attributes of AMT that have been most useful to the marketing departments. If the AMT is successfully implemented these would include :

i. lower product cost,
ii. quicker delivery time,
iii. improved product quality,
iv. greater variety of product,
v. more prestigious image.

[Sections : 2.2.3, 6.3.1]

48. The advantage, for the marketing departments, of adopting AMT is mainly in the attributes and properties of the products being made. However, marketing has a vital input in providing the production and design activities, with accurate short and long term forecasts. With this level of integration, production is able to plan for future process technology and product designs.
[Sections : 2.2.3, 6.3.1, 6.3.3]

49. The research observed that the marketing department frequently had a large influence in formulating corporate strategy, but they had little input into the selection of AMT equipment or other specific manufacturing and design tactical functions. This highlighting the lack of inter-departmental communication in the sample companies.
[Sections : 4.3.3, 6.3.1]

The Effects of CAD and CAE Technology on Product Design and Designing for Manufacture Procedures

50. The research has established that those companies, who have adopted AMT, have increased the number of types of product they manufacture. The technologies, and especially CAD, have enabled more creative designs to take place, and improved communication between the production and design activities. However, these may not have been the primary intentions for the adoption of CAD and AMT.
[Sections : 5.1.1, 6.1.3]

51. In general, with companies focusing on the activities they do best, and with more reliable component suppliers, there is less incentive to manufacture every part "in-house". This has also resulted in greater emphasis being placed on purchasing modular sub-assemblies for easy assembly. It has also enabled the number of standard components required to manufacture each product to be reduced. However, consumer demand for increased product choice and technical sophistication has meant that

additional specialised components have been required from external suppliers.
[Sections : 5.1.2, 6.2]

52. The research has found that companies have been able to make large cost savings through rationalising existing manufacturing systems and product designs. However, those companies, who have adopted AMT, have given themselves the opportunity to become more competitive. If the technology has been adopted with minimal preparation, and not as part of an overall plan or package, then few benefits have been achieved. However, the research observed some companies, who were using large investments into AMT, and had thought about their manufacturing methods and systems (if not incorporating all of their business activities). These companies were seen to be more successful, as an operating unit, as they appeared to be more active and organised.
[Section : 5.4]

Managing the AMT Equipment Suppliers and Building a Partnership with the Component Suppliers

53. After formulating an equipment specification, it is not always clear that both the user and the supplier know, and agree precisely, the functions required of the equipment. This is, primarily, due to different interpretations of the final contractual agreement. Other problems arise when modifications are made, or new applications found, and these interact implicitly and explicitly with the contents of the contract.
[Sections : 4.3.2, 7.1.2]

54. The competitive economic climate has forced companies to improve the relationships with their component suppliers. This has led to a significant trend towards having fewer component suppliers providing a higher proportion of the final product. One consequence of the new business partnerships has been the implementation of British Standard 5750 on "Quality Systems", to

define the responsibilities of, and relationship between, the customer and the supplier.
[Section : 6.2]

55. The major manufacturers are beginning to treat their component suppliers as a sub-system to their own business. This sense of realism has been brought about mainly by external commercial pressures, and not through automation.
[Sections : 6.2.1, 6.2.3]

56. The need to draw suppliers and independent consultants into the project management team has been found to be essential. However this is not happening in many cases. The research observed that, in the opinions of the AMT suppliers and their agents :

i. the main reason for adopting automation is to reduce unit cost,
ii. few companies consider alternative solutions to their problems,
iii. consultancy should be carried out by an independent company,
iv. one supplier (or agent) should be responsible for all the equipment,
v. companies should adopt a "step by step" or gradualistic approach,
vi. a minimum number of modifications should be made,
vii. where possible basic and proven technology should be used,
viii. the most flexible form of equipment should be implemented.

[Section : 7.1.3]

57. In general, the AMT supply industry does not have a good impression of the way in which many UK companies operate. They believe the companies are never sure as to precisely what they want, making agreement on equipment specification difficult.
[Sections : 4.3.1, 7.1.2]

58. The suppliers favour the "Turnkey" approach to the implementation of AMT, which ensures that they are responsible for the commissioning of the equipment. However, in these cases, companies are in danger of allowing the supplier to take over the control of the project.
[Sections : 7.1.2, 7.1.4]

59. The larger users have gained experience in dealing with the suppliers, whilst the smaller companies are much more sceptical. It is in the AMT equipment suppliers' short term interests that the equipment functions properly, and in their long term interests to ensure the implementation is a success.
[Section : 7.1.3]

Trade Union Attitudes towards AMT

60. Despite the falling number of trade unions, and their memberships, they are still influential in UK companies. If there is good communication and trust between management and the trade union, then there is a better chance of a productive partnership. Too often, management are reluctant to provide enough appropriate information whilst the trade unions are preoccupied with protecting the employment, pay and conditions of their existing members. Their dogmatic approach, to the protection of restricted working practices and traditional attitudes, has limited the adoption rate of new technology. On a national basis they are in a position to assist the smaller companies on the awareness, implementation and training for AMT, but they have failed to take up the initiative.
[Section : 7.3]

61. Collectively, the trade unions, financial institutions, government, and equipment suppliers (or their agents), all have broader experience in their own fields, but they do not ensure that their actions are in the best interests of the adopting company. Thus the primary responsibilities, for ensuring that

all aspects of the project are followed through to a successful conclusion, remain with the adopting company.
[Sections : 7.1, 7.2, 7.3, 7.4]

<u>Integrating AMT into the Whole Business System</u>

62. Government initiatives, in the early 1980's, assisted the larger companies, but the recent "enterprise initiative" focuses more on the smaller firms. Companies have taken advantage of the grants given by the government agencies when managing their projects. They have also had to take account of the implications to their business, and of the considerable amount of government legislation over the last decade. However, on the broader issue of the single European market, taking effect in three years time, fewer resources have been given.
[Section : 7.4]

63. Those companies, who are more advanced and progressive, have realised the importance of integrating all the activities of the business together, and to using a common database. The capability of modern computer facilities has made this possible, and encourages individual departments to communicate with each other more freely.
[Section : 6.5]

64. In businesses, which had ensured the effective implementation of an Integrated Business Information System and AMT, the research observed that there was total commitment from the management. However, the original ideas were often generated from personnel lower down the organisational structure, at middle management or senior engineering levels.
[Section : 6.5]

8.2 Conclusions to the Research Hypotheses

The thesis achieved its main objectives of investigating the systemic implementation of AMT in 20 British engineering companies, and various hypotheses about their effectiveness and management. The original hypotheses (from section 3.1.1), repeated below, are followed by a description of conclusions achieved from the research in each case. Difficulties in the collection of specific manufacturing data and information on corporate strategies, common to all the sample companies, have resulted in some problems of explicit interpretation.

Each research hypothesis has been cross-referenced to the relevant paragraphs in the summay of research findings, section 8.1. Appendix XXIV tabulates the link between the research hypotheses and the findings. It also illustrates the inter-active nature the topics related to AMT.

General Research Hypotheses

Hypothesis 1 : The adoption of AMT is essential to build and maintain a company's competitive edge.

Findings :

If properly integrated into the manufacturing process and business system, AMT is of considerable benefit to a company. The capability of reducing unit cost, increasing product quality and being more flexible, allows the company to be more responsive to changes in consumer demand. If adopted alongside complementary changes, within the manufacturing system and business as a whole, it gives the company's operational management greater control. These latter factors may be just as important as the use of AMT itself.

[Paragraph Numbers : 2, 46, 47, 52]

Hypothesis 2 : Companies do not formulate cohesive corporate strategies in which an equal emphasis is given to each business activity.

Findings :

The research has been unable to obtain a formal and measurable statement of the sample companys' corporate strategies, aims and objectives. Therefore, it has not been possible to assess the relative emphasis given to each business activity. There is frequent inference that such a balanced distribution of funds has simply not been analyzed and attempted by the companies in question.

[Paragraph Numbers : 9, 13, 34]

Hypothesis 3 : Companies optimise their individual activities and resources rather than the system as a whole.

Findings :

In general, companies tend to focus on individual business activities in an attempt to optimise the sub-system, but they are slowly moving towards taking a more global systems view of their business. This trend has been initiated principally by the commercial need to become more competitive, but enhanced by the introduction of inter-departmental computer links and information systems. However departmental structures, that have evolved with the company, have promoted individualism and isolation. Therefore, for the company to optimise the system as a whole, communications must improve, and attitudes become more flexible. Project and method/work study teams, with inter-departmental representatives, should be appointed and financial budgetary allocations reviewed.

[Paragraph Numbers : 4, 14, 19, 28, 55, 59, 63]

These required an investigation of the strategic and tactical decision making process within those companies adopting AMT.

Hypothesis 4 : Standard accounting procedures and investment appraisal techniques undervalue AMT systems.

Findings :

The existing accounting procedures and practices undervalue the true value (or worth) of AMT to a company, both on the balance sheet and in investment appraisals. This is because financial accounts can only consider tangible costs, benefits and values. They are unable to quantify intangible variables such as the strategic value. If a complete systems approach is going to be adopted, then less emphasis has to be placed on accounting information, and more on the long term strategic value to the company. Thus, for example, quantitative investment appraisal needs to be seen as just one aid to management decision making in conducting critical examinations and processing checklists, rather than as a sole decision criterion.
[Paragraph Numbers : 1, 2, 3, 4, 5, 6]

Hypothesis 5 : The strategic and tactical considerations of implementing AMT are discussed in isolation, and not as a whole.

Findings :

Short term production and financial targets are emphasised, rather than long term planning strategies. This has encouraged existing project teams to reassess all the strategic and tactical decisions on a piecemeal basis, as they affect the business at the time of the implementation. This results in optimising short term results, but creates long term inconsistencies and inflexibilities.

In addition, most of the sample companys' development plans had short time horizons, which only incorporated projects being contemplated at the one point in time. Therefore there was no formal company policy addressing the problems of standardising the procedures of the implementation process and ensuring that successive team decisions were compatible.
[Paragraph Numbers : 1, 7, 8, 9, 10, 11, 12]

Hypothesis 6 : The characteristics of company development plans and strategies have an influence on the implementation of AMT.

Findings :

The development plans of companies are unique, and naturally reflect the historical evolution, traditions, attitudes and culture of the company. They are operating in different environments and businesses with different products, markets, size and relative prosperity. Furthermore, they have to be incorporated into a plan. This is bound to have an impact on the content of the development plan and the business strategy.
[Paragraph Numbers : 7, 9, 13, 14, 15, 16, 17, 18]

Hypothesis 7 : Companies invest in automation intuitively, and for the wrong reasons.

Findings :

Companies in general have sound reasons for investigating automation, as they are aware of the attributes and capabilities, frequently published in the trade journals. For those companies, who have successfully implemented AMT into their system, production costs have been reduced, and product quality improved. However, it is not always clear whether companies have identified problem areas, whether they have properly assessed alternative solutions, or indeed whether they can attain business and operational targets more effectively and efficiently. There is a tendency for company management to believe that AMT is the ultimate sole solution.
[Paragraph Numbers : 19, 20, 21, 22, 23]

Manufacturing Systems - Hypotheses

The effect AMT is having on the resources of materials, labour and machines within the manufacturing systems of a company, was investigated.

Hypothesis 8 : Management demands for new employee agreements are a direct attempt to install Japanese working methods and practices.

Findings :

The culture of the Japanese people is much different from that of Western Europeans. This means that there can be no direct plagiarism of Japanese Human Resource Management systems, as adopted in their industries. However, the companies sampled were all adapting some of the basic principles and objectives to the British environment. Such adaptions are necessary to achieve greater utilisation of labour, resources and improved competitiveness. This is a reaction to international competition, especially from Japan itself.
[Paragraph Numbers : 24, 25, 26, 27, 28, 29]

Hypothesis 9 : Advanced Manufacturing Technology is the main factor behind the changes to the production systems and procedures within a company.

Findings :

The large multi-million pound investments in AMT have been a catalyst for complementary changes in working practices and production systems to take place. In the sample of companies surveyed, the changes are initiated in the project teams, and many of the new systems are adopted in parallel, rather than in sequence over a longer period of time. However, the main factor behind the system changes and implementation of AMT is the drive to become more competitive.
[Paragraph Numbers : 21, 30, 31, 32 33, 34, 35, 36]

Hypothesis 10: Information collected to monitor the performance of the company's manufacturing systems is not directed towards assessing the strategic aims and objectives.

Findings :

Companies (especially those with commercial production control systems) are known to collect large quantities of data and information on many different aspects of the manufacturing process and the business as a whole. This information is not always in an easily comprehensible form, and access to company employees is often restricted.

However, the company personnel were not clear, themselves, as to the targets they were striving towards, other than those directly related to their operation. Therefore, it is not easy to see how any global aims and objectives can be monitored and assessed in these circumstances.

[Paragraph Numbers : 1, 22, 37, 38, 39]

Hypothesis 11: There is always some form of AMT available that can provide an appropriate solution to a production problem.

Findings :

Automation may not be the best initial solution to every production problem. There could be other more effective ways to achieve the aims and objectives of the business system. Even though there may be various forms of AMT, applicable to different production volumes and processes, there is a limit to its capabilities. Not every process can be automated, and neither will AMT be a panacea for future success and competitiveness.

[Paragraph Numbers : 17, 40, 41, 42, 43, 44, 45, 46]

Business Activities - Hypotheses

The investigation centred on the role and influence of maintenance, procurement, marketing, and product design in the adoption of AMT.

Hypothesis 12: AMT has no direct benefit to the marketing department.

Findings :

Some isolated instances were found of companies, which have been able to manipulate directly their manufacturing departments' adoption of AMT for marketing purposes. In general, the consumer is more conscious of the product itself rather than the technology used to make it. However, the marketing departments benefit from the consequential attributes of AMT, especially in terms of product quality. They can also benefit from being part of a totally integrated system, in which their market intelligence is used to enhance the information system and contribute to improving the competitiveness of the design system.
[Paragraph Numbers : 29, 47, 48, 49]

Hypothesis 13: The true cost of "designing for manufacture" is not fully appreciated by the design department.

Findings :

The increasingly widespread use of CAD has alerted the companies to the inefficiency of previous methods and practices within the "design process". Similarly, AMT has alerted production engineers to the great benefits that can be achieved by the effective utilisation of such equipment. In order to achieve the full advantages of the two "islands" of automation, there has to be a direct technical link in the form of CADCAM, and an informational link in the form of a design process for manufacture. This is the process of ensuring that the most cost effective materials, manufacturing processes and machining methods are adopted. It is a perpetual process of review, where there is always room for improvement.
[Paragraph Numbers : 30, 35, 40, 50, 51, 52]

Hypothesis 14: Component suppliers are not included as an integral part of the business system.

Findings :

Those companies, who have actively introduced "Quality Circles", "Just in Time" inventory control systems, more sophisticated products, and have focused their manufacturing systems, have highlighted the importance of building better communications with the component suppliers. These more advanced and progressive companies are following Japanese practices in developing long term partnerships, in which there are special order guarantees for "good" work, and an appreciation of each partner's problems. It is a realisation that the component products are a contributory cost and a sub-process to the main assembly philosophy. However, there is room for further improvement through collaboration on intelligence that will benefit the system as a whole.

[Paragraph Numbers : 53, 54, 55, 56, 57, 58, 59]

External Influences on the System - Hypotheses

The study covered the business environment activities of the suppliers of AMT equipment, the financial institutions, the Trade Unions and the Government, with particular emphasis on their attitudes towards AMT.

Hypothesis 15: Trade Unions are a positive restriction to the adoption of AMT.

Findings :

In those companies, where there is multiple trade union representation, the adoption of AMT and other complementary manufacturing systems has been restricted. The rate of change has been slower, due to inter-union conflicts, meticulous attention and guarantees required on pay, safety and conditions, and on the selection of operators and the necessary retraining. These discussions are usually separate from those of the management project team. The more successful companies have incorporated these features in the project teams, on which there has been employee representation. This policy of greater cooperation between employees and management has increased morale and motivation, resulting in lower staff turnover and absenteeism.

[Paragraph Numbers : 60, 61]

Hypothesis 16: Companies have to manage the external bodies, such as management consultants and the AMT equipment suppliers, as well as their own personnel and operations.

Findings :

Especially in those cases where companies are adopting AMT for the first time, management consultants and equipment suppliers are given a free role in the areas they look at, and in deciding the technology that is ultimately adopted. The company's management and project leader have not, in general, focused the attention of the consultants on the areas in need of change, and given them guidelines on the nature of the process technology needed to complement the existing manufacturing process. There is a need to incorporate these external suppliers of equipment and independent management consultants into the project team in order to extract their ideas and experiences.

[Paragraph Numbers : 3, 10, 61, 62, 63, 64]

8.3 10 Point Model for the Strategic and Tactical Management of Advanced Manufacturing Systems

The recommendations drawn from the research have resulted in the identification of a ten point model. Such a model would need to be implemented prior to, or in parallel with, the installation of AMT. It is important to note that the model encompasses the whole business, and not just those business activities directly involved with the automation. Due to the systemic nature of business operations the model headings described below have no formal hierarchical order :

1. Company Strategies.
2. Communication Between Business Activities.
3. Manufacturing Development Plan.
4. Procedure for Implementing AMT.
5. Complementary Manufacturing Systems.
6. Design for Manufacture.
7. Labour Flexibility.
8. Investment Appraisal - Method and Criteria.
9. Manufacturing Performance Measurements.
10. A Systemic Appreciation of the Interactive Nature of Advanced Manufacturing Systems.

