THE UNIVERSITY OF ASTON IN BIRMINGHAM

BUSINESS IMPLICATIONS OF MANUFACTURING INNOVATION:

The Experience of Increasing Automation in Smaller to Medium Sized Companies

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Despite the considerable potential of advanced manufacturing technologies (AMT) for improving the economic performance of many firms, a growing body of literature highlights many instances where realising this potential has proven to be a more difficult task than initially envisaged. Focussing upon the implementation of new manufacturing technologies in several smaller to medium sized enterprises (SME), the research examines the proposition that many of these problems can be attributed in part to inadequate consideration of the *integrated* nature of such technologies, where the effects of their implementation are not localised, but are felt throughout a business. The criteria for the economic evaluation of such technologies are seen as needing to reflect this, and the research develops an innovative methodology employing micro-computer based spreadsheets, to demonstrate how a series of financial models can be used to quantify the effects of new investments upon *overall* company performance.

Case studies include: the development of a prototype machine based absorption costing system to assist in the evaluation of CNC machine tool purchases in a press making company; the economics and strategy of introducing a flexible manufacturing system for the production of ballscrews; and analysing the progressive introduction of computer based printing presses in a packaging and general print company. Complementary insights are also provided from discussion with the management of several other companies which have experienced technological change. The research was conducted as a collaborative CASE project in the Interdisciplinary Higher Degrees Scheme and was jointly funded by the SERC and Gaydon Technology Limited and later assisted by PE -Inbucon.

The findings of the research show that the introduction of new manufacturing technologies usually requires a fundamental rethink of the existing practices of a business. In particular, its implementation is seen as ideally needing to take place as part of a longer term business and manufacturing strategy, but that short term commercial pressures and limited resources often mean that firms experience difficulty in realising this. The use of a spreadsheet based methodology is shown to be of considerable assistance in evaluating new investments, and is seen as being the limit of sophistication that a smaller business is willing to employ. Several points for effective modelling practice are also given, together with an outline of the context in which a modelling approach is most applicable.

Keywords: Manufacturing AMT SME Modelling Spreadsheets

To my family and the cats, Miss Puss and Louis

Acknowledgements

Being an athlete, the only event I can contrast research with is the Marathon; one starts out fresh, and for the first 20 miles the pace is quite steady. It is only over the last few miles that the *real* race begins.

During the course of this research the author has received help from too many sources to all mention individually. However, I would like to specially thank the following: Mr Alan Bennett my academic supervisor, who has been with the project throughout and has been a constant source of advice and help at moments of crisis. Dr Alastair Cochran, for the generous facilities provided to students and the excellent environment for research he has created within the Interdisciplinary Higher Degrees department. My thanks also go to fellow research students, Clive Bright, Jon Bader, Mike Wood and Alan Pilkington for their support. I would also like to thank Dr Mary King of the Department of Industrial Technology and Management at Bradford University whose initial suggestion it was that I undertake research during my undergraduate days led me to apply to IHD.

This research could not have been conducted were it not for the participation of several companies. In particular, I would like to record my appreciation of the assistance of Mr Tony Bell, Mr Richard Taylor and Mr Bill Cox at PE- Inbucon, for providing client companies with whom to work and valuable insights from the point of view of management consultants. In the case study companies I would like to thank Mr David Grundy and Mr Derek Rimmer of the VHME company. Mr Doug Wilkins and Mr Ted Wurr of the Midland Ballscrew Company. Mr Chris Moore and Mr Francis Buckle of the PP Print company and Mr Norman Taylor of the CM Machine Tool company for his advice throughout the research.

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Although, owing to the envy inherent in man's nature, it has always been no less dangerous to discover new ways and methods than to set off in search of new seas and unknown lands because most men are much more ready to belittle than to praise another's actions, none the less, impelled by the natural desire I have always had to labour regardless, of anything, on that which I believe to be for the common benefit of all, I have decided to enter upon a new way, as yet untrodden by anyone else. And, even if it entails a tiresome and difficult task, it may yet reward me in that those who will look kindly on the purpose of these my labours. And if my poor ability, my limited experience of current affairs, my feeble knowledge of antiquity, should render my efforts imperfect and of little worth, they may never the less point the way for another of greater ability, capacity for analysis, and judgement, will achieve my ambition; which if it does not earn me praise, should not earn me reproach'

Niccolo Machiavelli (1469-1527)

CHAPTER ONE

INTRODUCTION

Preamble

This chapter introduces the reader to the ideas behind the research which arose as a result of the problems identified in the introduction of advanced manufacturing technologies that have diffused widely through industry during the 1980's. However, successfully implementing these technologies is not an easy task as a growing number of reports provide instances of where the results of new technological investments have been disappointing. One of the reasons put forward to account for this is that while the effects of previous automation technologies on a business have tended to be localised, the effects of advanced automation are perceived to have 'wider effects' on the firms adopting them, and has led to an ongoing debate on the management of technological change, to which this thesis is intended to contribute.

1.0 Introduction

Throughout the 1980's British industry has been increasingly urged by a plethora of government, academic and industry reports to invest in advanced manufacturing technologies so as to stem a perceived loss of competitiveness in world markets and a 'falling behind' its competitors in the use of such technologies:

> 'Manufacturing industry is vital to the UK but is under considerable pressure to increase its competitiveness........Companies using modern manufacturing technologies effectively are able to achieve higher productivity and efficiency. New and advanced manufacturing technologies now being developed offer even greater scope for improved productivity and product quality. Those firms which do not make use of these technologies risk being overtaken by competitors achieving superior quality at lower cost' (ACARD, 1983)

> 'British industry is not applying new technology to its products and production processes at anything like the rate of its overseas competitors, (and when it does)....many apparently sound investments in new technology are a failure' (Avison, 1984).

Throughout the last decade a comprehensive process of automation has been going on in the engineering industry, and the rate of technological change is probably greater than at any time since the industrial revolution. Whilst in the 1970's many of the technologies discussed in this thesis were available (albeit in less sophisticated form), it was during the 1980's that this began to diffuse into industry at large. These technological developments coincided with major industrial restructuring as a result of the economic recession of the early 1980's and a tendency towards the 'globalisation' of world markets. As this thesis is written at the close of the 1980's, it provides a good opportunity to reflect on the claims made for advanced manufacturing technologies at the start of the decade and what has been learnt about them since.

What has become increasingly apparent as advanced manufacturing technologies have diffused more widely throughout industry, is that the technology will not on its own provide a "neat technical solution". Indeed, in discussing the application of new manufacturing technology (way back) in the 1970's, Skinner (1977) comments:

> 'The fact is that technology is too far ahead of its management. We already have enough technology to transform the batch manufacturing industries. We do not have sufficient awareness of how to implement and manage it'.

Whereas with previous generations of non-computer based technologies, the effects of improved manufacturing techniques were confined mainly to the existing productive functions within a business, the integrated nature of computer based manufacturing technologies with applications from design through to assembly, means that the effects of change are much *wider* and are felt throughout the *total business*.

This makes the adoption of new technology a much more complex and problematic task, as is well illustrated by Bessant (1982) who lists over 50 characteristics affecting the implementation of new technology in his study of manufacturing innovation. A key point is that these factors covered a wide range of technical, organisational and economic issues. The Advanced Systems Group of the National Economic Development Office in their report (AMSG, 1985) suggested the following reasons why new technology sometimes failed to live up to expectations:

- Lack of management commitment
- poor communications and incomplete involvement of employees
- inaccurate inventory records and engineering data
- unsuitable organisation structure
- a piecemeal approach to investment
- insufficient training
- under-resourced implementation programme
- lack of involvement with equipment suppliers
- underestimating software requirements

The ACARD (1983) report on AMT puts forward several guidelines for its successful introduction, including:

- Manufacturing technology is a top management responsibility and the main board must monitor its appropriate implementation

- AMT investment cannot always be justified by a conventional financial analysis. Justifications should include indirect savings, intangible benefits and the consequence of not investing.

- Implementation of AMT should take into account the eventual integration into an overall system.

- Manufacturing is a strategic issue and should be part of the overall corporate strategy.

Assuming that the problems identified and guidelines suggested are right, then implementing new technology poses considerable problems for the majority of firms and implies a radical change in the attitude and practices of top managers, together with a need to revise existing capital investment methodologies, and overcoming the problems of interfacing different manufacturing systems. Several accounts in the literature report instances where the results of new technologies have been disappointing (ie. Currie, 1989; Boddy and Buchanan, 1987; Ingersoll Engineers, 1986; New & Meyers, 1986). If these are still major problems for the larger firms who generally are first to adopt new technologies, then the problems facing the smaller/medium sized firm into which AMT is now diffusing are even greater, given that their resources are usually more limited.

The aim of this research is to identify, and where possible measure the wider effects and problems of more advanced manufacturing technology within small/medium sized firms as they progress in terms of the level of technology employed. To do this a modelling approach will be developed with the particular objective of attempting to assess their economic implications for the "total" business. While during the 1980's, academic and industrial practitioners cannot claim to have 'solved' the problem of managing technological change, the studies that have been conducted in this area have provided us with a better understanding of the processes through which change occurs and highlighted areas for future research, as Voss (1984) comments:

> 'Effective technology-based competition requires good management of new technology; of its development, selection and implementation. The current research thrust in areas such as information technology, Robotics, Computer Integrated Manufacture, etc., need complementing by research aimed at ensuring that the adoption and implementation of these technologies is effective'.