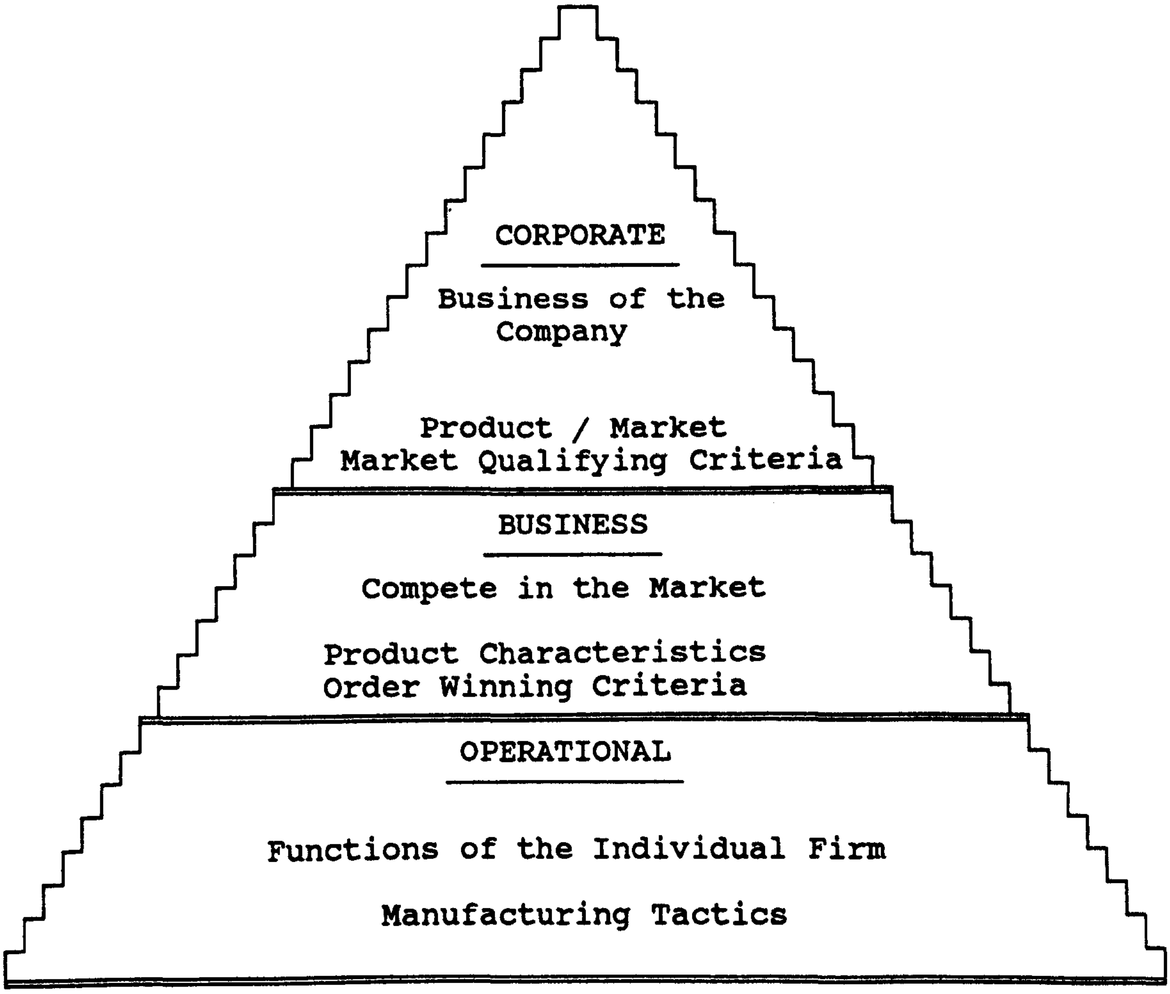
1. Company Strategies

Strategic Management is the process of deciding a strategy, and planning how that strategy should be put into effect. There should be three levels of strategy as shown in figure 8.3(1). The first level of "Corporate" strategy outlines the business of the company. The second level of "Business" strategy defines how the company is going to compete in their chosen market. Then the final level, "Operating" strategy, relates to the individual activities of the company.

The business strategies are concerned with achieving specific objectives within a particular business or in a specific product segment. They must have measurable aims and objectives, and be updated regularly, covering short, medium and long term planning periods.

Figure 8.3(1)

Company Strategies



In relation to AMT, the operating strategies refer to how the technology can be best used to achieve the specific goals of the company. Meanwhile, the tactics relate to resources of the system required to operate the AMT successfully. When formulating the company's strategy one must be aware of the :

i. scope of the organisation's activities,
ii. events taking place in the business "environment",
iii. limitations of the company's resources,
iv. implications of any decisions that are taken,
v. potential difficulties in implementing the strategy.

The company must analyze the factors above and generate a series of outcomes. Each scenario has to be analyzed, with an evaluation process, to select the best option and a procedure for ensuring successful implementation. The strategy has to provide both short and long term direction to a company. This must be formulated in a way such that the aims and objectives can be monitored and evaluated. Only in this way can the success of a strategy be known.

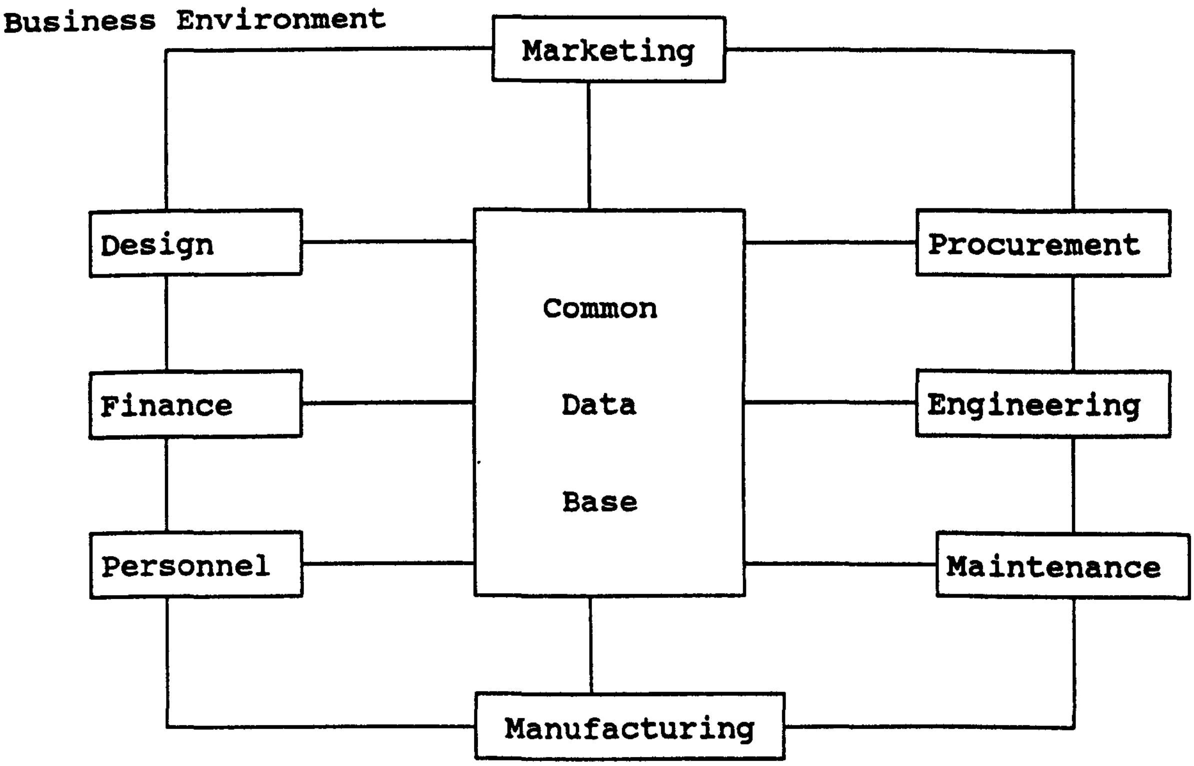
2. Communication Between Business Activities

The research has highlighted the need for all business project activities to break through inter-departmental barriers and communicate freely with each area. It is also important that they have access to a common database of information. Figure 8.3(2) illustrates how each business activity has two-way communication with a central database, and has some involvement with developments outside the business environment. It is essential that the database is maintained with "live" information which is not outdated.

In order to develop such a communication system effectively, it is necessary for companies to have a matrix form of organisational structure which promotes strong dynamic relationships and teamwork. Only if this takes place can adequate, consistent, and reliable information be obtained to formulate the company strategies and development plans. The structure will also simplify the development of project teams, and make a multi- disciplined approach to decision making more feasible.

Figure 8.3(2)

Communication Between Business Activities



The marketing and design activities have to be linked together, at an earlier stage, to assess present market forecasts and determine future product range, mix, and volumes that are going to be produced. Personnel responsible for these activities need to collaborate with the AMT equipment specialists to ascertain the capability of the machinery. This is to ensure that the investment is fully utilised. Furthermore, maintenance requires information on the technical aspects of the machinery so that its engineers may be trained, and on the proposed production schedules so that its own preventative maintenance programme can be implemented.

3. Manufacturing Development Plan

Given that a company has a guiding strategy, and effective communication between its activities, it is then in a position to formulate a tactical development plan. Business tactics are a set of action programmes designed to fulfil the business strategy, and are concerned with the employment of resources, from salesmen to process technology.

Sample company number 20 provided the research with a "manufacturing plan", modified from one implemented in 1984. It is clear that there are two distinct stages (see figures 8.3(3), and 8.3(4)). The first diagram shows the input information required to formulate the plan. This is similar to the information needed to formulate the company's strategies.

Figure 8.3(3)

Manufacturing Development Plan

Information Input

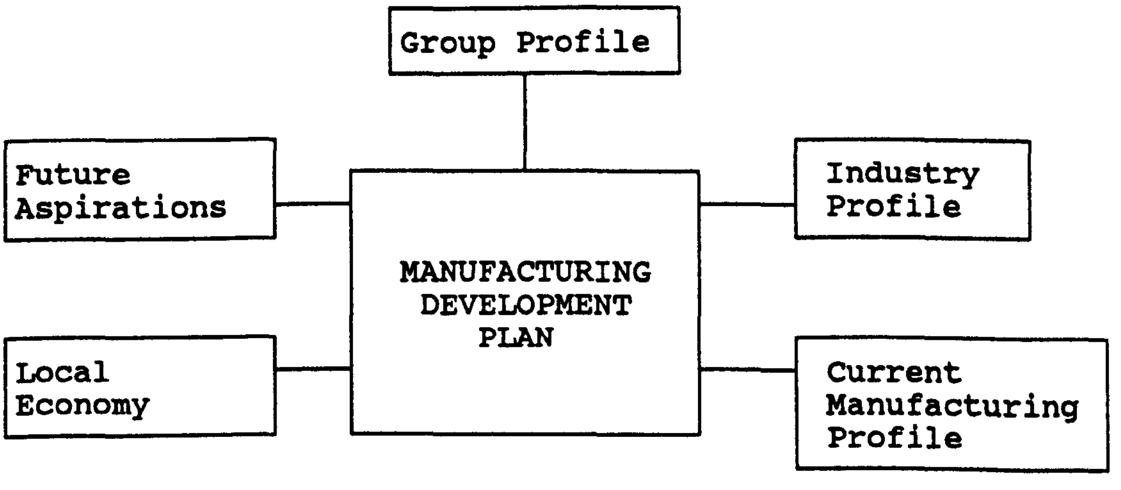
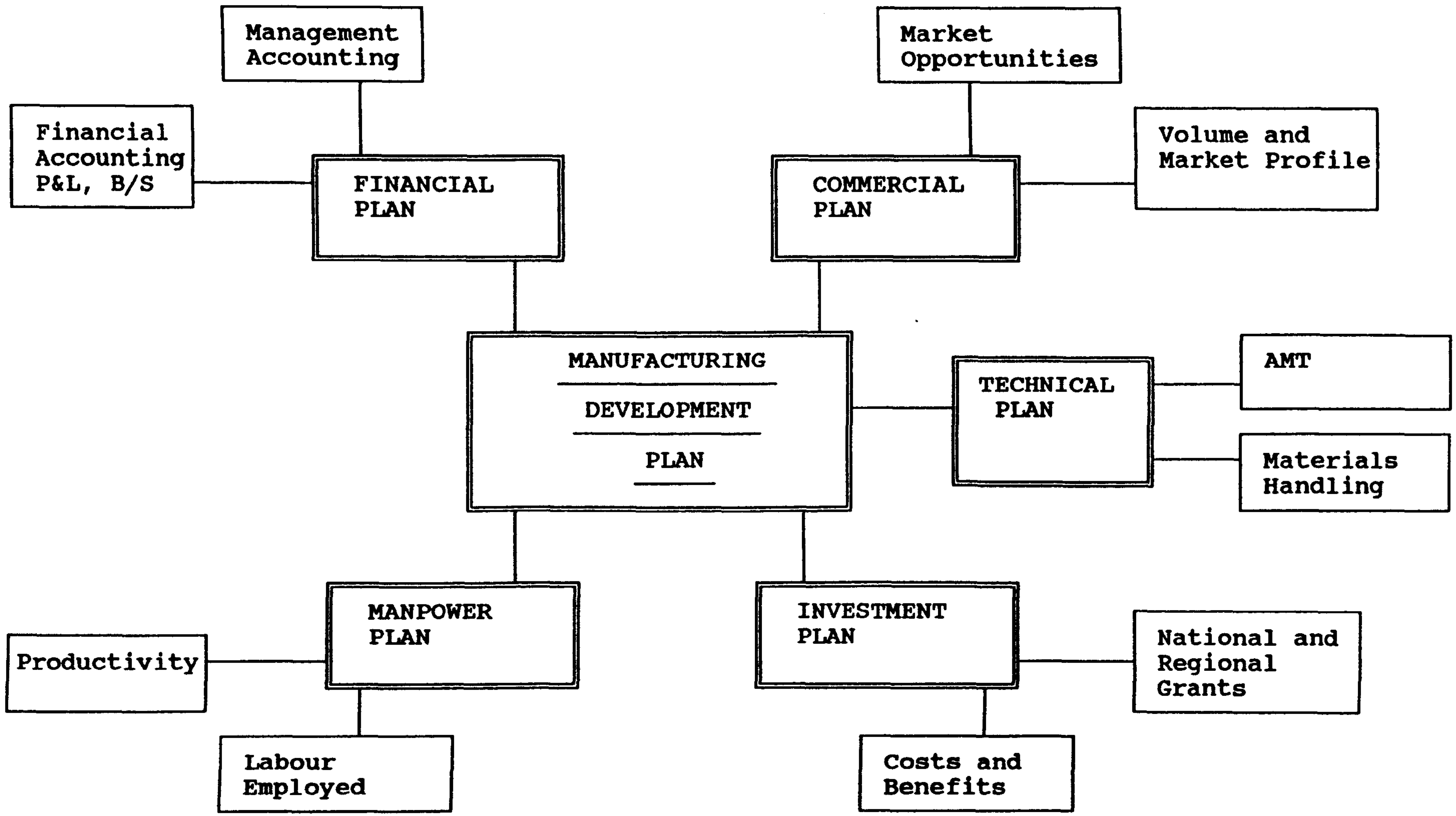


Figure 8.3(4)

Manufacturing Development Plan - Information Output



The second shows how the plan is split into five sub-sections, which are in turn sub-divided. The original 80 page "Manufacturing Development Plan" was submitted to the company's board for financial approval and to the government for grant aid. The output was a detailed plan outlining :

i. market forecasts for the succeeding five years,
ii. types of products the company was going to manufacture,
iii. equipment needed to meet the demand for each product,
iv. manpower numbers and skill requirements,
v. implications for the company's financial accounts,
vi. guidelines for the timetabled implementation of the plan.

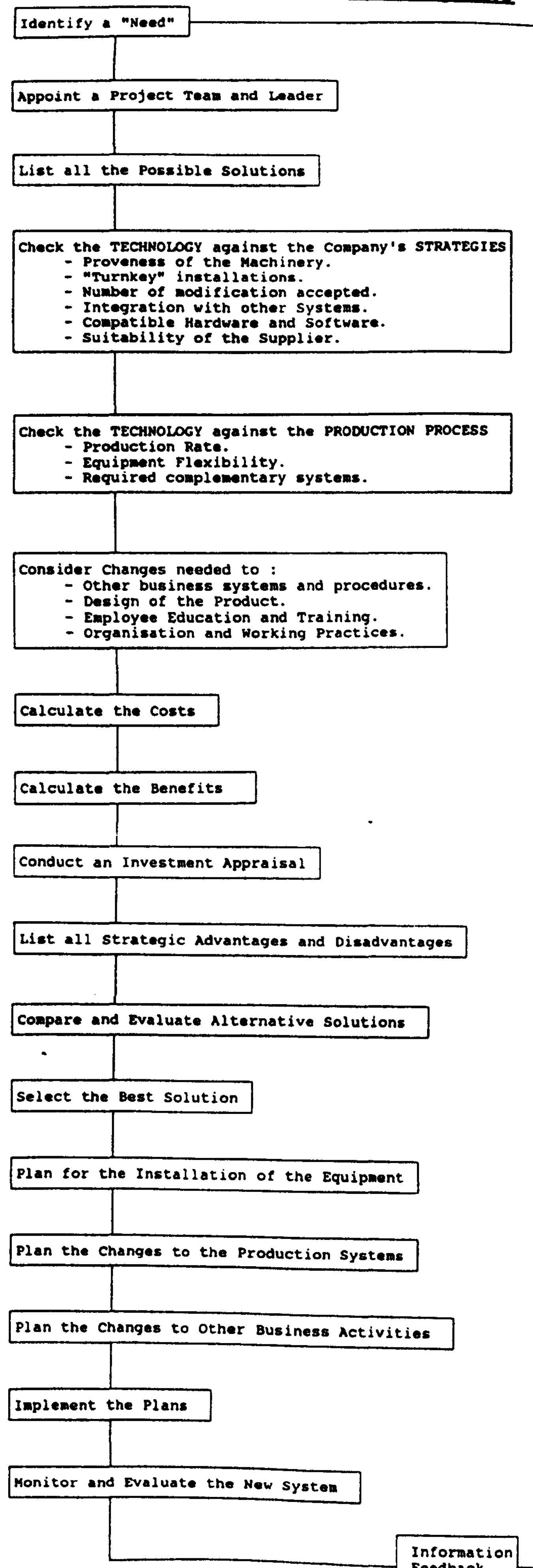
4. Procedure for Implementing AMT

One of the main problems with the previous plan was that it was a "one-off", with no sequel. The research fieldwork took place during the third year of their plan (in 1987), when the company was still implementing some of the original proposals. The benefit of carrying out annual updates to development plans is that considerations can be made of the results from previous installations, changes to company strategies and factors external to the business system. It will also enable the company to maintain plans covering pre-determined planning time horizons. However, they had arrived at a stage, common with the majority of companies sampled, of planning for the forthcoming year, in which they would submit capital expenditure proposals.

Figure 8.3(5) is a flow chart of a procedure that should be carried out, when a company is contemplating an investment into AMT. The difference between this procedure and a plan is that the plan is a collection of several individual investment proposals. Thus those companies, who had rolling development plans, were more likely to optimise the system as a whole, rather than separately optimising the sub-systems. The procedure encourages companies to form teams of "business analysts", whose task is to examine continuously the manufacturing and inter-

Figure 8.3(5)

Procedure for Implementing AMT



activity systems within the company, looking to improve inefficient activities. This process would also assist in the formation of long term plans and strategies for future competitiveness.

Once an area for change has been identified, a project leader should be appointed. Among his first tasks will be to construct a team whose members have the required levels of experience and knowledge. The leader's task should be to manage the project, by fully utilising the resources within the company and those from outside, capable of being welded into a team activity. They must involve every business activity, as the full potential of projects can only be attained if there is unrestricted communication, through which all the capabilities of the equipment emerge.

5. Complementary Manufacturing Systems

To utilise AMT machinery fully, its implementation has to be preceded by the assessment of, and possible changes to, the operating systems. These include the rationalisation of inventory control, production control, method of manufacture, value analysis, group technology, British Standard 5750, labour flexibility and "quality circles", the details of which are outlined in chapter 5 of the main text. This can only be achieved by the proper adoption of Method and Work Study groups, along with the collection and assessment of accurate and reliable data.

6. Design for Manufacture

One of the areas that companies need to focus on, and provide additional resources for, is the link between design and manufacture. With good communication it is possible for the design departments to know the capabilities and relative costs of the production process, and for manufacturing to be made aware of the changes to future product design.

The process requires a critical examination of the product design to reduce costs and simplify production processes. Designing for manufacturing techniques can be achieved by :

i. considering new materials (eg plastic or ceramics),
ii. sub-contracting difficult or inefficient operations,
iii. modular assembly,
iv. reducing the number of parts for assembly,
v. increasing the number of standard parts,
vi. tighter tolerance limits on components,
vii. simplifying assembly (eg using "snap" clips etc),
viii. reducing the number of manufacturing operations,
ix. increasing the number of standard components.

The benefits of carrying out such analysis can be widespread resulting in :

i. a reduction in production time,
ii. a reduction in number of component suppliers,
iii. a greater utilization of materials,
iv. a greater consistency of product quality,
v. fewer rejects and less production waste,
vi. improved opportunities for design modifications in relation to perceived market forecasts.

The process is greatly assisted if conducted with the aid of CAD and CAE, which together are a necessary feature for the progressive competitive company, as described in section 6.4.

7. Labour Flexibility

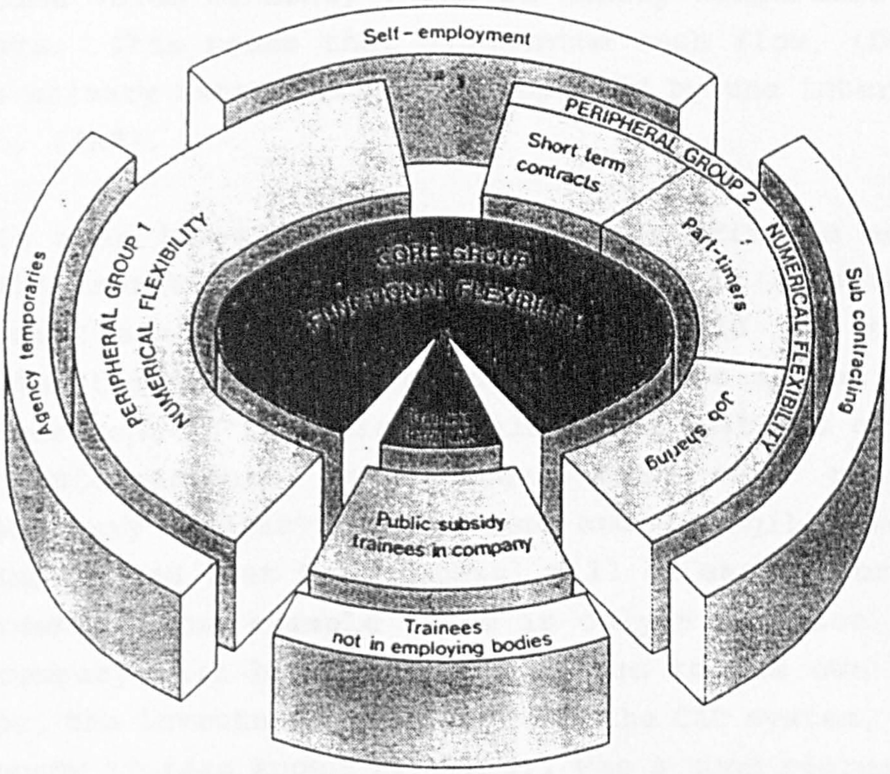
The changing global competitive climate (described in section 2.4), requires employment policies that respond quickly, smoothly and cheaply to the unknown changes in product markets and process technology. Traditional job demarcation, departmental, managerial and employee's attitudinal barriers and restrictive practices have to be broken. This requires a company to have a balanced form of labour flexibility, which comes in the three ways outlined below :

i. Numerical Flexibility : that is the ease with which the number of workers employed can be adjusted to meet fluctuations in the level of demand.
ii. Functional Flexibility : that is the ease with which the tasks performed by workers can be adjusted to meet changing business demands.
iii. Financial Flexibility : that is the extent to which the structure of pay encourages and supports the numerical and functional flexibility, which the firm seeks.

These three forms of labour flexibility are clearly outlined in a case study, (see section 5.2.1), and have been adopted in most of the companies sampled, with varying degrees of success. Labour flexibility would lead to a smaller core group of workers, who are trained and given contracts designed to maximise functional flexibility. The part time workers, self employed, temporary staff, and the increasing proportion of sub-contracted workers would become the peripheral group creating numerical flexibility. This is clearly shown in figure 8.3(6).

There must also be an effective human resource management strategy that ensures high morale, motivation, and encourages teamwork. Furthermore, employee involvement is required to operate effectively "group technology" and "quality circles", or related activities.

__Figure 8.3(6)__ __Labour Flexibility__



Source : Atkinson, J. (1985), "Flexibility : Planning for an Uncertain Future", Manpower Policy and Practice, Spring Issue, pp26-29.

A well trained core of workers in the specific skills and expertise of the company, built in the correct proportions will enable manufacturing to become more focused, and responsive in uncertain and shifting markets. However, in the light of British labour relations, many companies will need to be careful when trying to impose such a strategy. The change will have to be implemented gradually with consideration made to the :

i number of workers in the core and peripheral sections,
ii. pay differentials between the core and peripheral workers,
iii. skill requirements of the core and peripheral workers.

8. Investment Appraisal - Method and Criteria

The investment appraisal method used should take account of the "time value of money", and be easily comparable with other projects. This means that discounted cash flow, (DCF), should be the primary method adopted, supported by the internal rate of return, (IRR).

In many investment appraisals, the criteria adopted have used incremental cash flows. However, this research proposes that the factors to be considered should be broadened to represent the changes to the whole business system and not for the investment in isolation. This means that the criteria also takes into account the changes that take place to the complementary manufacturing systems and intangible benefits. It is acknowledged that the proposal will be easier for the larger investments. The example below is only a skeleton proposal as each company will have criteria unique to its own operations. However, the investment appraisal for the CAD system, implemented in Company 18 (see Appendix XVIII), was a good representation of the true value of the equipment, and one which can be developed further.

Table 8.3(1)

Recommended Criteria for an Investment Appraisal

Cost of :	
Feasibility Study	
Equipment and Accessories	
Plant Alterations	
Lost Production	
	Total Cost
Benefits from :	
National and Local Grants	
Tax Allowances	
Reduction in the Variable Cost of Production	
Increase in Production (Sales)	
Changes to Fixed Costs and Overheads	
	Total Benefits

Consideration must also be made for the :

i. Expected life of the equipment.
ii. Method of payment for capital equipment.
iii. Competitive position of the company.
iv. Cost of doing nothing.

Indeed the investment in AMS must not be judged on financial criteria alone, but also on the strategic value to the company. The primary task is to beat the external competition, and not merely to satisfy the internal investment appraisal criteria and accounting methods.

9. Manufacturing Performance Measurements

It is important for companies to adopt mechanisms by which they can monitor, analyze and assess different activities, within the whole system on a continuous basis. Only by implementing management techniques, such as Method and Work Study, can a company adequately identify those areas in need of change. This process has to assess the worthiness of AMT, against investment in, or changes to, other aspects of the system.

The research has continually stressed the importance of collecting accurate and reliable data. Without this, information needed to process the formulation of strategies and plans, is made more difficult, and therefore outcomes are less well founded. The research has highlighted six areas, for which data has to be collected, in order to assess the performance of the process technology, production systems and the business as a whole. The areas are :

i. Method/ Work Study.
ii. Learning Curves.
iii. Investment Appraisal.
iv. Product Life Cycles.
v. Market Forecasting.
vi. Product Costing.

It is widely recognised that the cost of data collection has to be justified by its possible value to the project in hand. Some data will be uneconomical to acquire, and too much may be misleading and confusing. Below is a list of performance measures which should form the basis of the data collected.

Table 8.3(2)

Recommended Performance Measures for Manufacturing System

Cost of Production :	Material Labour Overheads
Utilization of :	Material Labour Equipment (Available for & in Production)
Production System :	Batch Size Work Content Equipment Reliability
Production Times :	Lead Time to develop New Products Activity Production Time Lead Time to Manufacture a Product Machine Set Up and Changeover Times
Product Performance:	Efficiency Parameters Number of Defectives Warranty Payments
Product Design :	Number of Components Number of Standard Components Number of Operations

10. A Systemic Appreciation of the Interactive Nature of Advanced Manufacturing Systems

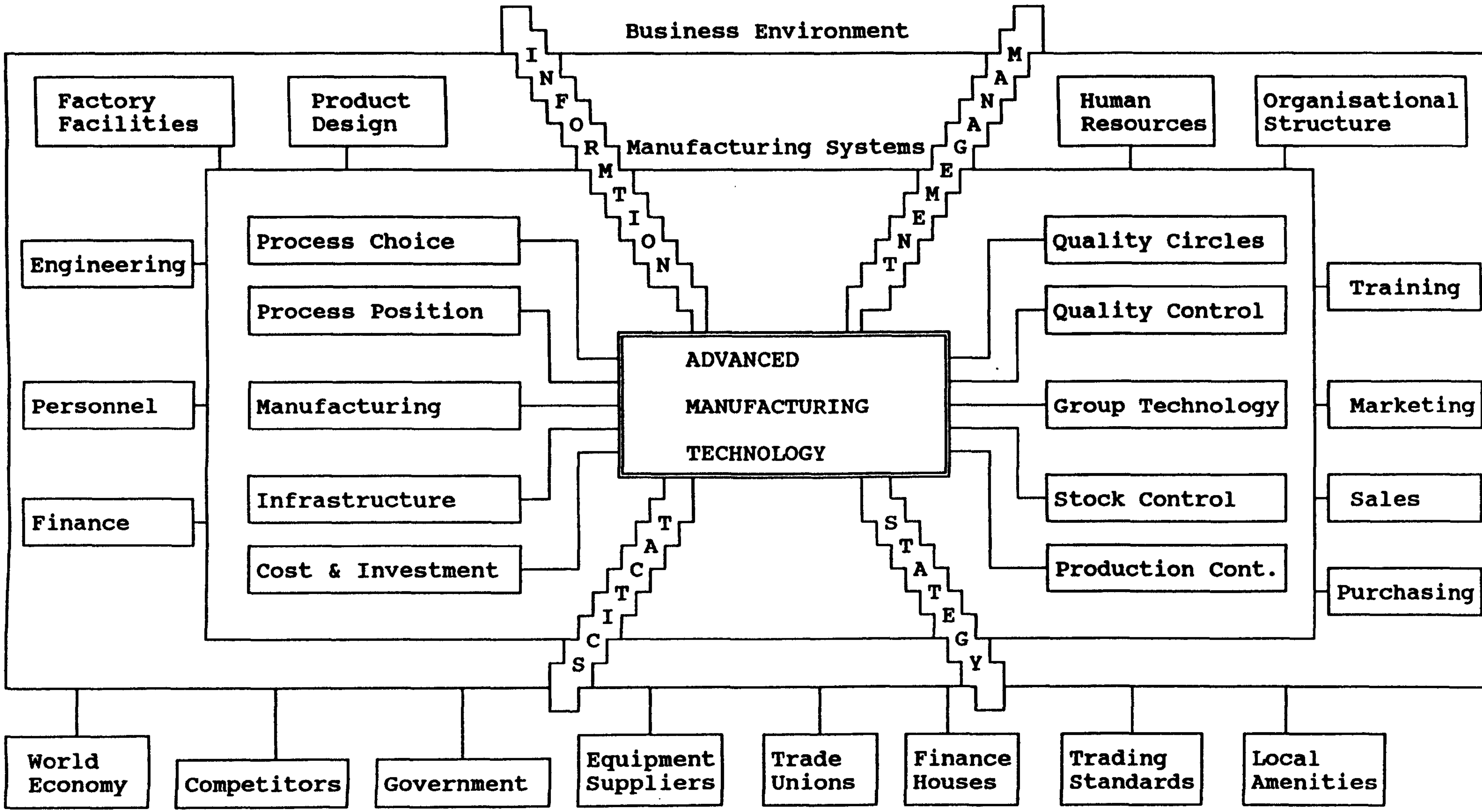
The tenth point of the model returns to the focal point of the research, Advanced Manufacturing Technology. In the nine previous points emphasis was put on the functions that have to take place within the activities of a business before AMT can be utilised to its full potential, and be a success. The necessary linkages are shown in figure 8.3(7).

Within this initial sphere, the AMT has to match the existing aims of the manufacturing strategy. It also has to be introduced alongside complementary changes to other production operating systems. The second sphere involves collaboration with other activities within the business. The third sphere involves considering the factors external to the company. In addition there are three themes common to the three spheres, namely strategic and tactical development, information and management.

The ten points in the model are themselves inter-linked and must not be treated in isolation. The drive to gain and maintain a competitive edge over the competitors is a continuous process. To this extent there are no boundaries, beyond which no further improvements can be made. It also illustrates the reasons why no formal hierarchical order can be given to the components of this model.

Finally, the business must operate collectively as a system, in which all the activities function to the benefit of the system as a whole. Furthermore, control systems have to be established to ensure that the system moves in the right direction, and attains the targets set out in the company's aims and objectives.

Figure 8.3(7) **Activity Network for Advanced Manufacturing Systems**



8.4 Further Research

Having concluded the thesis, there are a number of areas and ideas, that could be identified for further research.

1. Accounting Systems

Hypotheses 4, and 10, have indicated that the existing accounting systems are totally inadequate for many companies, and especially those who are, adopting AMT. The conclusions from the hypotheses found that existing accounting procedures and performance measures undervalued the benefits and worth of AMT, and their complementary business systems, to the company as a whole. The research would initially expand on model points 8 and 9, (regarding criteria and methods for investment appraisal, and manufacturing performance measurements), to isolate the required measurable variables and ensure that the most appropriate data is collected. This is necessary to measure the performance of the various business systems and methods that lead to the fulfilment of company strategies and targets.

The researcher would require an understanding of standard accounting procedures and a basic knowledge of the individual company's production operations. Information regarding the implications of AMT, on the direct aspects of a company's production system, would be obtained from this thesis. By conducting an in depth case study it should be possible to highlight the potential areas where some of the existing restrictive standard accounting practices, and procedures, can be remodelled.

2. Design for Manufacture

Section 6.4 of this thesis has highlighted the immense benefits that a company can obtain if it takes more care to design its products for automatic manufacture. However, the design process, as discussed in section 6.4.1, found that all the business activities from product initiation to production, are riddled with inefficient practices and procedures. Further research should develop model point 6, to devise a detailed model for "designing for manufacture", to ensure that there is an efficient design process and cost effective production.

The in-depth case studies would require knowledge of the capabilities and implications of adopting AMT; a central part of this thesis. Areas of particular interest are the procedures for designing new products and modifying existing products, the adoption of new materials and production methods, the tripartite communication between design, marketing and production. Further research in these areas will reveal the true value of designing for manufacture, and how the effective use of such a strategy, enables a company to become more competitive and achieve its corporate aims and objectives.