1.1 Background to Research

The initiative to set up the research project described in this thesis, arose from the experiences of its original sponsoring company, British Leyland Technology Limited (later changed to Gaydon Technology). The company was set up in 1979 as part of the reorganisation of the BL Group by its Chairman, Michael Edwardes to provide "technological advice" to the rest of the BL group on specific projects, and also to act in a kind of "gatekeeper role" promoting technological awareness among group companies. From its experiences of implementing advanced manufacturing technologies in the BL group, the management identified the growing interest in the potential that such technologies may have for medium sized companies, as an area in which they could market their expertise derived from automotive applications. In practice, this turned out to be more difficult than originally anticipated and several of the systems installed in client companies turned out to be less successful than expected. The company was interested in seeing if it was possible to study the wider effects of advanced manufacturing technologies in smaller/medium sized firms using a modelling approach to simulate the productive facilities of a company following the introduction of a new technology, and to relate this to the financial performance of the whole business.

BL Technology management considered the setting up of a research project to carry out this task, and approached the Interdisciplinary Higher Degrees Scheme at Aston University in Birmingham with whom the BL Group had conducted previous research. The IHD Scheme at Aston University was set up in 1968 to facilitate collaborative research on technical issues in a commercial and organisational context, following the Swann report which called for ".....Bold new experiments with the PhD...." (Swann 1968). The scheme now has over twenty years experience of this type of research. Since the projects have been based on a diverse range of problems, it cannot be claimed that IHD possesses unique knowledge in what would be recognised as a traditional academic field, ie. the physical sciences. However, a common theme running through most projects is that, they involve the researcher in analysing the effects of some kind of technical change, often highlighting issues at what might be termed the technology/social science divide. Thus the department can lay claim to having developed expertise in this area and a number of research projects had taken place in recent years which dealt directly with technological change in an organisational context, whose experiences the author was able to draw upon (Callaghan 1982, Drayson 1986, Lowe 1982, Pickard 1986).

Initially, the emphasis within the project had been seen by BL Technology as a technical one. This fitted in with the culture of the firm which was engineering dominated, and sought to provide 'technical solutions' to its clients. However, from spending some time in small/medium sized firms developing simulation models of their production facilities, discussions with management and reviewing literature on the subject of technological change, the complex organisational process involved became increasingly apparent to the author. During the first year of the project, the BL Group (now Rover Group) began to restructure its component companies, including BL Technology. This led to an increased emphasis that all group companies should concentrate their effects on internal group projects and not seek outside work. As a result of this, BL Technology were unable to provide the necessary client companies for the author to work with. This process of restructuring was to eventually result in the termination of BL Technology altogether, which necessitated a major rethinking of the aims of the research.

With the benefit of hindsight, the author does not consider that it was possible to develop an all-embracing software package that could simulate the effect of different technologies in a smaller company. The models that were developed were unwieldy and the management in companies supplying the data found the computer simulation language used, difficult to understand. Indeed, even if the model could show that the system worked in a technical sense, this is only part of the adoption process in a company and does not address the wider organisational issues, often non-technical ones, which often play a key role in determining whether a technology is successful or not.

The author considers that several of the problems that BL Technology had encountered in working with smaller clients, arose from the fact that the experience of most of its staff was derived from working with other BL Group companies, whose staff possessed a high degree of "technological awareness", and were well used to the introduction of advanced technologies such as flexible manufacturing. In their smaller client companies this tended to be less so, and BL Technology, in attempting to fit a 'technical solution' to manufacturing problems, did not always sufficiently take account of the suitability of the technology for the company from an *overall* business perspective. An example of this was in an automotive components firm with limited experience of automation where BL Technology had installed an advanced machining centre a year earlier. Discussing with the production director of the firm how successful the investment had been for the company, he thought that the machine was unlikely to achieve its expected payback within the planned period. This was partly because it had taken longer than expected to get workers to break from long established working practices, to operate the machine in its most cost effective manner, and also because of difficulties in integrating its higher output with the older, less productive manual machines around it. He suggested that BL had underestimated the importance of these issues, particularly the non-technical one, and that while from the point of view of a production engineer the machine was ideal for making the components it was bought for, viewed in terms of the *overall* business, a less sophisticated CNC machine might have been a more suitable level of technology.

From these early experiences, the emphasis in the project changed from a purely modelling one, to assessing the impact of new technologies and their "wider" effects within a business using a variety of techniques, involving discussion with staff and documentary sources from a number of smaller/medium sized manufacturing companies. Models were still developed to assess the financial performance of these technologies upon overall business performance, but instead of the use of a complex programming language, a much simpler and easier to comprehend method was employed using a series of microcomputer based models, which was better suited to the level of managerial expertise within the companies supplying data.

Two initial propositions were stated at the start of the research:

- *That advanced manufacturing technologies have frequently not fulfilled their original expectations in improving overall corporate performance.*

- *That the main reason for such unfulfillment has been the integrated nature and effects of AMT on those aspects of the business not immediately associated with the innovation.*

Following the closure of BL Technology, the author was fortunate to obtain the participation of the West Midlands manufacturing division of PE-Inbucon, a leading management consultancy firm, who were able to suggest client companies willing to participate in the research.

1.2 Manufacturing Innovation

Considerable research has been conducted in the field of new technology adoption during the last thirty years since the influential study by Carter and Williams (1957). A large body of knowledge now exists on the adoption process and the factors which affect it for a wide range of technological innovations (for example: Nabseth and Ray, 1974; Science Policy Research Unit, 1973; Rogers and Shoemaker, 1971). Traditionally, innovation has been perceived as taking two forms - product and process: the terms are self-explanatory, the former referring to new articles and the latter to how they are produced, although the distinction is not always so clear as the example of capital goods will demonstrate. During the course of the research it was apparent to the author that the form of change taking place within the collaborating firms as a result of the introduction of new technology, did not really fit into either of these two categories. This led to a search of the literature for a model of innovation that better described the experiences of these firms. In this respect the concept of *manufacturing innovation* developed by Bessant (1982, 1983, 1985) was found to provide a useful model for this task. This refers to incremental changes in the manufacture of goods that does not change the basic product or process. Since the concept of "manufacturing innovation" is a key aspect of the research, the author will begin by discussing its theoretical basis.

As Abernathy and Utterback (1978) show, over the life cycle of an industry, both product and process innovation can be seen to occur, with the emphasis changing as the industry matures as shown in figure 1.1. For example in a relatively young industry such as electronics, the initial emphasis is on radical product innovation. As an industry matures, the competition becomes more intense, the initial easier opportunities for

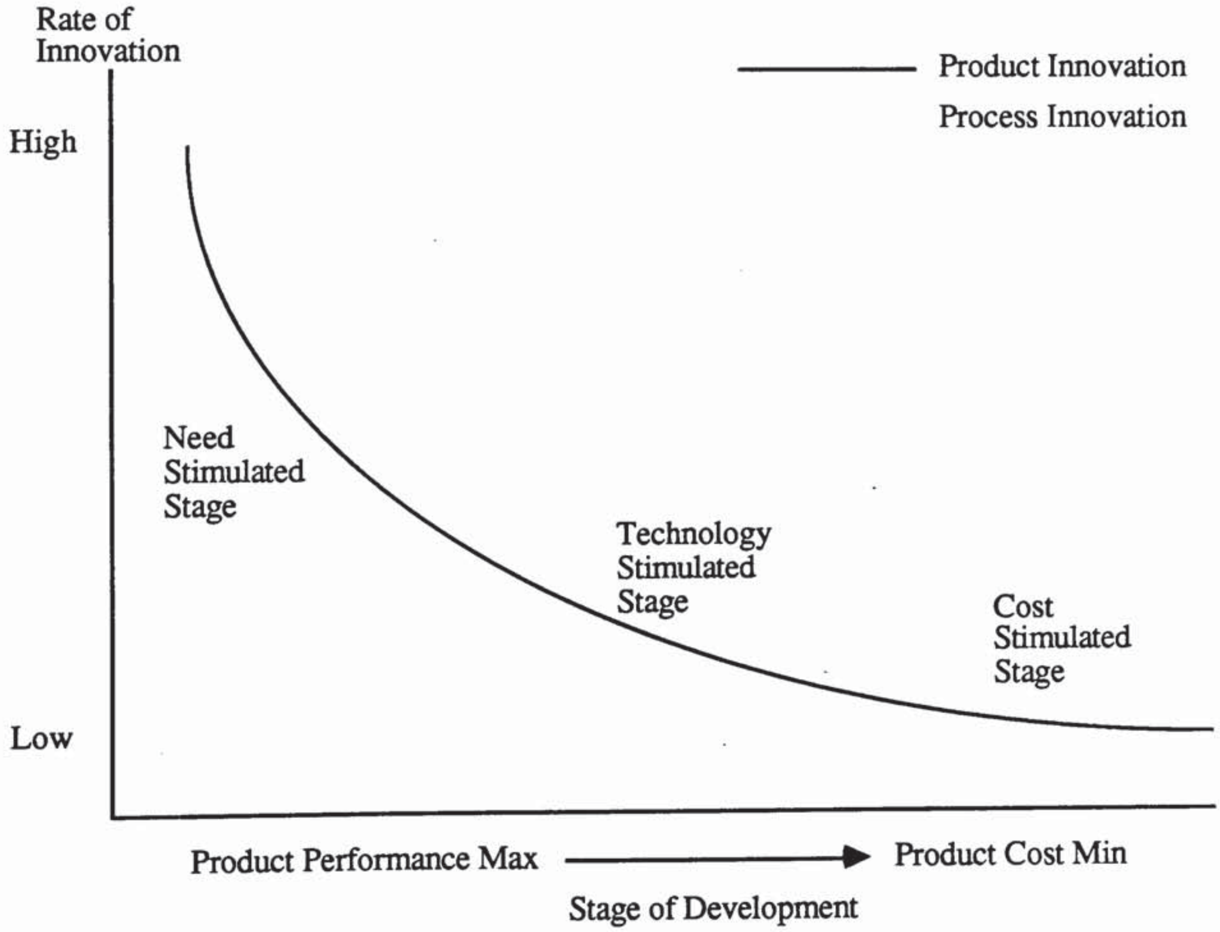

Figure 1.1 - Model of the rate and type of innovation (adapted from Abernathy and Utterbeck, 1978)

product development are used up and further product development faces rising costs and shows a pattern of diminishing returns. This shifts the emphasis to process innovation to improve the way in which products are made.

This model of change over the life cycle of an industry also introduces what Bessant and Grunt (1985) describes as '...a second degree of innovation which is that of *degree* of change'. This refers to the fact there are wide differences in the degree of "novelty" between various innovations. Bessant gives the example of the aerospace industry, where the difference between propeller driven and jet powered aircraft is large, whereas the developments in metal alloys used to make the fan blades of the turbines of the engines may be relatively small. Both are product innovations, but what differentiates them is that the former represents what can be classified as a "radical" innovation, while the latter is an "incremental" one. Innovation can therefore be conceived in terms of a continuum stretching from radical to incremental change. This fits in with the pattern of innovation often found in industry where an initial radical innovation is followed by a series of incremental changes and improvements. Thus over the life cycle of an industry, the initial emphasis is on radical innovation with incremental change becoming more significant as the industry matures. Relating this to competitiveness, as industries mature, so they experience growing competition from other sources and their options become more constrained. Their continued success becomes increasingly dependent on their ability to make incremental improvements in terms of productivity. In due course these too become more difficult and costly to make and show a pattern of diminishing returns, thereby once again creating the need either to develop "radical" product or process innovations, or acquire them by other means.

Radical innovation however, remains an expensive and speculative avenue to follow and many firms either lacking the resources or the inclination, opt to try and stay ahead in a very competitive market on the basis of continued incremental improvements. Incremental process innovation can therefore be expected to be a significant factor in the competitiveness of mature sectors of manufacturing industry and such a pattern can be seen in the engineering industry studied in this research and in others such as textiles, printing and foundries. For example, Hollander (1965) shows in his study on rayon production at Du Pont, more than half of the reduction in the cost of producing rayon had been the result of gradual process improvements which could not be identified as formal projects or changes. Enos (1967) in a similar study, shows that the cumulative effect of such incremental developments in petroleum refining processes, produce productivity gains that often exceeded the gain from the initial, more radical, innovation. This implies that there exists a need to understand the process and its implications in greater detail and what differentiates it from more radical forms of innovation.

Bessant (1982) uses the term *manufacturing innovation* to refer to this kind of incremental process change and defines it as the:

> '....introduction of new manufacturing technology without changing the basic nature of the product or process involved. This type of change can be anything from a simple replacement or updating kind of innovation - for example, minor improvements in the accuracy of a press or moulding machine made by modifying the existing control system - to something more complex and expensive. An example of this might be the use of industrial robots for welding, painting or manipulation. Despite their apparent novelty their use does not usually involve any *basic* change in the production processes into which they are introduced'.

While it may be argued that manufacturing innovation can be regarded as a subset of process innovation, Bessant points out that it possesses several distinctive characteristics. Firstly, the incremental changes in equipment and control systems which can be classified as manufacturing innovation, are not usually as expensive to make as more radical process innovations and are often cheap enough to fall within the day to day production budget under the control of production mangers and supervisors. Secondly, such innovation is often within the understanding and experience of those directly involved in the production function, which make it easier to fit them in with the existing pattern of innovation and attitudes to technical change within an organisation. This can be expected to result in a higher rate of innovation adoption. An important aspect of such innovation is that being lower in cost and novelty, decision making and responsibility for it often lies at a lower level in an organisational structure, that is, closer to the production process than at board level. In this respect it is more involved with *tactical* rather than the *strategic* decision making associated with radical process innovation.

Much of the existing literature on innovation focuses on radical innovation, which in part is due to the fact that it is easier to identify, since the decision making take place at distinct points in time and at a higher level in the organisational structure and involves a few key people. Manufacturing innovation by comparison tends to be continuous and diffuse, involving more people and occurring over a longer period of time.

1.3 Research Methodology

In studying the process of innovation two main methodological approaches have been used - case study based and survey based. From the original outline of the research it was clear that BL Technology envisaged that the case study approach would be most suitable, drawing upon the experiences of their client companies.

The case study approach has however, received some criticism in the past for producing results which are:

> '.....highly specific, making little contribution to the general understanding of the problem under investigation'. (SSRC, 1979)

In contrast, other studies on innovation research, (Bessant & Lamming, 1984; Downs & Mohr, 1976; Rothwell, 1977; Utterback, 1974) suggest that there is a lack of case study material and that research methods in this area should:

> '.....gear themselves towards a closer study of a smaller number of firms - and aim at collecting richer and more specific information about their behaviour'. (Bessant, 1982)

However, given that the nature of the incremental changes under consideration in manufacturing innovation is diffuse and involves more people within an organisation, the case study approach was considered to be effective for this task, since it offered a more adaptive and in-depth approach to understanding the underlying dynamics of the process and could be modified as the research progressed. This is not to suggest that this approach does not have its problems as Nabseth and Ray (1974) point out:

> '.....the difficulty is that these micro level studies have to be based on company data, which are always difficult to come by, with the further impediment that any results must usually be published in such a way that information about individual companies is not disclosed. Indeed, this dual difficulty with the data is probably the main reason why such reports and monographs are scarce, compared with the more theoretical macro studies'.

Case study material also faces the problem of relating it to the more theoretical models of innovation. In terms of research techniques, two main approaches were used. The first involved standard techniques - the use of interviews, observation and documentary evidence. The other involved using microcomputer based spreadsheet models to try and understand how the company expected to benefit from technological change. The advantage of asking managers to provide information for such models is that it requires them to actually have to quantify the expected benefits in precise economic terms, rather than stating the benefits in more general terms. The justification process, as was found during the research is not just an evaluation of economic benefits, it can often perform a *political* role within a firm. Thus, the way a financial justification proposal is drawn up, the categories of costs/savings included and how the values in it were obtained, provide a useful insight into how a company evaluates new technology.

Much innovation research focuses on what are the "good"characteristics for successful innovation . In this research the author also wanted to try and understand what had been the *wider* problems of introducing new technologies. In particular, where a new technology had been introduced to overcome a specific problem, but was found in practice to have implications for the business other than in the area where it was implemented. Figure 1.2 summarises in very general terms several of these wider technical, economic and organisational effects that may occur in the adoption of new technology in a company. For example, if a company adopts CNC technology this not only affects the actual manufacturing process of the business, through reduced production cycle time, higher precision and higher quality products. It has wider organisational effects on skill requirements, production planning and quality control. The reduction in manufacturing lead time and ability to manufacture new products and shorter product life cycles will also provide the sales department with new opportunities. Other technologies such as CAD/CAM and computerised materials control and shop floor data collection systems may be required as the firm moves towards an integration of technologies which will require an increasing need for a "systems thinking" approach by the management. Thus as a firm adopts systems which link together the production, design and management control functions within a business, it can be expected that its internal organisation will be expected to change, as well as its relationship with its market environment.

Many authors describe the problems, but few provide illustrations or try to analyse the possible economic consequences, except in general terms. In large process and product innovations the economic consequences are more readily discernible, but with manufacturing innovation the expected economic benefits could also be expected to be more diffuse. Thus the research aimed to try and get a greater understanding of these benefits. Therefore, in addition to obtaining information about the economics of an innovation, it was hoped that the task of developing the models themselves would provide a valuable insight into the process of manufacturing innovation within the company itself.