3. Integrating Business Activities

The chief recommendation of this thesis has been for the manufacturing company, to become more integrated, to take a systems approach to there whole business and to adopt a systemic approach to the implementation of AMT. Since UK companies have been slow to automate and integrate there is much scope for research in this relatively new, but critical, area that would expand on model point 10. This emphasised the inter-active communication required within the business system, when adopting AMT, which involves every business activity. However, the specific aims and objectives of such research would need careful delineation for specific case situations.

APPENDICES

Appendix I

Design Questionnaire

1. What type of products are made by your company ? ....

....

2. How many designers are working within your department ? ....

3. Approximately, how many employees work for your company ? ....

4. What numbers of designers fall into each of the following categories ?

Mechanical .... Electrical .... Industrial .... Others .....

5. Please rank in order of importance (1= most to 7= least), the key DESIGN FEATURES (ie the distinctive characteristics) of your company's products :

appearance	......
assured quality	......
practicality	......
cost	......
manufacturability	......
material used	......
innovative / original	......
other (please specify)	....

6. What rating would you place on each of the following possible reasons for your company designing new products ?
(1 = Very Important and 5 = Not Important)

diversification of product range	1	2	3	4	5
replacement of existing products	1	2	3	4	5
more specialisation	1	2	3	4	5
open up new market areas	1	2	3	4	5
use more cost effective materials	1	2	3	4	5
use more cost effective production methods	1	2	3	4	5
new scientific or technological developments	1	2	3	4	5
other (please specify)	1	2	3	4	5

7. Please rank in order of importance (1= most to 6= least), the source of ideas for new product designs :

management	......
sales personnel	......
customers	......
product designers	......
other employees	......
outside consultants	......
other (please specify)	....

8. Who, or what group of people decides on whether new ideas or designs are developed into new products ?

....

9. Please rank in order of importance (1= most to 5= least), the major restrictions or constraints placed on you as a designer ?

traditional design practices/ old methods	......
management specifications	......
market need	......
product cost	......
manufacturing capability	......
other (please specify)	....

PTO

10. Has your company adopted any Advanced Manufacturing Technology ? Yes /No
If Yes, please circle the technologies installed (Robot,FMS,CNC,DNC, Other)

11. During the last 5 years, how has your company's manufacturing resources affected the following: (please circle the appropriate response)

in = increased de = decreased nc = not changed

(i)	the number of types of products manufactured has	in / de / nc
(ii)	the opportunities for creative design have	in / de / nc
(iii)	communication with the production department has	in / de / nc
(iv)	the number of times a type of product is redesigned or modified during its lifetime has	in / de / nc
(v)	number of components per product has	in / de / nc
(vi)	number of standardised components per product has	in / de / nc
(vii)	number of quality checks during the whole production process :	
	carried out by the employees, manually has	in / de / nc
	carried out automatically by the equipment has	in / de / nc
(viii)	the number of component suppliers has	in / de / nc
(ix)	the proportion of components bought from suppliers has	in / de / nc
(x)	the number of manual manufacturing operations has	in / de / nc

12. Do your designers use a CAD system ? Yes / No
If Yes, (a) What system is it ? ....

(b) How many workstations do you have? ......
(c) What functions do you use CAD for ?

(i) .... (ii) ....

(iii) .... (iv) ....
(d) What communication do your CAD workstations have with other areas of the company, such as manufacturing ?

....

....

(e) How much initial training is a designer given in CAD ? ....days

(f) Do you think that CAD is a prerequisite for AMT ? Yes / No

13. Please rank in order of importance (1= most to 7= least), how you perceive your customers would rank the following criteria when wishing to purchase your type of products?

price	......
materials used	......
availability	......
assured quality	......
aesthetics	......
functional value	......
novelty / new	......
other (please specify)	....

PTO

14. (a) Who would you say has the greatest influence on your company's product design ? (please circle the most appropriate response)
Manufacturing / Management / Customers

(b) Does your company Design Products for the Market ? Yes / No

(c) Does your company Design Products to an individual customer specification ? Yes /No

15. How far into the future does your company design for ? ...... years

16. How long did it take to completely design your last new product ? (from idea generation to production)
.... years

17. Approximately, what proportion of a product's cost is attributed to design and development ?
.... %

18. How many types (or models) of products are manufactured by your company?
......

19. Approximately how many production "units" are produced each year ?
......

20. What is the average Product life cycle time for your types of product your company manufactures ?
.... years

21. Is this average product life cycle time ?
increasing / decreasing / not changing (please circle)

22. How frequently are new types of products introduced ? every ..... years

23. How often do your company designers conduct full :
(i) DESIGN audits (review) on each product ? every ..... years

(ii) PRODUCTION audits (review) on each product ? every ..... years

24. There are different opinions on the meaning of "DESIGN". What does "DESIGN" mean to you ?

25. What factors do you think make design departments more responsive to the changes that are taking place within the industry in which you compete ?

Name : .... Company : ....

Position : .... Town : ....

Thank you for taking the time to answer my questionnaire.

Please return to : Mr C. R. Senior, Research Student, Dept of Business and Management, University of Stirling, Stirling, Scotland. FK9 4LA

Appendix II

Supplier Questionnaire

For questions asking for proportions" please use the following code :

A : less than 20%
B : 20% - 40%
C : 40% - 60%
D : 60% - 80%
E : more than 80%

1. What is the main reason behind a company's decision to automate :
   i. to provide a solution to PROBLEMS with the existing machinery or production system ? .....
   ii. to meet forecasted future customer demand ? .....
   iii. take advantage of new advances in technology ? .....
   iv. to remain competitive ? .....
   v. because the company 'feels' that it has to ? .....
   vi. other (please specify) ....

2. Prior to automating do companies consider :
   i. improving present products on existing technology ? .....
   ii. improving present manufacturing technicues ? .....
   iii. use more cost effective materials ? .....
   iv. overhaul existing machinery ? .....

3. What are the alternatives to a company installing AUTOMATION ?

   i. ....

   ii. ....

   iii. ....

Form your own viewpoint the most successful automation implementations seem to be achieved when the adopting company....(please tick chosen response)

4. Obtains consultancy advice from :
   i. independent companies .....
   ii. suppliers .....
   iii. internal expertise .....
   iv. other (please specify) ....

5. Obtains equipment and supplies from :
   i. many small suppliers .....
   ii. one main supplier who produces all the equipment .....
   iii. one supplier who subcontracts some of the work .....
   iv. systems house .....
   v. other (please specify) ....

6. TIMES the installation, so that the company :
   i. leads the rest of the industry .....
   ii. invests continually in new technology .....
   iii. waits until the technology has been proven .....
   iv. waits until they are able to LEAPFROG their competitors .....
   v. other (please specify) ....

7. Purchases equipment which has :
   i. already been proven .....
   ii. adapted or modified from other uses .....
   iii. specially built for the purpose .....
   iv. other (please specify) ....

(2)

8. Development of an automatic system should be :
   i. introduced step by step
   ii. by product or production line .....
   iii. completed in one go .....
   iv. other (please specify) ....

9. Companies who are building up an automatic system should :
   i. start dedicated and build in flexibility later .....
   ii. start with the most flexible system .....
   iii. start by making the existing system as efficient as posible.....
   iv. other (please specify) ....

10. What in your own opinion are the first four criteria for a successful implementation ?

   i. ....

   ii. ....

   iii. ....

   iv. ....

11. How do suppliers enter into a market for automation ? ....

   ....

12. How do suppliers know what is required by potential users ? ....

   ....

13. What proportion of suppliers of automation :
   i. fail to put their customers problems first ? .....
   ii. unwilling to adapt their products to a customer's local circumstances ? .....
   iii. have too much control over the management of the project ?.....
   iv. fail to provide an efficient 'after sales' service ? .....
   v. force their products or those of their suppliers onto the customer eventhough it may not be optimal ? .....

14. What proportion of companies who automate :
   i. fail to match the skills of their employees with those required for the technology ? .....
   ii. buy personnel with the required expertise ? .....
   iii. formulate and implement a cohesive manufacturing strategy which complements their corporate stategy ? .....
   iv. do not take a systems view of the company ? .....
   v. do not plan beyond the present phase of automation ? .....
   vi. do not make full use of the automation which is installed ?....
   vii. do not design their products specially for manufacture ? .....

15. What in your opinion are the leading reasons for British Industries slow uptake of automation (especially robotic technology) ? ....

   ....

   ....

Appendix III

Maintenance Questionnaire

For companies who have adopted AUTOMATION or ADVANCED MANUFACTURING TECHNOLOGY (AMT):

1. What level of importance do the following factors have in the formulation of a company's maintenance strategy ? (1=Important, 5=Not Important)

i.	safeguard firms assets	1	2	3	4	5
ii.	production operates at lowest total cost	1	2	3	4	5
iii.	prolong the life of the assets	1	2	3	4	5
iv.	minimise down time	1	2	3	4	5
v.	reduce accidents	1	2	3	4	5
vi.	other	1	2	3	4	5

2. What level of importance does the maintenance strategy have in the formulation of the companies overall corporate strategy ?

Important 1 2 3 4 5 No Importance

3. What level of importance is placed on maintenance in the design of automation and AMT equipment ?

Important 1 2 3 4 5 No importance

4. What maintenance strategy should a company adopt for AMT (letter F) and what is usually the strategy adopted at the present (letter P) ?

repair only when the machine breaks down .....

have 'stand by' or replacement machinery .....

build production lines with extra 'routes' (ie flexibility) .....

preventative maintenance .....

other (please specify) ....

5. What proportion of companies :

i. overmaintain their equipment .....

ii. do not carry out systematic training programmes .....

iii. give complete job descriptions to their employees .....

iv. underestimate the value of a comprehensive maintenance strategy .....

(2)

6. List the major problems in maintaining automation and AMT ?

i. ....

ii. ....

iii. ....

7. What are the characteristics of a good maintenance engineer ?

i. ....

ii. ....

iii. ....

iv. ....

In your own opinion and on a scale of 1 to 5 :

8. How much TECHNICAL training is necessary for a maintenance engineer ?

Technical 1 2 3 4 5 General

9. How much of the training should be PRACTICAL ?

Practical 1 2 3 4 5 Theoretical

10. What proportion of the training should be carried in the following ?

'In-house'	ALL	3/4	1/2	1/4	None
eqipment suppliers	All	3/4	1/2	1/4	None
educational establishments	All	3/4	1/2	1/4	None
professional institutions	All	3/4	1/2	1/4	None
other	All	3/4	1/2	1/4	None

11. How long does it take to train a maintenance engineer from scratch ?

.........years

12. How much time should a maintenance engineer spend each year on training ?

.... days/ year

13. How many maintenance engineers should be trained ?

.... % of the workforce

14. How much money should be spent on training ?

.... £ / man /year

.... % of the turnover

Appendix IV

Characteristics of the Companies Surveyed

Brief reviews of the companies surveyed, their product mix and the major influences they have had to face, both internally and externally, are described in Appendix V. Below is a list of some of the main points that are common to the companies, and by which they may be categorised.

Features of the Companies Surveyed

From the survey of twenty companies, the numbers falling into engineering categories of heavy, medium and light engineering are 4, 6 and 10 respectively. All the heavy engineering companies were jobbing shops, whilst the remainder were split into batch or mass produced. Indeed the traditional mass production could not be clearly distinguished from batch production. For instance, cars and tractors are manufactured to a specific customer order in batches, along a mass production line. The problem of identifying a company's production classification is further complicated when the company sells a large range of products from a variety of production lines.

Four companies had no trade union representation, three had single union agreements and the remainder had several trade unions. The companies with most trade unions were the larger, older, and carried out more types of business. In all cases the number of trade unions had followed the national trend (outlined in chapter 7.3), and in most instances conducted negotiations as a joint representative body.

Six of the companies had completely changed their products over a number of years. Two of these were due to a fall in demand or elimination of their original products, and therefore change was required for continued survival. The others were changing their products to expand and diversify their existing business and markets. The remaining four companies continued in the business in which they were originally established, although their products have been updated.

There are six companies who rely on one customer for more than 50% of the sales turnover, and therefore their business performance and product range is influenced by an external force. Where the dominant customer has been a nationalised industry, the sales turnover has been in decline. In total five companies were facing a continued decline in sales despite the implementation of automation. Six had found no significant change over the last five years, whilst nine had witnessed an increase in sales.

Those companies, which had seen a fall in sales over the last five years, were making a greater conscious effort to export their product and services. Half the companies surveyed were now more reliant on sales to overseas countries. The remainder also have increased export sales, at the time when world markets are more open, but that they are less dependent upon them.

The degree of control that a company has over its product is variable and uncertain. Only five of the companies had a "vertical integrated" system in which they controlled every aspect of their product from R&D to sales. These companies were the most autonomous, and were least influenced by external sources. It was these companies that were selling their products to a market as opposed to a specific customer. The jobbing shops and those companies, which manufactured under licence, were restricted by customer specification and product limitations.

The degree of control a company has over its product design, assembly and organisation was observed to be critical to its ability to implement change effectively. It was very rare to find a uniform demand through out the year, and in five cases the seasonality of their product created serious problems in production scheduling. This seriously strained all the resources in the system for a few months and then left them under utilised for the remainder of the year.

It was very difficult to establish any meaningful relationship that existed between the company visited and the holding company. It appeared that most contact revolved around financial matters, such as the availability of finance, budgets and performance targets. The applicable companies claimed that they were autonomous operating units, or profit centres within the entire business, and therefore they were free to adopt their own AMT and design activities.

Companies' Financial Performances

To find data for each company which could be used to make comparisons, one had to revert to information published in the annual financial accounts. These are summarised in "Kompass" IV UK 1988 "Financial Data". Although companies have different reporting times no allowance has been made for this. Reporting dates vary from December 1985 to December 1986.

The criteria selected were year incorporated, turnover, profit before tax, fixed assets, capital employed, return on capital employed, (ROCE), and return on turnover, (ROT). Of these turnover, fixed assets and capital employed are a function of a companies size whilst profit, ROCE and ROT are functions of a companies performance.

The actual data is recorded in Appendix VI. Each company was then ranked in terms of the seven criteria from the highest to the lowest. These are shown in Appendix VII. For example company 2 has the highest turnover, and also the lowest profit (or largest loss). Appendix VIII however, takes each company in turn, and the number in the table represents the ranking position for each of the criteria. Therefore, for example, company 1 is the forth oldest and twelfth ranked in ROT.

External Influences - Customer Awareness

These are the outside factors that affect the company's ability to exercise total control over its operations and trade. They are based on the idea that a company has to be aware of its relative position in the market and the customer to whom a product and/or service is being sold. The factors mentioned all have to be considered when formulating a strategy for the future.

Manufacturers have to become more responsive to changing markets and products. The customer knows that there is more choice in terms of the number of manufacturers, and in the number of possible variants. Therefore, in order to be more responsive to increasing industrial competition and demanding customers, a company must exercise greater control of the business and its costs. This is one vital reason why many companies seek involvement in AMT.

This means that a company must be more aware of the requirements of the customer. No company says that they manufacture products in the expectation that people will automatically buy them. This results in companies employing more personnel to conduct their market research.

One key factor is the manufacturer's contact with the end customer. Companies, who have more "vertical integration" within their business, tend to be more responsive than those, who deal with intermediaries. This is because the lead time for the intelligence to filter through the system is longer. The extent of the vertical integration and communication with the customer can determine the constraints placed on the manufacturer. For instance, jobbing shops tend to build to a specific customer order, whilst mass produced products sell to a market consisting of customers. It also affects the number of functions that the business has to carry out. Naturally, for these reasons, single source products and single product ranges are dangerous.

Therefore a company which is wanting to be totally aware of its environment has to take account of :

1. the ability of the company to manufacture what it wants to,
2. whether the company sells direct to a customer or a market,
3. the position and relative status of the competitors,
4. the historical esteem or the company,
5. the seasonal variation in product demand,
6. the structure and status of the company and its ability to control its own internal affairs.

Internal Influences - Historical Development

These factors refer to the position of the company at the present time and to the resources available in order to compete and attain its objectives. The company will have to utilise tactically its resources to overcome the external influences mentioned previously within its existing structure.

The historical development and background has a great influence on the strategies that a company adopts towards its business in general and AMT in particular.

The age of a company has no bearing on the type of technology that the company has adopted. What is a function of age is the culture of the business. Older companies have survived varying economic climates and have developed procedures that have been operational for many years. It is in the older companies where restricted practises, complacency, inflexible management attitudes and bureaucracy have been established. Consequently, these companies have grown more resistant to change.

The new consumer orientated environment pays little respect to traditional product manufacturers. Customers tend to purchase the required quality product, at the lowest price, with diminishing regard for past company esteem. Therefore no company can rest on its laurels, and can only rely on past esteem if they have been able to maintain their trading image. Furthermore, it is difficult for an established company to change its identity and, consequently, this may delay or even prevent a company from developing additional markets.

Therefore the internal influences on a company depend upon how the factors, summarised below, have evolved over time:

1. human relations and working environment,
2. communications through the Management Information System,
3. design procedures for new products and manufacture,
4. production system and equipment used.

Appendix V

Summary of the Individual Companies Surveyed

Below is a brief account of the 20 companies surveyed, including their historical evolution, the products manufactured, technology adopted and any recent events that have affected the business.

Company 1

The present company was formed in 1974 from the amalgamation of two companies, whose existence can be traced back to 1904. The company designs and manufactures underground mining machinery for individual customers. The business was steady until the late 1970's, when there was a sharp fall in the level of domestic demand. From this time the company has found it necessary to accelerate the introduction of new manufacturing methods, product designs, to retain competitiveness and build up overseas markets. The product itself has become larger and more sophisticated with the company having to rely on the expertise of the other companies in the field of control and safety systems.