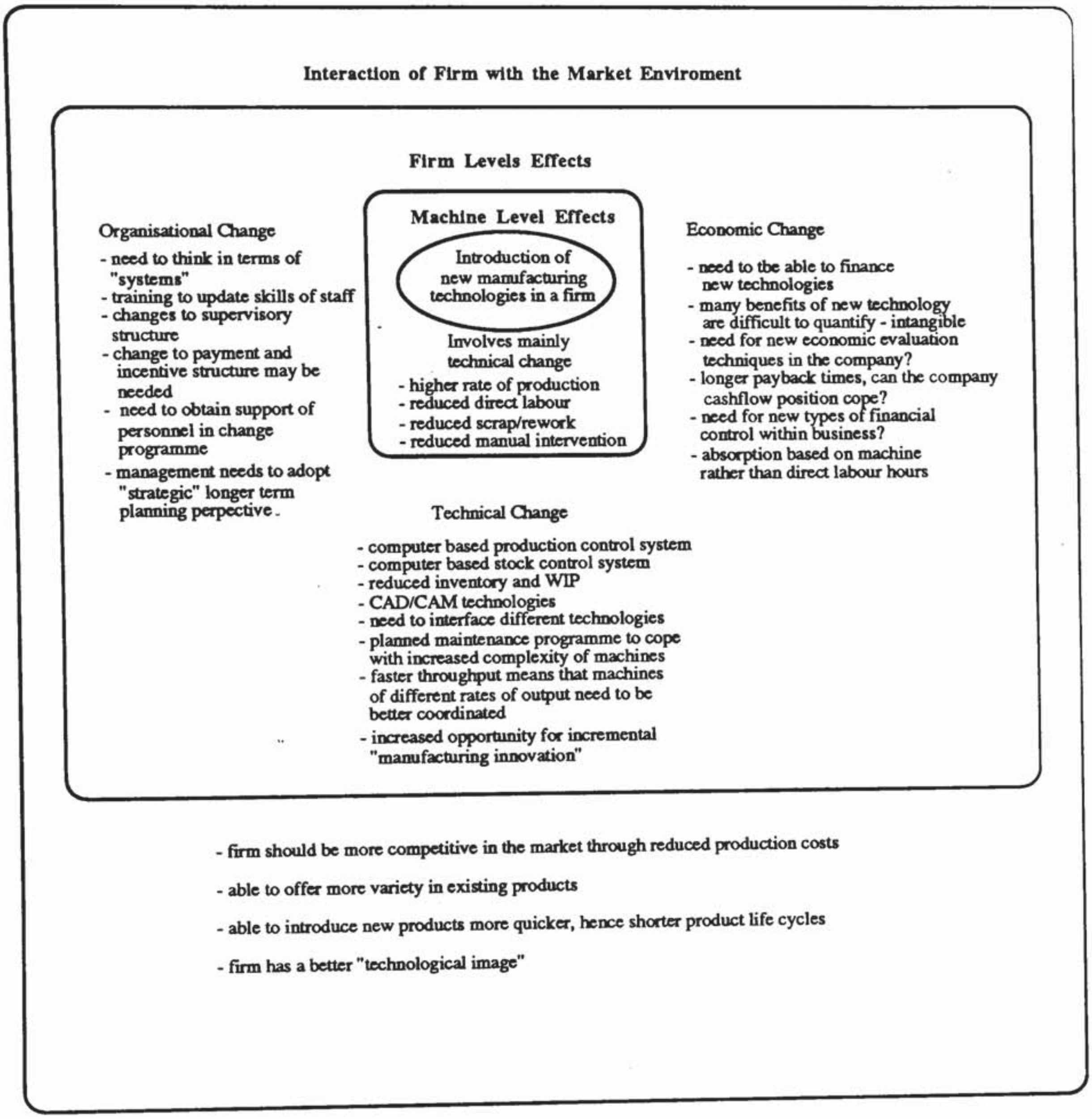

Figure 1.2

Wider changes which may occur within a business as new technology is adopted

Describing briefly the techniques used:

Interviews: The basic technique used for getting information throughout the research, was by interviewing the management of the case study firms. When initially approaching a firm, the author would adopt a semi-structured approach with a list of prepared questions to ascertain whether the company was suitable for the research purposes and if so, to what extent would they be willing to supply information. The initial interviews usually lasted between one and three hours and were usually held with the most senior managers, usually the managing director or the financial director. The author attempted to obtain information on the following topics:

- general information about the company, its background and history
- financial performance of company
- organisational structure
- competitive environment and market structure
- general management philosophies
- planning and decision making, both formal and informal
- the use of computers in the company
- product strategy
- manufacturing facilities
- motivations for investing in new technologies
- previous experiences of introducing new technologies
- financial justification procedures used
- examples of manufacturing innovation within the company
- educational background of management
- industrial relations
- effect of government legislation
- links with external organisations for technological assistance: universities, consultants,

In all the companies which were modelled with spreadsheets, the author was able to visit on a regular basis, which helped to build up a good working relationship. In the other companies, several visits were made giving opportunities to hold repeat interviews, which usually provided higher quality information. It was noticeable that the longer the author worked with a firm, the more the management felt able to take the author into their confidence and were prepared to disclose sensitive information. Several managers commented on the fact that these interviews provided them with the opportunity to think out aloud and perhaps consider their company's problems from a new angle. Also, the comments by the author gave them a different perspective on the company, since they came from someone outside their organisation. On a number of occasions, it was also possible to interview people who had worked with the company in a professional capacity such as a machine supplier or a consultant.

Spreadsheet Models: The spreadsheet models could be said to have two main purposes. Firstly, as a method of trying to represent the economic changes occurring within the case study companies as a result of technological change, by the development of "total model" of the business. Secondly, as an aid to communication with managers, since in asking them to try to quantify economically the changes taking place, it gave an insight into how they perceived the likely effects of technological change. In order to obtain the opinions of managers, the author visited the companies on a regular basis to discuss the results. An advantage of the spreadsheet software package used in the research was its ability to produce high quality graphics to represent data which was of considerable assistance. On several occasions the author was able to involve the managers more directly by either transporting the computer to an individual firm, or arranging for them to visit the university. This was found to be a particularly effective way of developing the models, as it provided direct feedback and gave the company management an insight into the technology used in the research, with which few were familiar.

Documentary Sources: To backup the interviews and provide information for modelling, the author sought to obtain documentary material wherever this was possible, for example,the financial justification for a new machine. Often it was possible to use this material in the context of the interview, which was of considerable benefit in getting managers to explain the reasons behind particular decisions. Material collected included the following:

- company annual reports
- company operating budgets
- financial justifications for new investments
- organisation charts
- sales literature
- documents outlining company policy
- company reports
- consultants reports/feasibility studies
- overview reports on a particular industrial sector

- on-line database survey using company name as the key word to list all information published on it in newspapers and journals (a number of the firms had featured in the trade press concerning their financial performance and future plans including new technology investments).
- associated academic literature, reports, conference proceedings

Projective Interviews and Diagrams: An important aspect of developing the spreadsheet models was to ask managers to put different investment scenarios to test. This was not a straightforward task since in most of the case studies the investment being modelled had not yet been made and so the scenarios developed were largely hypothetical. However, drawing upon their experiences and the documentary and other material available, most managers were able to construct what the author considers to be a realistic set of models. An interesting aspect of projective interviews, was asking the managers what they would do to improve the situation of the company if they had the necessary resources and power. This provided an interesting insight into the contrasting ways in which different managerial positions perceived the company's problems and would endeavour to overcome them. From such interviews, the author also tried to build up a picture of the managers ideas of the business and its existing problems, and the "ideal" conceptual model of the business they wished to move towards. For several of the companies the author has also tried to represent diagrammatically the original motivations for introducing new technology, and the problems encountered, to illustrate the "learning experiences" of the management.

Observation: While this technique was not used in a systematic manner, most companies suggested that a tour of the factory would be useful in familiarising the author with their operations and help in getting more out of the interviews. This also provided the opportunity to see in action a particular innovation and to gain an impression of the overall working environment. Much can often be learned about a firm just by looking at, for example, the amount of work in progress lying around a factory, the state that machines are in, which ones are operational, and the general "pace" of the factory.

1.4 Case Study Companies Selected - Table 1.1 lists the companies which participated in the research by supplying information and Table 1.2 provides a checklist of the technologies used. All were involved in one or another with engineering manufacture, with the exception of the chapter seven case study which was a printing company. Of these companies seven could be classified as small/medium sized of which three were used for modelling purposes. The companies were selected on the basis that they had recently experienced or were planning technological change, two being put forward by PE-Inbucon and the remainder arising through personal contacts. Although assistance of PE-Inbucon and a large manufacturer of machine tools proved to be of considerable value, since it allowed the author to compare the experience and knowledge of the adoption of manufacturing technologies of their managers, with the insights gained from the smaller case study firms. Given the small sample of firms used in the research this was also a useful means of trying ensure that the results and insights obtained, had wider application to industry at large. It should be noted that a condition of several of the companies in supplying information was that, they remain anonymous and so the names of the companies has been changed to disguise their identify.

1.5 Outline of Thesis Chapters

An outline of the chapters which will follow is now provided, which describes the overall research in detail:

Chapter Two - Develops the idea of "levels of automation" in modern computer based manufacturing technology and develops a model of how such technology could be expected to affect a company as it progressed in terms of automation.

Chapter Three - Looks at the literature on the organisational, technical and economic aspects of introducing advanced manufacturing technology.

Chapter Four - Describes the methodology used to select the modelling technique used in the research of computer based spreadsheets and the features that were built into the models.

Chapter Five - Discusses the introduction into the first case study firm, VHME Press Co, of a large CNC machining centre and the setting up of a spreadsheet model of the overhead absorption budget based on machine hours to assess the economic effect of the new machine.