The company was one of the first in the UK to implement an FMS in 1981. It cost £7M, and was a unique system, although some similar software had been developed in the US. One of the major problems is the number of tools required to manufacture the parts. The tool management difficulties have grown more acute due to the fact that 10 times the original number of variants can be manufactured, and this has not been offset or exploited through an extensive programme of re-design for manufacturing.

Since the installation of the FMS, which was a one-off expenditure for the production department and for which it gained large grants from public sources, the company has continued to purchase AMT. It believes in establishing "Group Technology" and has certain cells of "stand-alone" AMT, which support the FMS and are very flexible. The company is well down the learning curve but is restricted, to some degree, by a declining market, old factory facilities and employee classifications.

Company 2

This company has had a long and chequered history as a large UK manufacturer of motor cars, and has recently been sold to a private company with government assistance. Growth in the middle of the millennium was mainly due to rising demand in domestic and commonwealth markets. However, industrial relation problems, low quality products and workmanship gave the company a poor image, which it still has not managed to escape.

From the middle of the 1970's traditional overseas markets were no longer as loyal in the light of increasing global competition. The company has continued to decline and can no longer be classed as a major high volume car manufacturer. Its new product introductions are slow, return on capital has not been realised, due to gross overestimation of demand. It has recently been collaborating with a major Japanese manufacturer, which has improved its esteem, and provided a new impetus for change.

The size of the company makes it difficult to automate much at any one time. Most of the fixturing is decided during the planning and implementation stages of new product modules. Any automation introduced is supposed to be more cost effective than using manual operations. However, the plant, which is generally highly mechanised, has a few high profile and prestigious AMT projects. Their development has not been entirely smooth and the true value of the investments will only be known when the company is able to adapt the automation for different product models.

Company 3

The manufacturing site visited, although large, forms only a small part of a group that manufactures and constructs power stations all over the world. The fall in the number of domestic orders forced the company's manufacturing plants to rationalise their operations and look for other work to utilise their new heavy duty machinery. Nevertheless, a reduction of 50% in turnover in the space of five years lead to severe changes in the business, primarily in labour reduction. The company, which was reliant on one customer for many years, is now having to look to overseas markets for orders.

This company was also given a one off budget, in 1981, of £35M, by the holding company for the redevelopment of the manufacturing plant and its facilities. Impressive new factories were built and the latest new machinery, mostly "stand-alone" CNC machinery, was obtained. Up to date CAD and other computerised systems were installed, but this did not, by itself, create more work. However, with new "flexibility" agreements agreed with the trade unions, the company is in a much more competitive position. This has recently been shown by winning large contracts with China, and for desulphurisation modules in UK power stations.

Company 4

The American owned company, which manufactures high volume power tools, has developed over the past 64 years with the consumer boom. Manufacturing has become centralised and modular, with new product innovations a key aspect of future growth. The company's main problem is in production scheduling, as many of its products are seasonal. Automating the factory has been just one aspect in company's drive for quality and reliable products. Great emphasis is placed on providing "total customer service", which has helped to promote a good image for the company.

The manufacturing site is highly automated, and consists of all forms of AMT, from CNC machines to robotic lines. Despite having much automation, the company still regards people as being the most flexible and integral part of the system. This is due to the high variety of products manufactured, and the quick changeovers required.

Company 5

The American owned company builds diesel engines and has five plants in Britain. Up until the 1980's its products sold on the basis of the company's prestigious name and reputation it had built up the years. However, it then faced strong competition from other emerging European and Japanese suppliers of equal esteem, but with lower prices. Thus, to remain competitive the company had to become more efficient and responsive, and was unable to rest on its laurels.

There are a number of CNC machines, used mainly in providing the sub-assemblies, and one FMS, which combines a number of machines together into a system. Despite automating the sub-assemblies, much of the final assembly remains manual, as it is in this area where the different modules are assembled to provide the variants.

Company 6

The Swedish owned company claims to be the market leader in most of the product fields it has entered, which is predominantly household appliances. The competitive advantage has been obtained over many years, and is maintained by a decentralising decision making, product diversification, high quality and the implementation of advanced production techniques.

The company has one of the greatest densities of robots in a UK factory. This is not too surprising, as a large proportion of these are simple pick and place devices and the remainder are concerned with injection moulding, the commonest application for industrial robots. This equipment is now standard within the company, and an experienced maintenance and engineering team has been built. Their education and training has been conducted in conjunction with a local Polytechnic, who understand the technology, as well as the workings of the system.

Recently engineers from within the company have developed their own assembly cell for the manufacture of their basic product. It is hoped that, with the in-house expertise attained, the cell may be adopted to assemble a wider range of product and a modified duplicate made.

Company 7

The company was established in April 1988, from the telecommunication operations of two large British electronics companies. The merger took place in order to create a British competitor in a global market. Both companies, during the 1970's, were reliant on overseas technology, had high priced products, assembled products manually, and consequently lost market share. The new company intended to utilise the combined strengths, to become a world competitor in an expanding market sector.

For the company's products to remain at the fore front of technology, they are forced to use the most advanced manufacturing technology. Most of the machinery in use is stand-alone technology purchased from established suppliers, as the company is formulating strategies so that, where possible, the AMT, purchased from a common supplier for each of the companies manufacturing sites.

Company 8

This is a 110 year old sub contract engineer who specialises in the heavy engineering sector. It is totally reliant on being given specific work by customers, who do not have the in-house resources or expertise to carry out the work. Future growth depends on the company's ability to adopt and respond to the prevailing market conditions and demand.

The factory is a good example of a flexible workshop, with up to 40 stand alone CNC machines of various sizes and capabilities. However the lack of a sequential progression, and cramped factory facilities give the appearance of disorder.

Company 9

The company is a subsidiary to an American multinational, manufacturing turbocharger for heavy duty diesel engines. Being a major supplier to a customer, whose final product was becoming more varied and less competitive, it was forced into making parallel changes. There was pressure to become more cost effective, and to react to whatever mix the market dictated at any given time. This was a problem that resulted from the business being dependent upon one supplier.

There is a remarkable mixture of old and new, traditional and modern manufacturing facilities within the company. The decision was made to automate only the small part of the production process which was responsible for making the key component. This resulted in a complex and lavish FMS being implemented in one area of the factory. The system used a variety of equipment suppliers, and the company has now set up a small business, as an agent, to sell the equipment.

Company 10

A large manufacturer of high volume, low cost DIY kitchen and bedroom furniture. The company, which has recently been taken over, has total vertical integration of its business activities. It has concentrated on manufacturing everything in-house and has invested heavily in capital projects.

Much of the technology used in the factory was dedicated mechanisation, with some AMT designed to conduct specific operations. This is in sharp contrast to the tool shop, which had only recently purchased separate CAD and CNC machines, and was in the process of integrating them. To some extent this illustrates the diversity of operations necessary within a company, which chooses to manufacture as much as possible in-house.

Company 11

This major multinational company is the largest manufacturer of computers in the world. The company is at the forefront of new technology and relies heavily on new product innovations for future growth. Since the company is a major supplier of computer systems, part of its philosophy is to ensure that they can be seen to operate the technology successfully within their own business. To maintain their competitive position supplying business systems with "back-up" support services, it requires meticulous attention to detail.

Despite being world leaders in computerised systems their factories are not totally automated. They do purchase the most reputable equipment on the market, and will only automate those areas that will give a return on investment in excess of 40%. There are excellent examples of fully integrated cells of AMT, and also areas which are labour intensive, as their broad product range is forever changing. However, with minimal inventory and many process computers, there is the feeling that the company has total control of its operations.

Company 12

A manufacturer of industrial valves in small batch production. The company is having to respond to customers, who are becoming increasingly specific and individual in the products they require. In addition there customers are increasingly more cost conscious and strict on meeting delivery deadlines.

For these reasons the company has to be very flexible and consequently has many stand alone machines. These are mainly CNC machines, which require less intervention from an operator and are capable of carrying out more manufacturing tasks in one work cycle. Therefore the company has to assess its precise requirements, before trying to select from a broadening number of possible machines. Only for certain functions and series of operations, which are common to most of the products, is it possible to consider integrating a series of machines.

Company 13

A high profile manufacturer of luxury cars. In 1982, the company was privatised, since when there has been strong growth in sales, due to the high US demand, which accounts for approximately 50% of total sales. Despite large increases in productivity over the last three years, the company still lags behind its major competitors, who generally produce much higher volumes. However, industrial relations problems and restricted practises have not been completely resolved, leaving some doubts about developments. The free flow of capital into the business has assisted in the development of new models and advanced manufacturing methods.

The company purchases AMT, which has already been proven by other car manufacturers, since it is not in the business of developing the most updated production technology for itself. They would prefer to modify some AMT to make better use of it, for example, by allowing different modules to go through the same machines. The majority of the automation is at the initial body-work sections of the process, whilst the fitting and assembly areas remain labour intensive.

Company 14

This is a long established company, whose primary business of shipbuilding stopped in 1970 due to an empty order book. The company had to make a quick transition to manufacturing industrial gas turbines on the basis of a manufacturing associate agreement with a large American company.

The company has now developed a major project management function to support and expand the turbine business. It is also looking for subcontract work, from other companies, to utilise fully its machinery and personnel resources. It has also implemented new "flexibility" agreement with the plethora of trade unions. However, the business remains heavily dependent on external sources, and political climates.

The standard and quality of the work has never been in question and the company has received several awards from the licensee for its quality of workmanship. However, three factors have led the company to begin the automation process with the introduction of CAD and CNC machines. These were: the need to improve cost competitiveness, the computerised compatibility with the licensee and the capability of conducting more subcontract work to utilise its employees, who have fluctuating workloads. Despite being at the early stages of automating, the company is preparing itself for further developments.

Company 15

The company's origins can be traced back to 1867, and has always been associated with agricultural equipment and particularly tractors. Their position, as market leaders, has steadily been eroded, as the industry has excess capacity, and the customer is now more demanding in what he wants. To rectify the decline, the company has had to rationalise its operations and manage all the associated problems. Being a world supplier of tractors, its business fluctuates with international exchange rates and political events, especially in third world nations.

Being vertically integrated, the company has to adapt to all the difficulties associated with each area and the consequential production volumes. This has lead to a large variety of technologies being used, from dedicated transfer lines to flexible manufacturing cells, and from manual to automatic operations.

Company 16

The company is a major manufacturer of automatic cash dispensers, has been forced to change considerably over the last 15 years. This is primarily due to the product being changed from mechanical to electronic, and secondly due to the intense competition that came in the 1970's. The company became a "self service" financial centre in 1981, responsible for its own action, product, design and development. Now operating on 10% of its original workforce, claims to be either better or at least equal to its major competitors.

The company has also effectively implemented a JIT stock control system, which has allowed it to analyze areas of efficiency more accurately. It has a mixture of dedicated and flexible automation for the repetitive production of PCB's, and extensive testing of the final product respectively. Its technology generally is standard and "stand-alone", with no unique application or complex series of machines.

Company 17

Small to medium sized company manufacturing thermostats. Its programme of automating was initiated to respond to increased competition, by purchasing CNC machines and CAD facilities. The equipment is standard and is not integrated. The company remains labour intensive and is restricted by old factory buildings.

Company 18

A major British company manufacturing a broad range of electrical products in several plants around the UK. Rationalisation has lead to a reduction in manufacturing sites and product range. The aim is to concentrate resources in the most profitable areas, which is leading the company down the path of automation. However, the company still maintains departmental barriers and has frequent conflict between management and unions.

Many of the company's products are intricate designs that require manual assembly, and, without more designing for automated manufacture, it will continue to have difficulty in implementing AMT. With this in mind the design department has purchased its own CAD system, and production has invested in two special computerised machines. One problem is that the two departments work quite independently, with little inter departmental cooperation evident.

Company 19

Subsidiary to an American company wishing to establish a manufacturing bridge point to Europe, in 1985, to manufacture and distribute its products. The firm deals in high value business computers in an expanding and competitive market. With a proven product and a "green" field site, the company has not had any of the difficulties associated with having to change products or markets.

By trying to gain a special area of the computer market, it is not able to attain the volumes to justify any AMT in addition to standard dedicated automatic insertion machines. Therefore much of the production operations are manual.

Company 20

The largest manufacturer of books in Europe. Faced with closure at the end of the 1970's, the company put forward a development plan to salvage the business. The success of the plan has only put the company back on to an equal footing with its international competitors. The company is unfortunately sandwiched between the publishers and the retailers, and does not have any control over the content of its product, or the marketing of it.

The company's plan involved purchasing dedicated equipment that had been available on the European market for many years, and was quite well established and proven. This required major changes to the traditional working practices and attitudes. There was also investment into robotic systems, palletising, the end product, and AGV's for materials handling.

Appendix VI

Financial Data for each of the 20 Companies Surveyed

C O M P	Year Est.	Turn-over (£M)	Profit Pre Tax (£M)	Fixed Assets (£M)	Capital Employed £M)	ROCE %	ROI %
1	1904	175	3.6	27	76	4.7	2.1
2	1930	3412	-455	773	601	-75.8	-13.3
3	1965	298	5.6	34	56	10.2	1.9
4	1925	212	25	56	184	13.4	11.7
5	1956	114	-26	65	82	-31.3	-22.5
6	1921	191	3.6	42	92	3.9	1.9
7	1903	1131	123	196	333	37.0	10.9
8	1946	N/A	-0.1	2.6	3.5	-3.7	N/A
9	1952	39	0.1	15	28	0.5	0.3
10	1978	4	0.1	2.3	2.7	2.9	1.7
11	1912	3078	421	711	910	46.3	13.7
12	1889	9	0.7	2.5	6.2	11.1	7.7
13	1982	830	121	238	312	38.8	14.5
14	1906	78	-1.5	5.7	21	-7.1	-2.0
15	1956	271	-28.9	231	34	-84.1	-10.7
16	1895	146	41.3	30	119	34.7	28.4
17	1946	13	0.9	2.4	5.8	15.4	6.6
18	1932	183	6.4	35	72	9.0	3.6
19	1968	161	11.8	26	29	40.7	7.3
20	1949	144	15.5	29	75	20.7	10.8

Source : Kompass IV, "UK 1988 Financial Data".

Appendix VII

Rank of each Company for each of the Financial Criteria

RANK	Year Est.	Turn-over	Profit Pre Tax	Fixed Assets	Capital Employed	ROCE %	ROI %
1	12	2	11	2	11	11	11
2	16	11	7	11	2	19	13
3	7	7	13	13	7	13	11
4	1	13	16	15	13	7	4
5	14	3	4	7	4	16	7
6	11	15	20	5	16	20	20
7	6	4	19	4	6	17	12
8	4	6	18	6	5	4	19
9	2	18	3	18	1	12	17
10	18	1	1	3	20	3	18
11	8	19	6	16	18	18	1
12	17	16	17	20	3	1	6
13	20	20	12	1	15	6	3
14	9	5	9	19	19	10	10
15	15	14	10	9	9	9	9
16	5	9	8	14	14	8	14
17	3	17	14	8	12	14	15
18	19	12	5	12	17	5	2
19	10	10	15	17	8	2	5
20	13	N/A	2	10	10	15	N/A

Appendix VIII

Relative Position of each Company for each Financial Criteria

COMP	Year Est.	Turn-over	Profit Pre Tax	Fixed Assets	Capital Employed	ROCE	ROI
1	4	10	10	13	9	12	11
2	9	1	20	1	2	19	18
3	17	5	9	10	12	10	13
4	8	7	5	7	5	8	4
5	16	14	18	6	8	18	19
6	7	8	11	8	7	13	12
7	3	3	2	5	3	4	5
8	11	N/A	16	17	19	16	N/A
9	14	16	14	15	15	15	15
10	19	19	15	20	20	14	14
11	6	2	1	2	1	1	3
12	1	18	13	18	17	9	7
13	20	4	3	3	4	3	2
14	5	15	17	16	16	17	16
15	15	6	19	4	13	20	17
16	2	12	4	11	6	5	1
17	12	17	12	19	18	7	9
18	10	9	8	9	11	11	10
19	18	11	7	14	14	2	8
20	13	13	6	12	10	6	6

Appendix IX

Implications of Implementing Robotics

The ten conclusions to the report by Northcott, J. (1986) titled "Robots in British Industry : Expectations and Experience", The Policy Studies Institute.

1. Robots ACCEPTABILITY is high, with 81% of users saying that robots were worthwhile, 61% plan to buy more, and the same number announced increased profits.

2. The IMPACT ON THE WORKFORCE was encouraging, as only 2% experienced opposition, whilst 71% reported favourable attitudes. Communication between management and workers was good, as over 80% of companies consulted workers before installation.

3. BENEFITS were numerous, but improved quality, more consistent products, increased output and reduced labour costs were the main factors.

4. Most companies undertook feasibility studies before IMPLEMENTATION, and half the users opted for "Turnkey" installations. Second and succeeding installations were found to be easier in achieving and justifying. The implementing companies were found to be those, who had experience with previous technologies.

5. There is an EDUCATION AND TRAINING shortage in the expertise of users, vendors and consultants. However, the retraining of the workforce is successful, and redeployment of displaced workers is not too difficult.

6. The FINANCIAL ATTITUDES are mixed, as robots tend to be a long term investment. More widespread use could be promoted, if there were cheaper robots and associated equipment.

7. The initiation of robots into the factory environment, on 50% of the cases, were by non MANAGEMENT personnel, and only 30% came from the boardroom. It was reported that robots are three times more common in overseas owned groups operating in the UK.

8. The DTI give ASSISTANCE by a support scheme, which was significant on the robot investment decisions. However, 14% of companies were unaware of grant aid.

9. ROBOTS ARE NOT ISLANDS and are becoming just elements of wider advanced manufacturing systems.

10. In the FUTURE 60% of user's plan to buy robots in the next two years, whilst 38% of the companies, not yet using robots, anticipate using them in the next two years, principally in assembly.

Appendix X

Quantifiable Benefits of AMT

Direct Cost Savings

1. Reduced labour.
2. Lower recruitment costs from reduced labour turnover.
3. Eliminated lost production during training of new workers.
4. Reduced operating costs from improved machine and plant utilisation.
5. Reduced scrap.
6. Reduced rework.
7. Reduced product warrantee costs.
8. Components redesigned to reduce material costs.
9. Flexibility enables cost reductions to be made during product life.
10. Flexibility allows redesign to eliminate quality problems.

Reduced Inventory and Work in Progress

11. Reduced lead times resulting in reduced work in progress.
12. More reliable production times enables work in progress to be reduced.
13. Fluctuating work load produced as required to eliminate "buffer stocks".

Reduced Future Capital Costs

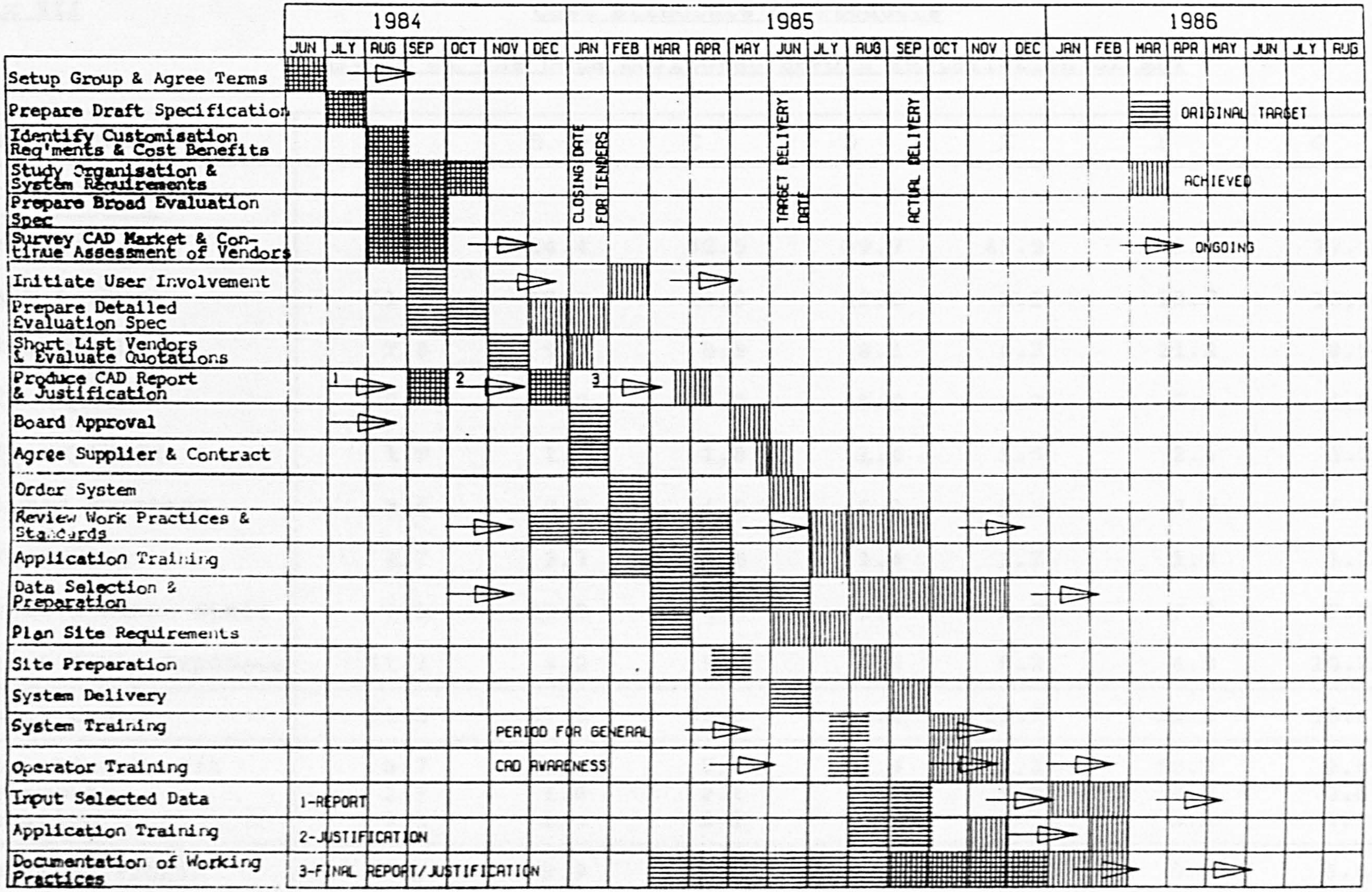
14. Increased output avoids purchase of additional machines and plant.
15. Product changes can be made with lower capital costs.

Increased Sales

16. Extra sales from improved quality.
17. Extra sales from lower costs and prices.
18. Increased output from existing plant gives more sales.
19. Flexibility allows earlier launch of new products, thus increasing sales over product life.
20. Shorter down time during product change prevents loss of sales.
21. Flexibility enables new products to be introduced more often, resulting in extra sales.
22. Hazardous and undesirable tasks performed reliably, enabling shorter and more reliable delivery promises, leading to increased sales.
23. Improved company image for sales promotion.

Appendix XI

Program for the Implementation of a CAD System



Appendix XII **Cost Structure of Products**

Analysis of the Data Collected BEFORE Installation of AMT

Model Letter	A	B	C	D	E	F	G	H
Cost Component								
Materials	30.5	24.4	32.5	39.7	41.9	33.8	37.3	35.8
Direct Labour	11.8	13.2	10.9	12.2	8.2	13.7	10.9	14.6
Indirect Labour	7.8	9.3	8.9	8.1	6.2	11.2	8.9	9.8
Staff Labour	9.2	8.0	7.2	5.2	5.9	7.9	6.8	8.8
Fixed Expenses	1.9	1.3	1.8	1.6	1.5	2.4	1.2	1.3
Variable Expenses	8.6	9.0	14.0	6.1	8.3	7.7	6.1	5.4
Depreciation	2.7	2.7	1.6	1.4	1.7	1.2	1.2	1.2
General & Admin Staff	7.9	10.9	6.2	6.9	9.0	7.2	7.9	7.9
General & Admin Expenses	11.1	8.2	9.2	6.6	8.2	4.8	10.3	7.1
Total Costs	91.3	87.0	92.3	88.1	90.7	89.8	90.6	92.0
Operating Profit	8.7	13.0	7.7	11.9	9.3	10.2	9.4	8.0
Interest	2.7	1.9	2.1	1.1	1.9	0.9	0.6	1.0
Taxation	3.1	1.3	2.1	2.6	2.9	3.4	3.2	3.1
Retained Profit	2.9	9.9	3.5	8.3	4.4	5.9	5.6	3.9

Source : "Advanced Manufacturing Technology - The Impact of New Technology on Engineering Batch Production", AMS Group, NEDO, (1985).

Appendix XII (continued) **Cost Structure of Products**

Analysis of the Data Collected AFTER Installation of AMT

Model Letter	A	B	C	D	E	F	G	H
Cost Component								
Materials	22.6	21.4	27.7	33.9	35.7	28.8	31.7	30.5
Direct Labour	7.2	7.9	4.6	4.4	2.7	5.6	4.2	5.3
Indirect Labour	6.7	7.4	3.6	3.3	2.9	4.9	3.9	4.2
Staff Labour	7.4	6.9	4.5	3.5	3.5	4.2	3.7	4.5
Fixed Expenses	1.5	1.1	1.4	1.2	1.1	1.8	1.0	0.9
Variable Expenses	6.3	6.9	8.2	4.4	5.1	4.9	4.0	3.4
Depreciation	5.8	6.2	9.7	9.2	8.4	7.7	7.1	6.7
General & Admin Staff	6.5	7.8	4.8	5.2	6.6	4.5	5.4	4.9
General & Admin Expenses	10.5	7.0	8.3	6.3	7.6	4.0	9.8	6.5
Total Costs	78.6	72.4	72.7	71.3	73.5	66.4	70.8	67.0
Operating Profit	21.4	27.6	27.3	28.7	26.5	33.6	29.3	33.0
Interest	-1.3	-4.9	-3.1	-6.1	3.8	-6.4	-6.2	-5.8
Taxation	9.0	11.2	10.3	8.1	9.9	12.2	10.8	12.0
Retained Profit	13.7	21.2	20.2	26.7	12.8	27.8	24.7	26.8

Figures are expressed as a percentage of Turnover.

Appendix XIII

Actual and Projected Total First Degree Graduates

in Great Britain 1980 to 2000

Year	Graduates by Institution				Graduates by Subject Discipline				
	University	Polytechnic	Open	Total	Arts	Engineering	Business	Science	Mathematics
1980	65.8	30.1	6.3	102.2	13.8	13.7	24.4	14.6	3.9
1981	68.0	32.7	6.5	107.2	14.3	14.6	25.3	15.5	4.4
1982	70.1	36.0	6.5	112.6	15.5	15.2	26.9	16.1	4.8
1983	72.2	39.8	6.5	118.5	16.7	15.7	28.5	16.7	5.4
1984	71.2	44.2	6.6	122.0	17.9	16.0	29.1	17.4	5.9
1985	69.0	48.9	6.0	123.9	17.7	16.3	29.7	18.4	6.2
1986	67.0	51.9	6.5	125.4	17.7	16.1	30.2	18.6	6.2
1987	69.5	51.0	6.5	127.0	16.4	16.3	31.0	18.7	6.9
1988	71.2	52.9	6.5	130.6	16.7	16.5	31.8	19.6	7.2
1989	71.2	54.7	6.6	132.6	17.2	17.9	32.6	19.0	7.1
1990	72.1	56.2	6.7	135.0	16.7	18.6	33.0	19.1	7.7
1991	72.2	57.2	6.8	136.2	16.6	18.8	33.1	19.2	7.8
1992	73.6	58.0	6.9	138.5	16.6	18.9	34.8	19.1	7.9
1998	68.5	52.5	7.0	128.0					
2000	70.0	54.0	7.0	131.0					

Figures : Thousands of Graduates.
Source : Projections of Demand for Higher Education in Great Britain; 1980 to 2000.
Department of Education and Science 1986.

Appendix XIV Process Choice Characteristics for Different Aspects in 10 Surveyed Companies

Manufacturing Aspects	Characteristics of the 10 Companies Surveyed									
	1	2	3	4	6	7	8	13	14	20
Products and Markets										
Type of Product	J	L	J	L-B	L-B	B	J	L	J	L
Product Range	B	B	J	L-B	L-B	B	J	B	J	L
Customer Order Size	J	B	J	L-B	L-B	B	J	B	J	L
Level of Product Change	B	L	J	L	L	B	J	L-B	B	L
Rate of New Products	B	L	J	L	L	B	J	L-B	B	L
What does Company Sell	B	L	J	L	L	B	J	L	B	L
Market Winning Criteria	J	L	J	L	B	B	J	B	J	L-B
Order Winning Criteria	J	L	J	B	B	B	J	B	J	L-B
Manufacturing										
Process Technology	B	L	J	B	B	B	J	L	B	L
Process Flexibility	J	L	J	B	B	B	J	L	B	L
Production Volumes	J	J	L	L	L	B	J	B	J	L
Dominant Utilisation	B	B	B	L	L	B	J	B	J	L
Key Manufacturing Task	J	L	J	L	L	B	J	L-B	J	L
Changes in Capacity	J	J	J	L	L	B	J	L	L	L

Key: J = Jobbing B = Batch L = Line

Appendix XV

Problems of Maintaining AMT

Individual Responses from the Maintenance Questionnaire

Management

- Getting approval for implementation.
- Lack of managerial capability / Planned maintenance.
- No maintenance strategy.
- Quantifying the penalties for not maintaining.
- Fit in with production runs (scheduling).

Manpower

- Obtaining acceptance from the workforce.
- Experienced Manpower.
- Training and Awareness of Problem Areas.
- Multi-skilled craftsmen.
- Availability of maintenance engineers.

Information

- Lack of detailed instructions from the suppliers.
- Insufficient data.
- Poor communication between Production and Maintenance.
- Trouble finding the appropriate documents and manuals.

Resources

- Lack of spare parts control.
- No training of existing staff.
- Not enough time.
- Availability of spare parts.

Equipment

- Machines are not designed with maintenance in mind.
- The complexity of the machines.

Appendix XVI

Requirements of a Good Maintenance Engineer

Individual Responses from the Maintenance Questionnaire

Technical Expertise

- Technical competence.
- Continuously trained in all aspects of automation.
- Capable of maintaining the equipment.
- Trained, confident and tolerant.
- Adaptable to "hi-tech".
- Multi-skilled.
- Logical, careful and progressive.
- Capable of learning the latest techniques.

Managerial Skills

- Practical Management
- Able to maintain complete systems, not single machines.
- Aware of need to delegate to trained subordinates.
- Multi-disciplined attitude.
- Organised, ability to plan and cost justify existence.
- Supported by computers, management and staff.

Diagnostics

- Thinking logically.
- Good sound knowledge of the plant.
- Ability to recognise patterns of problems.
- "Knows when he doesn't know".
- Equipment familiarisation.

Communication

- Good communication skills.
- Awareness of new methods and tools.
- "He cannot be good on his own".

Business Understanding

- Understands customer's business and operation.
- Sympathy with the customer.
- Understand the need to make the plant available.

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Appendix XVII

Cash Flow Analysis for a CAE Investment in Company 14

Capital Outlay	$200,000
Installation Cost	$10,000
Development and Training Costs	$10,000
Reduction in Overtime	3600 hours
Reduction in Manpower	12 men
Cost of Overtime	$7.90 per hour
Cost of a Draughtsman	$7,500 per year
Cost of Supervision	$10,000 per year
Saving From Reprographics	$11,000 per year
Cost of Maintenance	$24,000 per year
Power Costs	$8,000 per year
Consumables	$4,000 per year

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Capital Outlay	200000						
Installation	10000						
Development and Training		10000					
Cost of Supervision		10000	10000	10000	10000	10000	10000
Cost of Maintenance		24000	24000	24000	24000	24000	24000
Power Costs		8000	8000	8000	8000	8000	8000
Consumables		4000	4000	4000	4000	4000	4000
Total Costs	210000	56000	46000	46000	46000	46000	46000
Operating Efficiency		50%	80%	95%	100%		
Savings From Overtime		14220	22752	27018	28440	28440	28440
Savings From Reduced Manpower		90000	90000	90000	90000	90000	90000
Savings in Reprographics		11000	11000	11000	11000	11000	11000
Total Savings		115220	123752	128018	129440	129440	129440
Annual Net Cash Flow	-210000	59220	77752	82018	83440	83440	83440
Discounted Cash Flow	-210000	51496	58792	53928	47707	41484	36073
Cumulative Cash Flow	-210000	-158504	-99713	-45784	1923	43407	79480

Company's Discount Factor	15.0%
Internal Rate of Return	27.4%
Net Present Value	$79,480
Accounting Payback Period	+3 years

Sensitivity Analysis

Discount Rate	Net Present Value (£)
0%	259310
5%	184062
10%	125616
15%	79480
20%	42524
25%	12522
30%	-12133
35%	-32622

Capital Outlay(£)	IRR	Net Present Value (£)
50000	-190%	229480
100000	-184%	179480
150000	40%	129480
200000	27%	79480
250000	19%	29480
300000	13%	-20520
350000	8%	-70520
400000	4%	-120520

Appendix XVIII **Cash Flow Analysis for a CAD Investment in Company 18**

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Capital Outlay	$990,000	(330,000)	(330,000)	(330,000)				
Total Costs		(330,000)	(330,000)	(330,000)	0	0	0	0
Travel and Communication			7500	15000	22000	37500	37500	37500
Reduction in Drawings and Materials			1250	2250	3750	6250	6250	6250
Moldflow			0	20000	70000	130000	130000	130000
Products Produced on Time			10000	30000	60000	100000	100000	100000
Additional Products in Range			140000	350000	560000	975000	975000	975000
Total Savings			158750	417250	715750	1248750	1248750	1248750
Annual Net Cash Flow		-330000	-171250	87250	715750	1248750	1248750	1248750
Discounted Cash Flow		-330000	-137000	55840	366464	511488	409190	327352
Cumulative Cash Flow		-330000	-467000	-411160	-44696	466792	875982	1203335

Company's Discount Factor 25.0%

Internal Rate of Return 73.5%

Net Present Value 1.20E+06 pounds

Accounting Payback Period +3 years

Appendix XIX

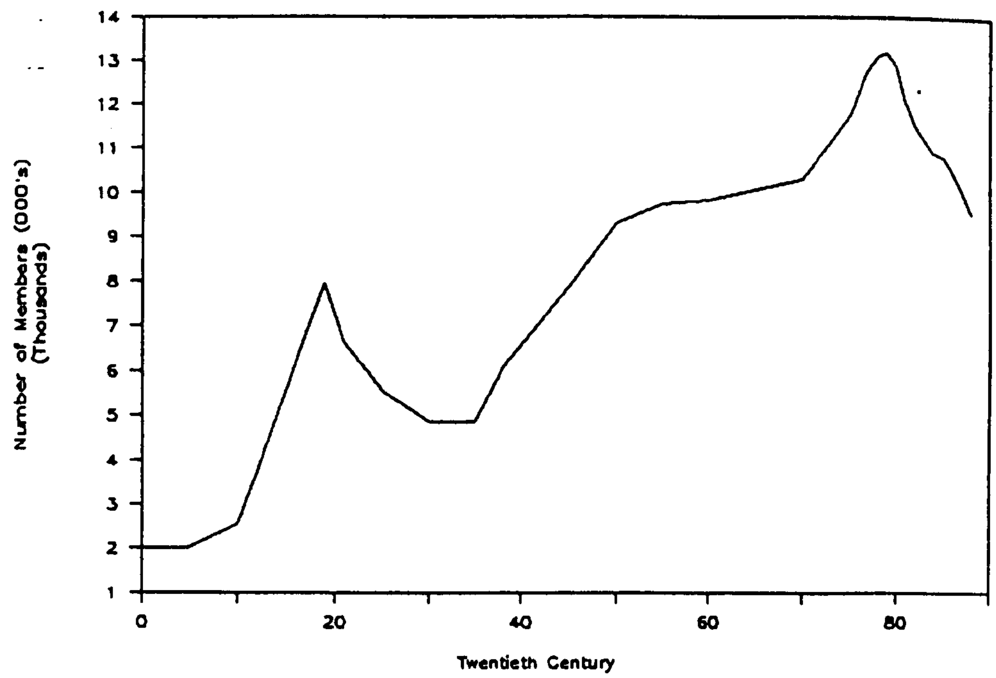
Trade Union Membership 1900 to 1988

The rise in trade union membership since the second world war peaked in 1979 at 13.2M, and coincided with a change in UK government from Labour to Conservative. Since 1979 membership has declined steadily to 9.5M in 1988, and is reportedly below 8M in 1989 (see table).