Chapter Six - Reassesses with the benefit of hindsight and spreadsheet models, the decision of the second case study company, Midland Ballscrew Co not to build a flexible manufacturing system which its management had which had been considered several years earlier.

Chapter Seven - In contrast to the previous engineering case studies, this describes the experiences of a sub-contractor printing firm and the problems encountered in introducing a new computer controlled printing press.

Chapter Eight - Gives an outline of several other companies who collaborated, who although not modelled economically with spreadsheets, provided insights relevant to the overall objectives of the research.

Chapter Nine - Is the final chapter, and brings together all of the lessons and experiences which emerged from the overall research. A discussion of the specific issues which arose from the work is given alongside more general statements concerning the usefulness of the analytical models used. The chapter finishes with the overall conclusions from the research work along with recommendations for the future progression of work in this area.

The first volume of the thesis finishes with the biography and is followed by a glossary of terms giving a brief outline of the technical terms used in the thesis.

Volume II of the thesis contains the appendices, showing the models used in the research with a brief explanation of each. The technical specification of *Excel* is also given, together with a brief explanation of the linking of models. The spreadsheet logic of each model is printed out to assist the reader in understanding the interrelationships within the models. Due to the size of the models it was not always possible to print out the full model logic, but that produced is representative and should provide the user with sufficient information to construct the models for themselves if required.

Table 1.1 Summary of companies supplying information

Company	Product	Owner/ organisation	Turnover (£)	No of Employees	Output Exported (%)
Case study companies modelled with computer based spreadsheets					
VHME Press Company	Manufactures a range of machine presses	one of a group of companies	£9.3M	100	50%
Midland Ballscrew Company	Produces a wide range of Ballscrews	one of a group of companies	£3.3M	70	30%
PP Print Company	Engineering cartons and general print work	Private company	£3.5M	70	10%
Other companies supplying information but not used for modelling purposes					
IHW Engineering	Automotive components	one of a group of companies	£12M	250	15%
MF Engineering	Finishing Tools	Private company	£1.5M	70	10%
CM Machine Tools	Major supplier of machine tools to UK engineering industry	Large international company	£30M	500 (UK)	40%
PE-Inbucon (Manufacturing Division)	Large management consultancy firm with large division in manufacturing	Private company	N/A	40 Manuf/ Division	Not Applicable
Yorkshire Valve Limited	Water control valves	Private company	£9.5M	150	20%
WM Components Limited	Automotive Components	Private company	£3.4	170	10%

Table 1.2 Checklist of Technologies Used at Case Study Companies

TECHNOLOGY	VHME PRESS COMPANY	MIDLAND BALLSCREW COMPANY	PP PRINT COMPANY
Administrative Data Processing	Uses mini-computer for sales and purchase ledgers	Company had IBM computer system in early 1980's, but found system unsuitable for its needs and removed it. Not replaced.	Uses computer for sales and purchase ledgers and have recently upgraded system
Standlone Personnal Computers	Uses standalone PC's for financial planning on spreadsheets and for wordprocessing	Limited use of PC's in financial control. Does not use PC 's for word proceeing.	Use of PC's and spreadsheets for financial planning. Also, some word processing applications are used.
Computer-Based Production Control	Computer uses mini-computer to run Material Requirements Planning package	Does not use any computer based system in production control, but is presently considering one	Uses mini-computer to run a basic production scheduling system
Just-in-Time	This type of system is unsuitable to the one-off/long lead time type production	The small batch nature of this company makes such a system unsuitable	The company finds its major customers expect it to deliever on a just-in-time type basis
Standalone CNC Machines	Company introduced first CNC in 1986 with the eventual objective of replacing all its manual machines with CNC	Company introduced first CNC in 1979 and nows uses this as its main production technology	Not Applicable
Advanced CNC Machining Centre	Company is now planning the introduction of its first advanced machining centre, and intend to operate it on a minimally manned basis	The company introduced a basic CNC machining centre in 1988 and is using this experience to plan for the introduction of a more advanced system	Not Applicable
Flexible Manufacturing	This technology is not really applicable given the one-off type of production	The company considered the introduction of an FMS in the early 1980's	Not Applicable
Robotics	The use of robotics for load/unload type applications is considered as a possibility	Have not yet considered, but may find application	Not Applicable
In-process inspection/ guaging	The planned introduction of an advanced CNC machining centre will use in-process guaging	There is scope for such technology but is not likely to used until the introduction of more advanced CNC	Not Applicable
Group Technology	Have considered, but company has undergone too much change in recent years to decide upon a settled production system	Have considered , but did not believe it to be suitable	Not Applicable
Computer- Controlled Printing Press	Not Applicable	Not Applicable	Have recently introduced first such machine with advanced print features, but have experienced technical problems
Have Modified/ Retrofitted Own Machines	Company has expertise to modify own machines and can call upon assistance from other group companies	The company has upgraded three of its manual lathes by retro-fitting CNC controls onto them	Have modified own machines on a small scale, did once experiment with fitting modern controls to old machine with limited success
Design Own Machines	Since the company manufactures machine presses it is involved in their design	The company does not design its own machines	The company does not design its own machines
Computer Aided Design	Company installed large CAD system in 1987 and have been pleased with results so far	The company is now on its third generation of CAD, but has experienced long learning curve	Not Applicable
Computer Aided Manufacture	Is using its experience of CAD to build up expertise for the eventual introduction of CAM	The company is developing a parametrics design system with a software house which could lead to the introduction of CAM	Not Applicable
Computerised Page Layout/Desktop Publishing	Not Applicable	Not Applicable	Have recently introduced these technologies which have brought rapid productivity improvements
Product Innovation	Involved with a university in developing high speed power presses	New customer requirements for ballscrews result in the company developing its existing technology to new applications	Product innovation in the print industry usually arises as a result of new types of press becoming available with new print features

Table 1.2

TECHNOLOGY	IHW ENGINEERING	WM COMPONENTS LIMITED	MF Engineering Limited
Administrative Data Processing	Uses mini-computer for sales and purchase ledgers	Uses mini-computer for sales and purchase ledgers	The company has sucessfully used a mini-computer for sales and purchase ledgers
Standlone Personal Computers	Uses standalone PC's for financial planning on spreadsheets and for wordprocessing	PC's used for word processing and some financial planning applications using spreadsheets	Personal computers used on a small scale for some basic machine component lists and some spreadsheet applications
Computer-Based Production Control	Computer uses mini-computer to run Material Requirements Planning (MRP) package	Mini-computer system runs a a Materials Resource Plannning (MRP II) package	Simple computer based system in use at present, but the information produced is not felt to be really felt to be what is needed
Just-in-Time	The company is presently considering a Just -in-TIme production system	The Company intends to use principles of JIT to reduce inventories and make more frequent delievires to customers	Not Applicable
Standalone CNC Machines	This technology is not really suitable for the company's products, since high precision is not really necessary	CNC tube bending machines used to make only 20% of output at present but future invesment will change this	The first standard CNC machine introduced in 1986, followed by another in 1987, both acknowledged to be very successful
Advanced CNC Machining Centre	Technology not suited to the products made by the company	Technology not suited to the products made by the company	The production requirements of the firm are for more specialist CNC burring machine rather than machining centres
Flexible Manufacturing	Not Applicable	Not Applicable	Not Applicable
Robotics	Robotic welding in assembly operations is presently under consideration	First simple pick and place robots being tested, and will be the forerunner of robotic cells	First robot introduced with special CNC burring machine - have had considerable problems with system
In-process inspection/ guaging	Not Used	The company has developed its own digital readout inspection machine which is now on the market	CNC burring machine has in-process guaging facility
Group Technology/ Machine layout	The company has reorganised its production layout to better suit the "flow" of production, but not really on a group technology basis	Group technology principles have been used to determine the cells in which production is being organised and into which robots will be introduced	Have not yet considered, but with more CNC technology, the layout and routing of parts will need revision
Specialised Machines	Specialised machines for assembly operations have been purchased from John Brown Automation using "plug board" logic control	The company has purchased several specialised machine to assist in the production of specialised parts	The first specialist CNC burring machine was introduced in 1989 Considerable technical problems with the machine and economic loss
Have Modified/ Retrofitted Own Machines	Basic modifications have been carried out on presses and milling machines to better adapt them to making parts for new products	Basic modifications have been carried out on manual machines to adapt them for making new products	The company has considerable skill at modifing old machines to keep them operational
Design Own Machines	The engineering department specifies unique features required to outside specialised builder	The company does not design its own machines	Thirty years ago the original owner designed electro-mechanical burring machines which are still used today
Computer Aided Design	Small CAD system recently installed, personnel still very much on learning curve in its use	Small CAD system used	Have not yet introduced CAD
Computer Aided Manufacture	Not yet considered	Production volumes/size of firm make this technology unsuitable	Not really suitable for the type and volumes of products made
Product Innovation	Incremental product innovation does take place, recent example is the design of a new type of car door hinge using CAD	The company is becoming increasingly involved in the design work of new components for vehicle assemblers	The tool finishing market and technology is quite mature and there is only limited scope for innovation, but the company has tried to improve burr heads which are easier to manufacture and assemble