Year	Union Membership (000's)	Unemployment %	Number of Unions	Mean Members Per Union
1900	2023	5.0	1323	1529
1905	1997	4.7	1244	1605
1910	2565	2.1	1269	2021
1919	7926	12.9	1360	5828
1921	6633	11.3	1275	5202
1925	5503	16.0	1176	4679
1930	4842	15.5	1121	4319
1935	4867	13.2	1049	4640
1938	6043	11.2	1024	5911
1945	7875	1.5	781	10083
1950	9289	1.2	732	12690
1955	9726	1.7	694	14014
1960	9821	2.7	654	15017
1970	10300	2.4	555	18564
1975	11760	2.9	407	28882
1976	12300	5.2	473	26004
1977	12800	5.7	481	26611
1978	13100	5.6	462	28355
1979	13200	3.2	453	29139
1980	12900	4.6	438	29452
1981	12100	9.3	414	29227
1982	11500	12.1	408	28186
1983	11200	13.3	394	28426
1984	10900	11.5	375	29067
1985	10800	11.9	370	29189
1986	10500	11.8	335	31343
1987	10000	10.6		
1988	9500	9.1		

Source : Department of Employment Gazette

Trade Union Membership Since 1900

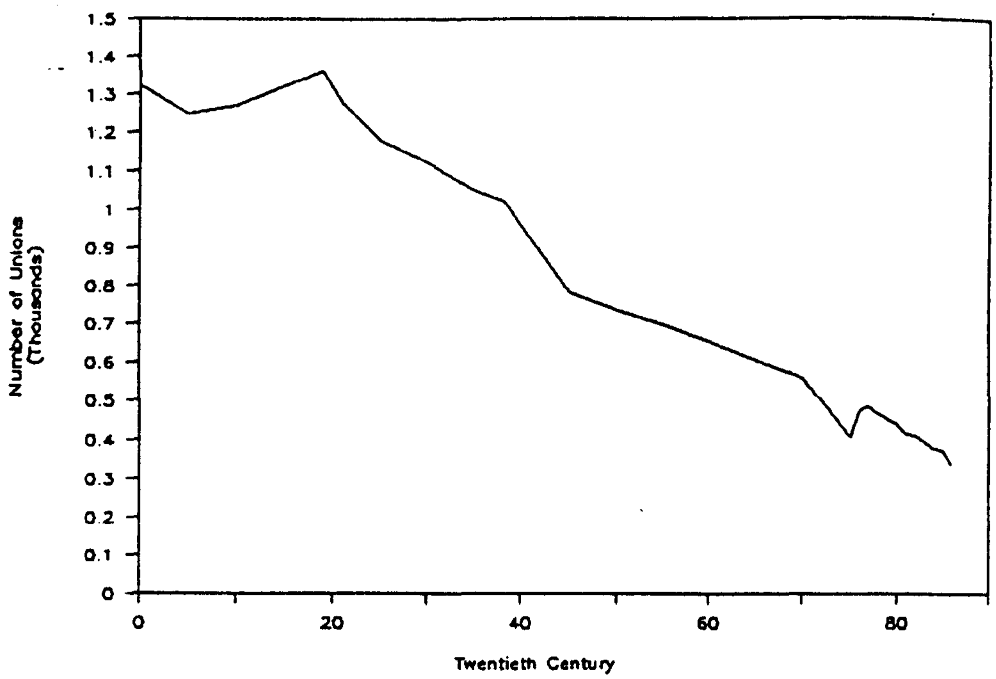


Two MORI opinion polls, conducted in 1979 and 1988, asked members of the public whether they thought the trade unions had too much power. 69% responded yes in 1979, whilst 31% responded yes in 1988.

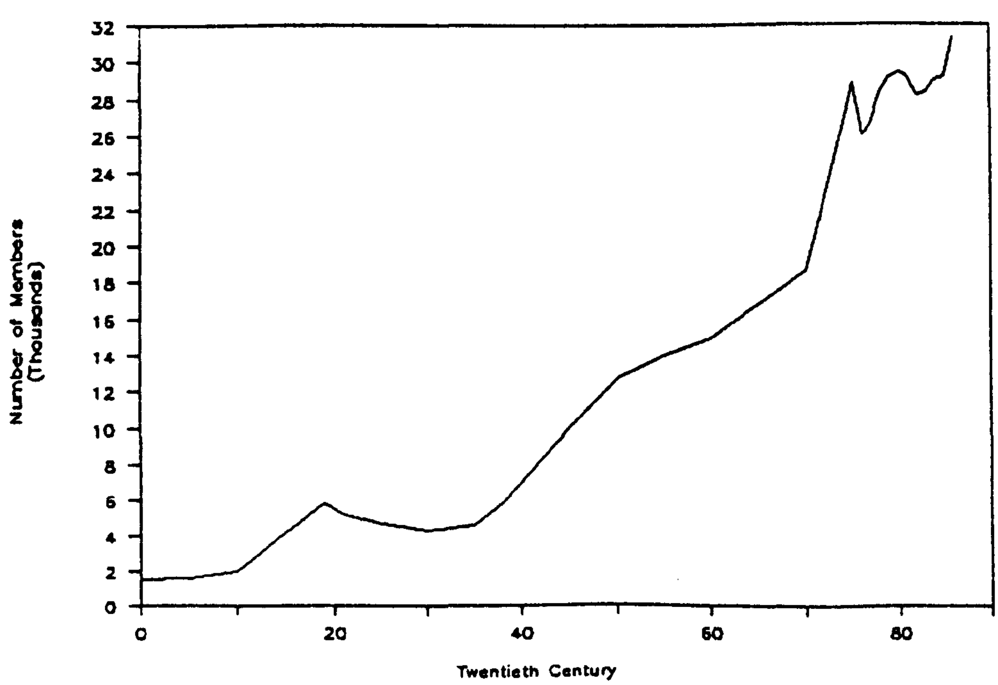
The number of trade unions has fallen from a peak in 1919 of 1360 to just 335 in 1986 (as shown in the table). The main reason for this is the amalgamation of individual trade unions, such as the Engineers' into the AEU, due to trades becoming less well defined, increased bargaining power, economies of scale and the virtual disappearance of certain trades.

The consequence of high membership and falling numbers of trade unions has been an increase in the number of members per trade union, which in 1988 was over 31,000. Furthermore, the level of unionization has fallen, from 55% of the working population in 1979, to 45% in 1986 (see table).

Number of Trade Unions



Mean Number of Members per Trade Union



Appendix XX

Thoughts from Company Personnel

To supplement the information given in the main text, individual thoughts and comments from the transcribed interviews, with company management and engineers, are given below. They have been divided up into six categories :

Human Resources
Product Design and Marketing
Corporate Strategy and Planning
Equipment Suppliers
National and International Issues
Manufacturing Systems

Human Resources

Management must be committed, enthusiastic, active and involved from start to finish.

Management has to appreciate what it can, and cannot do.

There must be a top-down approach to automation.

Management needs to be educated, it is known that there is a large training gap of Britain's top company managers.

Teamwork is essential, as the education system cannot hope to educate a person who has the required blend of knowledge in business, mechanics, electronics and design.

Industry in general does not know what it wants in terms of employee skills and education.

Skill is a combination of education and experience.

There are changed patterns of working and employment, the structure of industry and the nature of society.

Human progress is translating "ideas into reality".

The accelerated trend to greater productivity and efficiency in design and manufacturing requires fewer people.

Although direct employment in manufacturing is decreasing, there is a growing army of service and support staff.

Small firms find it difficult to get to grips with the new technology, or make the necessary investment in training.

The shortage of expertise and the need on all sides to find ways in which it can be developed.

Attitudes towards AMT investments need to be reassessed.

Training on technology needs must begin at the primary level, and proceed all the way through to University.

The introduction of new technologies has reduced the working week and resulted in improved standards of living and more leisure.

Product Design and Marketing

Comprehensive "Quality Assurance" programme is necessary to ensure product quality is high.

The key factors are those of batch size and product range as these determine the form of process technology required.

Industry believes that products and environments change too quickly for them to formulate a manufacturing strategy.

Companies must re-design before they automate.

Robots are "quality" machines, rather than labour saving machines.

Corporate Strategy and Planning

The managing director must be convinced that their production methods can be improved with automation.

Management Information Systems give a company the ability, through its information systems network, to monitor the costs and performance of each stage of the system. A company without such a system is unable to calculate the worth of a robot, or conduct a successful audit.

Too few companies ask themselves whether automation is going to solve the fundamental problem.

Automation has to be the last phase of a rationalisation plan.

Automate "step by step", otherwise known as "rolling" automation.

Solve the easy problems first.

Companies must have a business strategy.

AMT should not be justified on labour reductions alone.

The availability of grants should not influence a company's decision to invest in AMT.

There must be a team or project leader whose role is to manage the project.

The company's "philosophies" must be converted into strategies and plans before the "technology" is considered.

Consultants are a resource that have to be managed as they only give advice, and are not responsible for it.

Companies are short sighted. They do not place sufficient emphasis on future development.

Larger companies have to look over their shoulders at their shareholders as a response for not being innovative or modernising their production lines.

Banks generally finance short time scale projects, with proven and mature technologies, where the risk is low.

Many inventions are never developed into products because few bodies are prepared to provide the development support needed. There is a large (but decreasing) lead time between invention and industrial use.

For effective strategic planning a "top-down" approach is required.

The cost of making the wrong decision is very high.

Companies too often adopt AMT for the wrong reasons.

Automation is designed to manufacture existing products.

Computers have been used to do what we already do, but there is real potential to do things in ways previously impossible.

It is a question of balancing what computers do best, and what humans do best.

The importance of short term financial criteria and obsession with labour reductions should be reduced.

Planning is needed at all business levels.

Years of planning are required before systems can be implemented, and even longer before they can be judged a success.

The true benefits of AMT only accrue when the system is used to its full potential, and fully integrated.

The chief manufacturing task is to become more flexible, and responsive to the needs of the customer.

Equipment Suppliers

The equipment suppliers must aim for lower robot cost systems.

The reason for the slow market uptake, is that industrial robots of the current vintage are not yet as effective as humans in most jobs.

Suppliers must adapt their equipment for different manufacturing systems.

AMT has to be made more user friendly.

Research is concentrated into specialised aspects such as Artificial Intelligence, rather than on basic product development.

Reported inadequate after sales service by the suppliers is a big deterrent to the diffusion of AMT.

Design AMT to minimise maintenance and service requirements.

Close liaison should exist between the suppliers of AMT and the company planners to avoid pitfalls.

Too often the problems of "scaling up" the technology are overlooked.

Company specifications for equipment has to more closely represent the actual operations they want it to do.

Smaller companies rely more heavily on equipment suppliers.

The software is just as important as the hardware.

Companies have to manage the equipment suppliers just as closely as their own personnel and operations.

Equipment suppliers are more interested in short term sales, rather than long term growth.

The optimum method of implementing automation is through a "systems house" or Integrator.

Trying to manage the AMT equipment suppliers is a more sophisticated job than that of the conventional suppliers.

There is always the temptation to purchase a system that is too sophisticated for the task in hand.

Agents and Suppliers of AMT do not necessarily sell the "best" solutions to the company due to the restriction of their product range and commission rates.

Companies have to find the optimum balance of utilising "in-house" expertise, and the expertise of the suppliers.

National and International Issues

Britain has a national problem of under resourced research and training.

The smaller companies are in need of national assistance as they are less able to manage on their own.

Governments give in one hand, and take back with the other. Nothing is given away free.

AMT software and hardware businesses are truly international.

The UK government is the only government that abides by the rules.

Society is more demanding, and wants more choice than the present society can provide.

The British manufacturing companies have become complacent over the last generation, and have now a severe lack of understanding for being competitive.

British companies fail to appreciate the need for retraining and education.

Manufacturing Systems

Companies should initially focus on simplifying the environmental activities such as factory layout, machine changeover times, master production schedules, component supplier partnerships and information systems prior to automating.

There is a need for linkage between the "islands" of computing and automation.

Companies do not take a systems view to their operations.

Until the company fully understands their operating system, they will not appreciate the fundamental problems and barriers.

Company's systems have to be changed to meet the requirements of the technology.

The problems are not in actually operating the machinery, but in the effective use of them.

Proven technology should always be used at bottlenecks.

Advanced Manufacturing Technology must go hand in hand with other changes to manufacturing, and the business as a whole.

Appendix XXI

Thoughts and Comments from the Institutional Personnel

To supplement the information given in the main text, individual thoughts and comments from the transcribed interviews, with institutional representatives, are given below. They have been divided up into five categories :

Human Resources
Product Design and Marketing
Corporate Strategy and Planning
Equipment Suppliers
Miscellaneous

Human Resources

The control of the workforce and the reduction of employment is said to be the key criteria for adopting automation.

There is a shortage of people with the skills and knowledge of machine tools, and an appreciation of electronics.

New systems have meant the introduction of recording work and jobs done, making employees accountable for what they do.

Advances in human resource management revolve around motivation and job rotation.

"Accountants" do not understand the "needs" of the "Engineer".

High staff turnover resulted in a lack of continuity, with too many people re-learning the basics.

Worker participation is the key to future success.

Traditional management practices are just as bad if not worse than working practices.

People who had done the manual work appreciate AMT, and are aware when the machines are malfunctioning.

Employees have to be educated, to appreciate the advantage of new systems.

Ideas go from the workers to the board, whilst orders go from the board to the workers.

Every company and its employees have to gain experience and join the learning curve for implementing AMT.

Breaking with traditions is hard, (ie all aspects from human attitudes to production methods, and management practices).

People have to have the right attitude, discipline and temperament for automation. AMT requires a different "Culture".

Product Design and Marketing

Automation leads to more standardised and modular products.

Design changes are technological (to improve performance) and not to simplify the manufacturing process.

Automation places new emphasis on the need to design for manufacture.

Pulled by commercial reality to focus on our product range. Manufacturing now build to order and not to forecast.

Products have to become more modular.

Keeping pace with the rate of development of product technology is just as difficult as keeping pace with production technology.

Initially, automation has to manufacture existing designs.

Reason for automating was to broaden horizons from the traditional markets.

Corporate Strategy and Planning

Automation systems are easier to install on "green field" sites.

Our competitors have driven us into automation.

The control of the business and its key costs are critical.

Larger companies are focusing manufacturing by having their different sites producing different products.

Manufacturing Early Involvement (MEI) systems, where manufacturing, engineers, and designers collaborate at an early stage of new product development, are essential to fully utilise automation.

Concentrate on the manufacturing functions the company does well.

It is utopia to believe that you can have a factory of the future with no lights or people, but it could be the target.

The opportunity cost of not automating is a strategic problem.

With manufacturing becoming a smaller part of the company's operations as a whole, one must question the value of manufacturing at all.

Cannot afford to implement the wrong system or technology.

Optimise the whole system, and not the sub-systems.

Manufacturing Systems

Automation has "tea breaks" when it is positioned in the middle of a production line.

A greater proportion of manufacturing activities are critical.

The critical factor with robotics is the operational cycle time, as this governs the number of additional operations that can be carried out simultaneously.

The system is only as good as the weakest link.

Computer integrated business systems give a company total control of their business.

The most sophisticated manufacturing facilities do not guarantee success.

Despite all the publicity over AMT, it only affects a small part of the business. However, new inventory and production control systems affect everyone.

When apparently difficult systems are introduced successfully, they seem so simple.

Keep manufacturing simple.

Production balancing and scheduling has to be controlled more implicitly.

"Islands of Automation" will be concentrated around those functions it does best.

Rationalise the existing manufacturing systems before considering automation, as many cost efficiencies can be made cheaply.

Cannot hope to integrate manufacture until there are many islands to be linked. It is unlikely to be feasible to make a new link every time an installation is made, but it can be part of a plan.

Research and Development resources often concentrate on the product rather than on how it is made.

Computer integrated manufacture forces companies to integrate and communicate, but shop floor data collection remains the greatest hurdle.

Data is never collected on the performance of each different machine, but on the system as a whole.

Production makes what it is told to make, and therefore product costing is not their responsibility.

It still remains a challenge to an engineer, to be able to manufacture what a designer wants.