Table 1.2

TECHNOLOGY	CM MACHINE TOOL COMPANY	YORKSHIRE VALVE LIMITED
Administrative Data Processing	Comprehensive mainframe system used with links to US headquarters	Manual system employed, PE plan was to develop computer systems in firm by installing a system linked to different factory sites
Standalone Personal Computers	Personal computers used on a small scale for some basic machine component lists and some spreadsheet applications	Not used
Computer-Based Production Control	Company run a comprehensive production control system on mainframe computer system	Manual system used, seen as very inefficient and keeping inventory/WIP levels unnecessarily high
Just-in-Time	The company has recently brought in a JIT system to manufacture a high volume small machining centre	Not Considered
Standalone CNC Machines	The company manufactures CNC machines and has extensive experience in their use and design	Predominantly manual machine tools with a few CNC ones - chronic lack of investment - CNC technology seen as a key priority
Advanced CNC Machining Centre	Manufactures and uses its own advanced machining centres	PE plan involved the introduction of large CNC machining centre
Flexible Manufacturing	The company built one for exhibition which is now installed in its UK plant	Not Applicable
Robotics	The company designs robotic systems to be used in conjunction with in larger systems	Not Applicable
In-process inspection/ guaging	Technology is extensively used	Not Used
Group Technology	Group technology techniques adapted to its own unique needs are used in factory	Not Applicable
Specialised Machines	Being one of the leading builders of specialised systems it uses several in its own factory to make and assemble machine tools	The company has purchased several specialised machines to assist in the production of specialised parts
Have Modified/ Retrofitted Own Machines	The company has the expertise to carry out extensive modeifications on many of its machine and has recently modified its FMS	Basic modifications have been carried out on presses and milling machines to better adapt them to making high precision parts
Design Own Machines	Extensive expertise in this area	The company does not design its own machines
Computer Aided Design	Key technology in company and large state-of-the-art system used	Small CAD system used
Computer Aided Manufacture	Considerable experience of running a large fully linked CAD/CAM system	Production volumes/size of firm make this technology unsuitable
Product Innovation	Extensive product innovation taking place continously in order to remain competitive - use of advanced technology in this task is "routine"	Customers often provide only a basic specification of the component required, giving scope for product innovation in detailed design work

Chapter 1 References

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CHAPTER TWO

THE CONCEPT OF LEVELS OF AUTOMATION IN MANUFACTURING

Without doubt machinery has greatly increased the number of well-to-do idlers.
Karl Heinrich Marx (1818-1883) *Capital*

Preamble

Within this chapter the author seeks to establish the legitimacy of the concept that a profile of levels of sophistication of automation in manufacturing technology can be developed and is a useful one in aiding our understanding the nature of automation. This concept is then applied to the standard turning/milling/drilling type machinery common throughout current manufacturing industry. To achieve these objectives, the author draws upon an original profile of mechanisation levels developed in the 1950's and subsequently develops the themes of this work to apply it to modern metal-working practices to establish a relevant profile of automation levels. The concept of how the cost structure of a firm may change as it progresses in terms of level of automation is then discussed.

2.0 The Concept of a Mechanisation Profile

In a comprehensive study of the nature and experiences of automatic manufacturing in the United States in the early 1950's, Professor James Bright at Harvard University in this Work *Automation and Management* (1957) developed a structure of analysis of the state-of-the-art of automation existing at that time. Prof Bright established from his research the concept of a *Mechanisation Profile* set against the framework of seventeen levels of mechanisation. In his introductory notes, Prof Bright describes the concept as follows:

> 'The concept of levels of mechanisation is based on the assumption that there are different degrees of mechanical accomplishment in machinery. In what ways does machinery supplement man's muscles, his senses, his mental processes, and his judgement? Are there significant differences in responsiveness of machinery? What characterises them?
>
> It seems quite possible to examine the characteristics of mechanical response or performance by a systematic analysis of the way in which man uses tools and refines them as he creates a more automatic production sequence'. (p.41)

If the levels mechanisation of Prof Bright are arranged in order as shown in figure 2.1, several significant relationships can be seen. Consider the nature of the power used at each of these levels. On the two lowest ones manual power is used, all the rest are based upon mechanical (non-human) power. Having set aside the source of power as a determining factor of levels, levels 3 and 4 show an interesting difference. On level 3 -

<table>
<tr><th>Initiating Control Source</th><th colspan="2">Type of machine Response</th><th>Power Source</th><th>Level Number</th><th>LEVEL OF MECHANISATION</th></tr>
<tr><td rowspan="9">From a variable in the environment.</td><td rowspan="6">Responds with action</td><td rowspan="3">Modifies own action over a wide range of variation</td><td rowspan="15">Mechanical (non-manual)</td><td>17</td><td>Anticipates action requires and adjusts to provide it</td></tr>
<tr><td>16</td><td>Corrects perfermance while operating</td></tr>
<tr><td>15</td><td>Corrects performance after operating</td></tr>
<tr><td rowspan="3">Selects from a limited range of possible pre-fixed actions</td><td>14</td><td>Identifies and selects appropriate set of actions</td></tr>
<tr><td>13</td><td>Segregates or rejects according to measurement</td></tr>
<tr><td>12</td><td>Changes speed, position, direction according to measurement signal</td></tr>
<tr><td colspan="2" rowspan="3">Responds with signal</td><td>11</td><td>Records Performance</td></tr>
<tr><td>10</td><td>Signals preselected values of measurement (includes error detection)</td></tr>
<tr><td>9</td><td>Measures characteristic of work</td></tr>
<tr><td rowspan="4">From a control mechanism that directs a predetermined pattern of action</td><td colspan="2" rowspan="4">Fixed within the machine</td><td>8</td><td>Actuated by introduction of work piece or material</td></tr>
<tr><td>7</td><td>Power tool system, remote controlled</td></tr>
<tr><td>6</td><td>Power tool, program control (sequence of fixed function)</td></tr>
<tr><td>5</td><td>Power tool, fixed cycle (single function)</td></tr>
<tr><td rowspan="4">From man</td><td colspan="2" rowspan="4">Variable</td><td>4</td><td>Power tool, hand control</td></tr>
<tr><td>3</td><td>Powered hand tool</td></tr>
<tr><td rowspan="2">Manual</td><td>2</td><td>Hand tool</td></tr>
<tr><td>1</td><td>Hand</td></tr>
</table>

Figure 2.1 - Bright's seventeen levels of mechanisation and their relationship to power and control sources

the powered hand tool - manual control can be thought of as embracing two elements: application and guidance. On level 4 however, one further aspect of the job has been further mechanised, that of guidance. The design of the tool constraints the limits of the physical action. The operators simply "controls" the tool within the mechanically defined limits. The operator has freedom of application only within these limits, but retains control of the application with respect to time.

On the fifth level of mechanisation - the fixed cycle power tool, not only is the guidance of the tool mechanised, but so is its application with respect to time. Other than starting and stopping the machine, or possibly adjusting its speed, the tool is non-manually controlled dimensionally and chronologically. Level 6 can be thought of as an extension of level 5 which links together a number of level 5 functions. Level 7 - remote control - actually could be applied to the three lower levels, but Bright inserts it at this point because:

> '....it enables the centralisation of control of a number of machines. This has a significant impact on the response of the production system and on the degree of automaticity, and it sets the stage for control of one machine element in terms of another's needs'. (p.47)

Level 8 is seen by Bright as representing the ultimate in *mechanical control,* the machine follows one pattern of action with a minimum of manual assistance. At level 9 a new factor is becoming predominant in the control action, where a factor in the operation itself at given moments becomes the initiating control element of the system. Response from this level on is no longer mechanical or fixed, but is variable. It is in recognising this change that Bright displays considerable foresight by stating that at higher echelons of mechanisation levels, machine responses are initiated from a variable in the production environment. In this way he emphasises the importance of feedback control - the key element in the science of cybernetics and embodied in modern computer-based automation technologies. He envisaged that the highest levels of automation would incorporate equipment that could modify its own course of action over a wide range of variation as is shown in levels 12-17.

Level 9 is thus the basis for higher levels of mechanisation, with performance varied according to measurement. At levels 9,10 & 11 the control response is not a specific action of the machine, as much as a signalling action. The machine examines the nature of its performance or environment, and either reports this performance and/or signals for human intervention for any adjustments that need to be made.

It is at level 12 that a new control factor is introduced, where the machine responds with action. From this point on all the succeeding levels of mechanisation embody the idea of feedback from its production environment, with the machine adjusting its operation appropriately. In the lower of these levels, the action response is very limited in character. In the higher levels, the action response develops from a relatively simple 'yes/no, type response to a more sophisticated range of responses.

Another distinction between levels 12-14 and levels 15-17, arises from the degree of feedback involved. Feedback is usually taken to mean self-correction, not self-setting. It is apparent that levels 12-14 do not employ this degree of feedback, but instead employ what might be termed "feed ahead" or "preselection". While this can involve relatively complex sensing control mechanisms, it is not so sophisticated a concept in theory since it does not include the correction of the machines own error. Thus, while levels 12-14 include the selection of a suitable course of action, levels 15-17 involve the correction of operational error, and indicate the rudiments of what might be termed "machine intelligence".