Finding the most appropriate system for the job in hand is the most difficult task.

One has to seriously consider production volumes and existing designs before considering the value of automation.

Post implementation audits are not carried out.

Miscellaneous

Fleet management makes the manufacturers responsible for what they make by carrying out servicing and maintenance.

Cannot copy the Japanese Methods and Practices.

Machine tools mostly come from overseas countries.

AMT is rarely used by those who develop and manufacture it.

Suppliers call out charges are excessive at £500 a day.

Appendix XXII

Outline of the Structure of Questions - Asked at the Surveyed Companies

General Questions

1. History, background and development of the company.
2. Corporate aims and objectives.

Questions on the Implementation of AMT

3. Sequence and timetable of events for implementing AMT.
4. Project team and leader.
5. Identifying the need for change.
6. Awareness of AMT equipment.
7. Consideration of alternative solutions.
8. Timing of the implementation.
9. Position of the manufacturing site.
10. Preparing for the automation.
11. Selection of the AMT equipment.
12. Justification and financing the AMT.

Questions on Manufacturing Resources

13. Manufacturing strategy.
14. Process positioning.
15. Choice of process.
16. Characteristics of the manufacturing system.
17. Investment and cost.
18. Infrastructure and organisation.
19. Focussed manufacturing.
20. Problems and implications of adopting AMT.
21. Measuring the performance of AMT.
22. Human resource management.

Questions on the Business Activities.

23. Product Design.
24. Procurement of component supplies.
25. Marketing products manufactured with AMT.
26. Maintenance of AMT.

Questions on the External Influences on the Company

27. AMT equipment suppliers.
28. Financial institutions.
29. Government.
30. Management consultants and professional institutions.

General Questions

1. History, background and development of the company.

How has the company developed since it was formed ?

What significant changes have taken place ?

Which of these changes were carried out by the company and which were enforced onto the company ?

What traditional ideologies and images has the company evolved?

How would you describe the overall competitive position of the company ?

What are the major factors which are affecting the company and the methods of trading today ?

What role does manufacturing play within the company ?

2. Corporate aims and objectives.

What are the company's short, medium and long term aims and objectives?

How have they changed over the last decade ?

How far into the future does the company plan ?

How is the company performing against its aims and objectives ?

What is company doing to achieve its aims and objectives ?

Who are the main competitors ?

On what grounds do they compete and in what way are your products different ?

Would you describe your company's strategy as defensive or offensive ?

Questions on the Implementation of AMT

3. Sequence and timetable of events for implementing AMT.

What were the company's previous experiences with new technology?

What procedures does the company have for accepting or rejecting AMT ?

What are the differences, if any, between procedures for past investments and those involving AMT ?

What timetable or programme was introduced to control the project?

4. Project team and leader.

Was there a special team formed to look after the AMT project ?

Who were the team of decision makers ?

From which specialities were they drawn from ?

How regularly did they meet ?

Who was the project leader, and what crudentials did they require?

5. Identifying the need for change.

When did the company realise that it had to change its existing manufacturing methods ?

Who was credited with initiating or identifying the need for change ?

What performance indicators were used to deduce the deficiency?

What manufacturing operation or area was identified for change?

Were any of the following factors influential :

- customer demand for product variety, quality, delivery ?
- new advancements in manufacturing technology ?
- new advancements in manufacturing techniques ?
- knowledge that some operational inefficiencies could be achieved ?
- need to maintain a competitive advantage over competitors?

6. Awareness of AMT equipment.

How was the company made aware that AMT was available ?

How and when, was the company made aware that AMT could be a possible solution ?

7. Consideration of alternative solutions.

Having established that change was required :

What alternatives to AMT did the company consider ?

Why were the following possible alternatives rejected :
- doing nothing ?
- buy a traditional machine simply for replacement ?
- subcontract the work to other companies ?
- use less sophisticated technology ?
- improving present products on existing technology ?
- improving present manufacturing techniques ?
- use more cost effective materials ?
- overhaul the existing equipment ?

8. Timing of the implementation.

Why was the decision to invest in AMT taken at the time it was?

Was the timing of the implementation a specific strategic decision or was it just the next stage in the automation process?

Was the timiming of the implementation influenced by the :
- level of consumer demand in the market ?
- known robustness of the technology ?
- prospect of being market leaders in the technology ?
- actions of competitive companies ?

Does the company :
- lead the rest of the industry ?
- invest continually in the most up to date equipment ?
- wait until the technology has been proven ?
- wait until it is possible to leapfrog competitors ?

9. Position of the manufacturing site.

Why was the factory located where it is ?

Was there any difficulty in installing the new equipment ?

To what extent do the present factory facilities restrict changes in layout and equipment ?

10. Preparing for the automation.

Does the company have a development plan for the implementation of AMT ?

How far through the plan is the company ?

How detailed is the plan ?

What areas of the company are affected by AMT installations ?

What physical preparation is required prior to the installation?

To coincide with the implementation of AMT did you need to alter:
- any manufacturing techniques ?
- the production operating schedules ?
- products or product lines ?

When did the installation of the equipment begin and how long did it last for ?

What unexpected problems were encountered during the implementation process ?

11. Selection of the AMT equipment.

How did the company decide what was the best alternative ?

How did the company draw up the equipment specification ?

What procedures were adopted for selecting the technology ?

How were the AMT suppliers chosen ?

What guidance did the suppliers give in the selection of AMT ?

To what extent did you rely on the experiences of other companies or management consultants ?

Was the installed system more or less complex than initially intended ?

Did the availability of the technology have any influence on the technology installed ?

Was the purchased equipment :
- already operational in some other company ?
- adapted to meet specific operational requirements ?
- custom built for the company ?

What are the special attributes of the AMT equipment ?

Do you obtain AMT equipment and accessories from :

- many small companies ?
- many small companies but controlled by a 3rd party ?
- one main supplier who can provide all the equipment ?
- one supplier who is responsible for small suppliers and the project as a whole ?

12. Justification and financing the AMT.

Who conducted the investment appraisal ?

What criteria were used in the projects appraisal ?

What method of appraisal was used ?

What criteria does the appraisal have to achieve before acceptance ?

How are non-financial criteria accounted for ?

Was the individual investment appraised or the whole system ?

What was the size of the investment(s) ?

What form of grant aid was available ?

What is the assumed life of the equipment ?

Questions on Manufacturing Resources

13. Manufacturing strategy.

What were the components of the company's manufacturing strategy?

How were the strategies implemented in practice ?

What role did AMT have in the strategy ?

What measures were used to monitor the performance of the AMT and the manufacturing strategy ?

What are the material and informational flows around the factory?

What are the inputs, precesses, outputs and feedback control loops to the system ?

14. Process positioning.

What is the layout of the factory ? (continuous, flow, functional)

How has the factory layout changed over the past decade ?

How would the process positioning be affected by significant changes in volume ?

How is the introduction of new technology affecting the number and proportion of products manufactured in-house ?

15. Choice of process.

What are the scales of production for the different processes within the company ? (one-off, low or high volume)

What are the corresponding methods of production for each process? (job, batch, continuous)

What is the nature of the manufacturing equipment at each stage? (dedicated, flexible)

What is the investment into the equipment at each stage and the corresponding operating costs ?

How do the above change with the volume changes depicted by the product life cycle ?

16. Characteristics of the manufacturing system.

What AMT has been installed ?

What automation is planned for the future ?

How sophisticated is the automation ?

How well integrated is the AMT with other production and computing systems ?

What is the nature of the process technology ? (general purpose, dedicated)

What is the process flexibility ?

What are the production volumes ?

How are changes in capacity coped with ?

What is the key manufacturing task ? (cost, delivery, accuracy)

What is the dominant utilization ? (labour, plant)

17. Investment and cost.

What is the level of capital expenditure ?

What is the level of inventory for :
- components / raw materials ?
- work-in-progress ?
- finished goods ?

What is the percentage breakdown of total costs :
- direct labour ?
- direct materials ?
- indirect labour ?
- factory overheads ?

18. Infrastructure and organisation.

How is the organisation controlled ? (centralised, de-centralised)

What is the organisational style ? (entrepreneurial, beuraucratic)

What is the level of specialist support to manufacturing ?

Has the introduction of automation resulted in a revision to the organisational structure of the company ?

19. Focussed manufacturing.

Has the introduction of new technology allowed the company to:
- reduce or increase production volumes ?
- orientate manufacturing towards products ?
- orientate manufacturing towards the market / customer ?
- greater specialisation amongst its employees
- improve its utilization rates ?

Is the company following / leading its competitors or its markets?

How has the introduction of automation influenced :
- the number of component suppliers ?
- order and frequency of buyers' orders ?
- tolerance levels demanded and quality expected ?
- monitoring of incoming goods ?

Has the present system evolved over time or is it being imposed in one go ?

Does the company try and model itself on other company's systems or processes ?

Has the company expanded its manufacturing site ?

20. Problems and implications of adopting AMT.

What have been the comany's impressions of the AMT that has been installed ?

What have been the implications for the company and the manufacturing activity of adopting AMT ?

What implementation procedures would be done differently with the benefit of hindsight ?

What have been the major problems ?

Could these problems have been overcome with better control, planning or expertise ?

What have been the social implications of adopting AMT ?

Has AMT made the employees / mangement more accountable ?

What expected problems or benefits have not materialised ?

What events have occured which had not been expected ?

In which area of the company has there been greatest change in the last decade ?

In which areas has greatest success been achieved ?

In which areas has least success been acieved ?

Where will future company resources be concentrated ?

21. Measuring the performance of AMT.

What performance indicators or measures are used to evaluate the automation and manufacturing systems ?

What specific data is collected to calculate these indicies ?

How is the data collected, recorded and stored ?

What use is made of each indicator ?

Has the introduction of new technology affected the way the methods by which the company measures its success ?

22. Human resource management.

With regard to AMT what training has been carried out ?

When was the training carried out ?

Is the training and development part of an overall plan ?

What skills and qualification are required to operate the new equipment ?

Did the company need to employ new personnel ?

How many employees does the company employ ?

How many employees did the company employ ?

How do you envisage employment levels changing in the future ?

What has been the effect of AMT on :
- job descriptions or specifications ?
- job grades and wage systems ?
- the level of supervision ?
- proportion of qualified engineers to manual employees ?

Questions on the Business Activities.

23. Product Design.

(Based on the questionnaire in Appendix I)

What is the process for designing new products ?

Where do new designs originate from ?

What has CAD and CAE systems allowed the company to do which was not previously possible ?

Is there any integration between CAD or CAE and other computerised or manufacturing technology ?

Is CAD /CAE used to design existing products better or totally new products ?

What emphasis do designers' make on the ease of manufacture ?

24. Procurement of component supplies.

Has the company reduced the number of component suppliers ?

Has the company reduced the proportion of components bought from external suppliers ?

How would you describe the relationship that you have with your suppliers ? and how has this changed over the last decade ?

To what extent do you implement BS 5750 ?

Have you any such standads imposed on you ?

What quality checks do you have on incoming components ?

25. Marketing products manufactured with AMT.

(Some questions in the Product Design questionnaire, shown in Appendix I, were directed towards the marketing activity)

What products are being made ?

What markets are they aimed at ?

What influence has this had on the company's strategies ?

How have competitive companies moved within this market ?

What types of products are manufactured ? (special, standard, unique)

What is the product range ? (narrow, wide)

How many variations of each product are made ?

What is the rate of new product innovations ?

How long does it take to introduce a new product ?

How has the introduction of AMT affected :
- the number of product variations manufactured using the new technologies ?
- the ability of the company to enter new markats ?
- the marketability of the company ?
- the spedd at which changes are made ?

How is the manufacturing activity affected by product life cycles?

How has AMT affected product life cycles ?

How closely do you monitor the product life cycles of your products ?

How well informed is production of forecasted production volumes?

26. Maintenance of AMT.

(based on the questionnaire in Appendix III)

Questions on the External Influences on the Company

27. AMT equipment suppliers.

(Based on the questionnaire in Appendix II)

How many suppliers were contacted to give estimates ?

How did the company select its suppliers ?

How would the company describe the relationship that existed between them and the suppliers ?

What problems were encountered when dealing with suppliers ?

In general do you think the suppliers of automation :
- fail to put their customers' first ?
- are willing to adapt their products to a customer's precise specification ?
- have too much control over the management of the project?
- fail to provide an efficient "after sales " service ?
- force their products or those of thier suppliers onto the customer eventhough it may not be optimal ?
- were relied on too heavily ?

How much involvement do you think the suppliers of automation should have in the selection, installation, training and mangement of AMT implementations ?

28. Financial institutions.

How did the company raise the finance for its AMT projects ?

What constraints were placed on any borrowed money ?

How knowledgeable do you find the financial institutions on AMT?

29. Government.

Have you had any involvement with any government bodies regarding AMT ?

What does the company think the role of the government should be, in general and with respect to AMT ?

What assistance or aid could the government give to promote AMT?

What is the company's opinions on the present AMT initiatives ?

Do you believe that companies in the UK expect too much assistance from the government ?

30. Management consultants and professional institutions.

How did the company asses the need to contact external bodies ?

How did the company become aware of what assistance and information was available from external bodies ?

Did the company obtain any assessments from external consultants with regard to AMT ?

Did the company have a clear role and specification for any external body or were they given a free hand ?

Has the company any comments on the way in which the consultants conducted their work ?

What kind of advice was forthcoming from the consultants ?

Did you seek advice from any of the professional institutions ?

What do you think should be the role of the professional institutions ?

Do you think they should play a more active role in promoting AMT?

Appendix XXIII

Specimen Data Recording Sheet

Topic : Justification of AMT Investments

Question: 1. Appraisal Techniques and Conditions
2. Tangible Benefits
3. Intangible Bebefits
4. Size of Investment
5. Source and Availability of Grant Aid

COMPANY	1	2	3	4	5
1					
2					
3					
4					
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7					
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9					
10					
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15					
16					
17					
18					
19					
20					

Appendix XXIV

Hypotheses - Research Findings Paragraphs Matrix

Hypotheses	General Research
1	2, 46, 47, 52
2	9, 13, 34
3	4, 14, 19, 28, 55, 59, 63
Hypotheses	**Implementation of AMT**
4	1, 2, 3, 4, 5, 6
5	1, 7, 8, 9, 10, 11, 12
6	7, 9, 13, 14, 15, 16, 17, 18
7	19, 20, 21, 22, 23
Hypotheses	**Manufacturing Systems**
8	24, 25, 26, 27, 28, 29
9	21, 30, 31, 32, 33, 34, 35, 36
10	1, 22, 37, 38, 39
11	17, 40, 41, 42, 43, 44, 45, 46
Hypotheses	**Business Activities**
12	29, 47, 48, 49
13	30, 35, 40, 50, 51, 52
14	53, 54, 55, 56, 57, 58, 59
Hypotheses	**External Influences on the System**
15	60, 61
16	3, 10, 61, 62, 63, 64

Appendix XXV

Research Findings Paragraphs - Thesis Section Numbers Matrix

Justifying and Financing of AMT

1	4.4.4	7.2.2		
2	4.4.2	4.4.3		
3	7.2			
4	7.2			
5	4.4	7.2.2		
6	7.2.2	7.2.3		

Planning for the Implementation of AMT

7	4.1.1	4.1.2	4.2.1	5.3.3
8	4.1.2	5.2.3	5.3.4	
9	4.1			
10	4.1	4.3		
11	4.1	4.3		
12	5.1			

Managing the Process of Selecting the most Appropriate AMT

13	4.1.1	5.3.3		
14	2.3	4.1.3	4.1.4	4.1.5
15	4.3.2			
16	4.4			
17	6.3.2			
18	5.1.1	6.3.2		

Implications of Previous AMT Installations

19	4.1.3	4.1.4	4.1.5
20	4.2.2	5.4	
21	5.1.1		
22	5.1.3	5.3.2	
23	5.1.1	5.4.3	

Implications of AMT on Human Resourse Management

24	5.1.4	5.2.4
25	5.2.4	
26	5.2.1	5.3.2
27	5.2.3	7.1.4
28	6.4.2	
29	6.4.1	6.4.2

Implications of Adopting AMT on Production Operations and Incorporating the Technology into a Manufacturing Strategy

30	5.1		
31	5.1.4	5.2.4	7.4.5
32	5.3.1	5.4	
33	5.3	5.4	
34	6.3.3	6.5	
35	6.1		
36	5.4		

Appendix XXV (continued)

Measuring the Performance of AMT			
37	4.3.1	5.3.3	7.1.2
38	5.3.1	5.3.3	
39	4.1.4	4.3.4	7.1.3

Finding the most Suitable Technology to Integrate into the Manufacturing System		
40	5.3.1	5.4
41	5.3.5	
42	4.3.3	7.1.3
43	6.5.1	6.5.2
44	4.2	4.4
45	4.2.1	4.3.1
46	5.4	6.1

The Affects of AMT on the Marketing Activity			
47	2.2.3	6.3.1	
48	2.2.3	6.3.1	6.3.3
49	4.3.3	6.3.1	

The Affects of CAD and CAE Technology on Product Design and Designing for Manufacture Procedures		
50	5.1.1	6.1.3
51	5.1.2	6.2
52	5.4	

Managing the AMT Equipment Suppliers and Building a Partnership with the Component Suppliers		
53	4.3.2	7.1.2
54	6.2	
55	6.2.1	6.2.3
56	7.1.3	
57	4.3.1	7.1.2
58	7.1.2	7.1.4
59	7.1.3	

Trade Union Attitudes to AMT				
60	7.3			
61	7.1	7.2	7.3	7.4

Integrating AMT into the Whole Business System	
62	7.4
63	6.5
64	6.5