The levels of Professor Bright can be grouped as follows:

Control Source	**Level**
- Handled by operator	1-4
- Activated by operator	5-8
- Activated by instructions from computer network	9-17

Type of Systems Response	**Level**
- Variable	1-4
- Prefixed with machine mechanics	5-8
- Responds with action	
- selects from prefixed alternatives	12-14
- modifies own action	15-17

Power Source	**Level**
- Manual/mechanical	1-8
- Electrical/electronic	9-17

2.1 The Validity of Mechanisation Levels

It is with the widespread adoption of increasingly more sophisticated production technologies made available by microprocessor based technologies, that there exists a need for a frame of reference - a system of classification along the lines established by Professor Bright in the 1950's. Such a frame of reference will assist in putting into perspective existing and potential automation developments. In commenting upon the validity of his automation levels, Prof Bright states:

> "These levels cannot be defended too rigorously. Examples can be cited that would somewhat confound this classification. Whether one level is truly mechanically 'higher' than another is perhaps, open to argument. Obviously, the move from one level to the next are not equally important, useful, technically different, or economically valuable. Their importance varies from plant to plant, and industry to industry. Doubtless, additional subdivisions could be defined, and one might argue for fewer levels.
>
> Some of these levels are occasionally entangled with much lower levels. The recording of performance for instance, often can be found on level 3. Frequently, machines on level 5 or 6 employ higher levels *for part* of their next operation. So this system of levels should not be considered a rigorous classification. However, it does not explain degrees of mechanical maturity. It attempts to lend order and understanding to the increasing refinement in the performance of more highly automated machinery."

Although established some thirty years ago, when computer technologies were in their infancy, the concept of *levels of automation* put forward by Bright remains relevant to present technology.

This is illustrated by authors who discuss the industrial adoption of advanced manufacturing technologies in a step-by-step manner, with companies moving from less automated machines to more advanced 'linked' automated systems. Steinhilpher (1983) in a paper entitled "Step-by-step access to flexible automation in manufacturing" develops the idea that medium-sized industrial production companies cannot afford the high investment cost of for a complex automation system in one step, nor indeed may it be appropriate a companys' market needs. The solution is seen as developing "low cost" manufacturing systems with differing degrees of automation which can be linked together , and built up in a step-by-step manner, thereby giving companies access to a more fully automated production system. Figure 2.2 shows a profile of the automation levels put forward by Steinhilper.

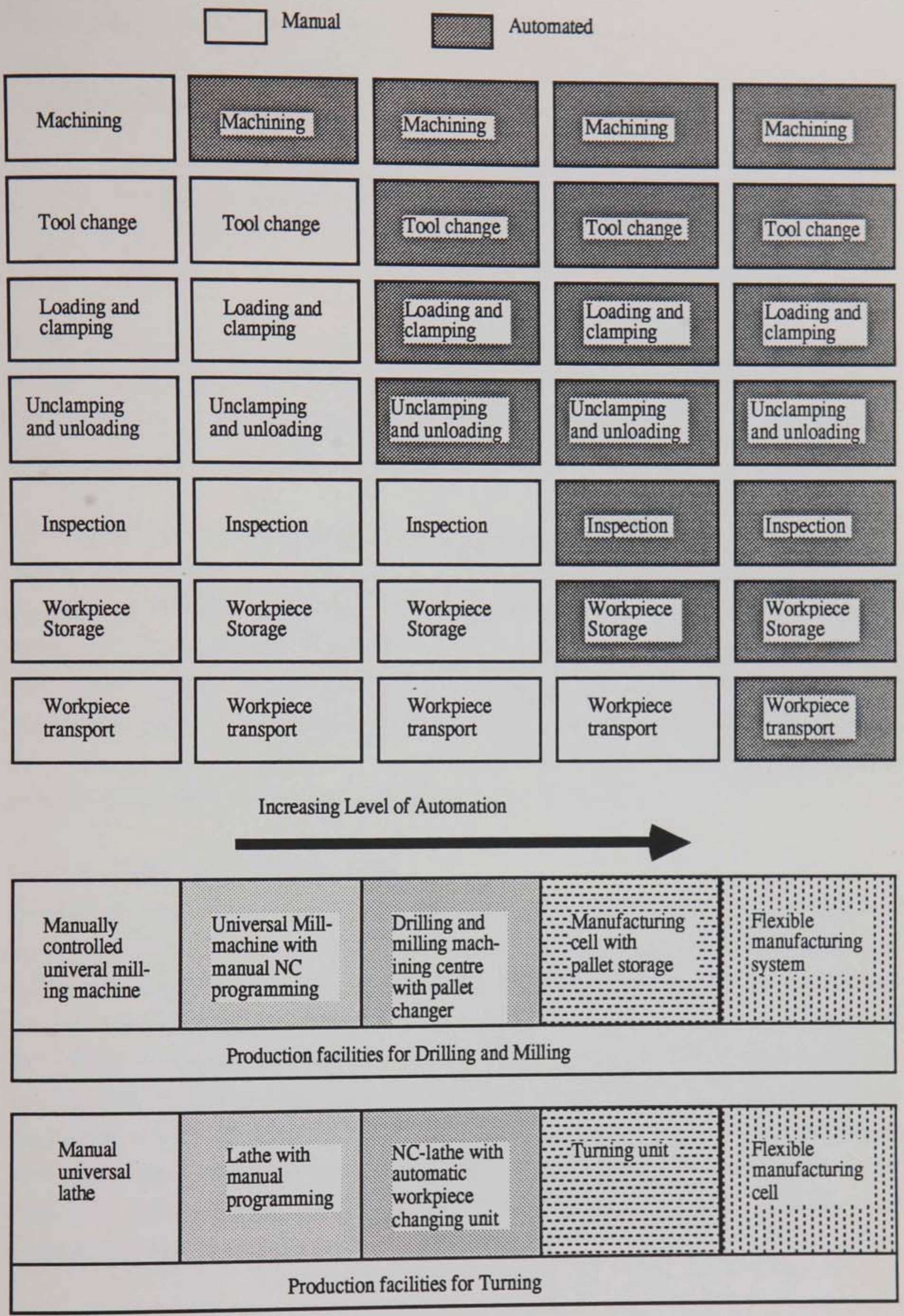

Figure 2.2 - Steinhilper's levels of automation

Flaxby (1985) of the SMT Machine company in a paper entitled "Flexible automation for turning - a step-by-step approach" develops the same theme and comments in his introductory notes:

> "For most companies the introduction of automated manufacturing will be a gradual process, with the planned development of small production cells which can later be integrated into larger systems. Automated manufacturing requires a basic machine which can be enhanced to include all the techniques for automated production."

While none of these authors explicitly use the ideas of *levels of automation* as set out by Prof Bright, their accounts by implicitly advocating a step-by-step approach to machinery acquisition embody the idea of differing levels of automation, using it as a framework of reference by which to describe their findings.

2.2 Levels of Automation in Manufacturing Technology

Having discussed the theoretical side to the idea of levels of automation, it is now possible to identify such levels with reference to current industrial production technologies. Figure 2.3 illustrates a framework ranking automation levels with productivity in broad terms. Please note that this diagram is for illustrative purposes only and is not intended to reflect any scale of the productivity ratios between levels. It is also not suggested that a company will be at any one particular level. Usually one would expect to find a series of levels of automation within a company.

Level 1 - Manual Machine Tools

Although current promotional literature on machine tools may sometimes give a different impression, the majority of machine tools are still manual machine tools with an average age of over 10 years. These machines still form the basic production system of many firms and so is the starting position from which firms decide to automate. Compared with Brights mechanisation profile, manual machine tools would occupy a position around levels 4-5, where the framework of the machine guides the machine with the application of the tool to the workpiece by a skilled operator. Here the operator would also have a large part in planning their own schedule of work. As shown in figure 2.1 all aspects of the associated machine facilities are also non-automated. This level of automation would be expected to be highly flexible, but have relatively low productivity.

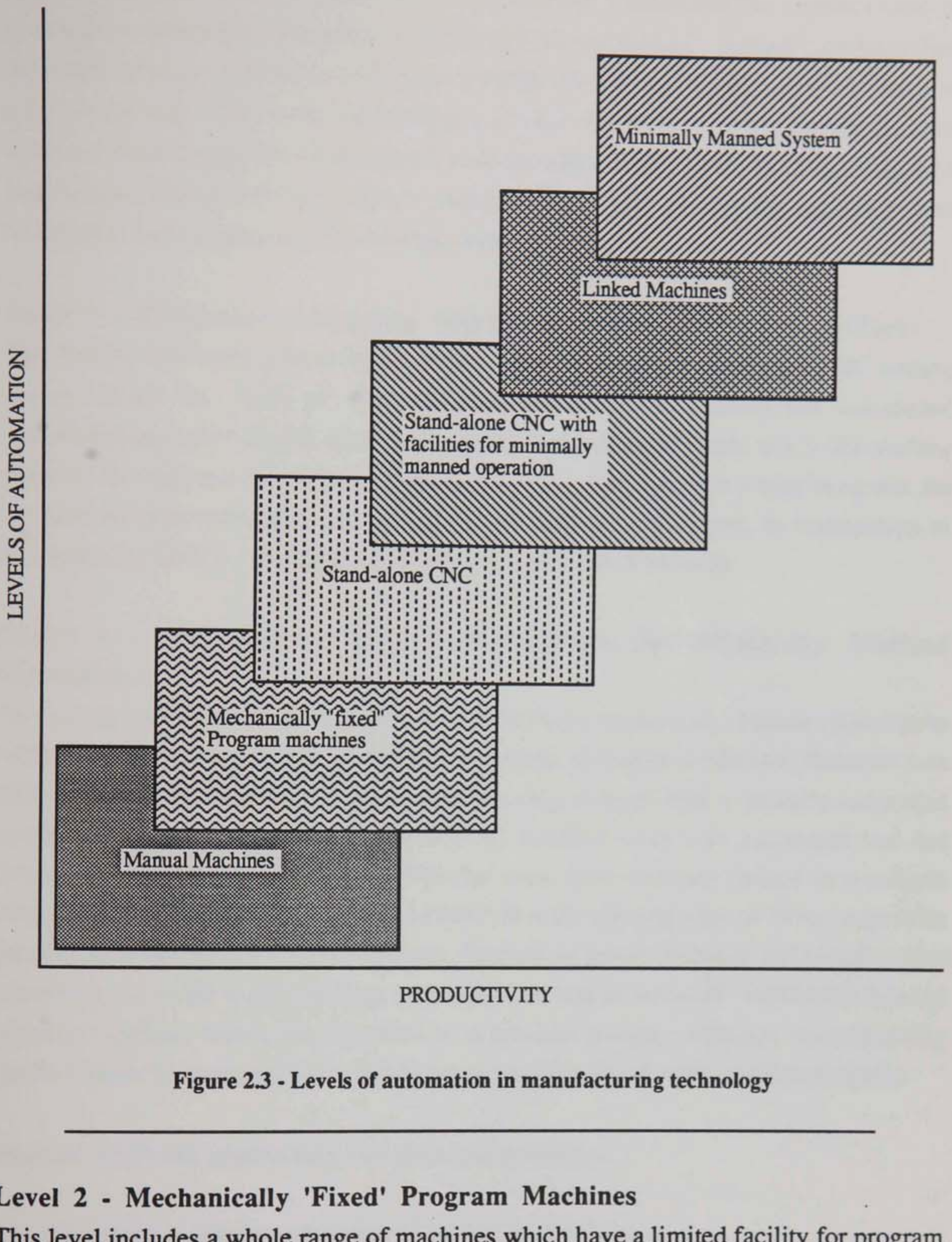

Figure 2.3 - Levels of automation in manufacturing technology

Level 2 - Mechanically 'Fixed' Program Machines

This level includes a whole range of machines which have a limited facility for program control by means of a sequence of fixed functions. Such machinery would correspond to level 6 on Bright's scale, where the machine performs a series of different actions in a prescribed sequence without manual assistance. Instead of one automatic event, this level of mechanisation links together the automatic performance of a series of operations. Included in this level would be capstan lathes, cam-controlled machines, plugboard programmed machines and early punched tape NC machines. While such machines are seen as obsolete today, in their time they offered a considerable improvement in productivity before the widespread adoption of CNC technology. Indeed, cam-controlled machines although inherently inflexible can offer an output performance comparable to CNC technology. Due to the obsolescence of such machines, it is not suggested that a company would progress from manual machine tools to this level, but that companies may have a collection of non-computer based, manual and fixed program machinery from which they want to progress to computer controlled ones.

Level 3 - Stand-alone Computer Numerically Controlled Machine Tools
This level is represented by the stand-alone CNC machine, for example a CNC turning centre. From the point of view of progressing to more advanced automated manufacturing technologies (such as a flexible manufacturing cell, this is the starting point of the engineering process, although for many smaller firms it may represent the ultimate in their production requirements and available resources. In comparison to Bright's scale CNC would incorporate elements of levels 9 upwards.

Level 4 - Stand-alone CNC with facilities for Minimally Manned Operation
In moving up the levels of automation it is necessary to have an ultimate objective to which the levels are orientated. A large proportion of current production literature sees this ultimate level as being flexible manufacturing systems with a centrally controlled computer controlling a series of linked CNC machine tools with automated tool and workpiece changing and storage. While for some firms this may indeed be a realistic objective, it is the contention of this author that for the majority of firms, especially smaller ones this is not a realistic objective due to their limited financial and organisational resources. A more useful concept is therefore to talk in terms of "minimally manned systems" (MMS) where the objective is to produce a highly efficient manufacturing facility which is consistent with the resources typically found in the smaller company.

Such an MMS will need to have two main characteristics:

(1) The ability to operate independently of the human operator

(2) The ability to be built up to a more sophisticated system

To fulfil these objectives a number of facilities are needed:

(1) Automatic component loading and unloading
(2) Automatic change between different components with no time/quality penalty
(3) Continuous monitoring of tool wear and breakage, with ability to take corrective action automatically so machining can continue
(4) Automatic swarf removal
(5) Automatic out of correction tolerance monitoring
(6) Ability to check components and respond to variations
(7) An integrated computer communications network between the various elements of an MMS system

It is not suggested that in any one company all these features will be required but that a company will adopt those as appropriate to its production requirements. The significant advantage of automatic loading/unloading is that they enable a higher machine utilisation by partly freeing the operator from the work cycle of the machine to perform other tasks. Techniques for tool condition monitoring and component gauging are available from most large machine tool manufacturers and in relation to Bright's levels represent the higher levels of automation 12-17 where the machine is capable of modifying its own action over a range of variation. It can be seen that level 4 as defined here does not really constitute a discrete 'level' in terms of technology, but is really a collection of refinements geared towards minimally manned operation.

Level 5 - Linked Machines

This level employs the same technologies as in the previous level, but would involve some form of "linking" between the machines so that resources can be shared. Such linking will probably involve some form of simple transport system (not an AGV) such as a carousel or rail guided vehicle since this would enable the machines to exchange workpieces and to some extent share tooling. In relation to Bright's levels, the linking of machines poses an interesting question in that since Bright's levels 12-17 have already been attained, and refer to stand-alone machines, does the linking of machines with cybernetic facilities realise a new distinctive level of automation with unique attributes outside of what he originally envisaged?

Level 6 - Minimally Manned System

For the small to medium sized company an MMS composed of "linked machines" with automatic load/unload, a simple transport system between machines with facilities for corrective action in relation to tool life and workpiece variation is seen as the ultimate extent of automation which might be considered.

2.3 Identifying Company Cost Factors

Having identified the different levels it is now possible to list the different cost factors that are relevant to a company and how they can be expected to change across the different levels. The basic motivation in considering changes to the operations of a machine shop is to serve one or more specific objectives, usually:

(1) reductions in direct unit costs
(2) reductions in lead time
(3) reductions in working capital
(4) reductions in indirect costs
(5) improvements in quality
(6) other economies in operating costs

These categories can be grouped as:

(1) operating economics
(2) speed of response to market requirements
(3) quality of product

The relative importance of each of these factors will vary from company to company depending on the type of product it manufactures and the market to which it sells. It is possible to distinguish that there are two types of variable which affect the company in considering a machine purchase, although both are linked and interchangeable to some extent. Firstly, there is the direct 'machine dependent' variables such as the capital and installation cost of a new machine which relates solely to that investment. Secondly, there is the 'company dependent' variable which relate to the on-going operation of the business, for example the expected return on capital invested, and the overheads of the company which need to be covered. It can be said that factors such as the overheads of the company can be linked to both. In modelling a company it is necessary to identify those variables which are likely to have a large influence upon the success or otherwise of a proposed investment so that by a series of sensitivity analyses, the relative effect of the critical variables can be gauged.

Conventional costing practice collects machining costs in terms of material, labour and overhead, the overhead rate being related to labour or machine hours, but otherwise averaged over the shop's activity to cover the various charges made to overheads. In building up a manufacturing company model the general variables listed below will need to be included to ensure that all production costs are covered. These were derived from analysing a series of company accounts.

The costs of a manufacturing company can be grouped as:

Cost of Ownership
- depreciation
- rent & rates
- insurance
- loss of interest on capital

Direct Costs
- operators wages including NHI, overtime, etc
- consumables, including tools, coolant, lubricants
- heat, light, power

Indirect costs
- supervisors' wages
- maintenance
- planning & programming
- jigs & fixtures
- inspection
- labouring & cranage
- management salaries
- administration salaries
- charges for external services (ie. consultancy)

Inventory Costs
- raw material stocks
- manufacturing work in progress
- assembly work in progress
- finished goods stocks
- rework in progress
- refinished parts stocks

While not an in-depth analysis it is worth considering the general trends in each category of cost with different levels of automation.

Grouping levels 1 &2, (the non-computer based manual and mechanically fixed program machine) together, a company with primarily these levels of technology would be expected to have proportionally higher direct labour costs than one on a higher level. Manual machine tools would often involve the operators planning much of their own schedule of work and a high skill factor may be involved in machine operation. It is unlikely that a sophisticated production control system will exist in such a company. Indirect costs for supervision and inspection may also be proportionally higher, but the company is less likely to need a highly trained management team and will not have the costs associated with the need for computing facilities for machine programming. Inventory costs are likely to be higher since this will be used as a buffer to overcome variations in demand, and the manual machines will not have the accuracy of CNC ones and so rework costs will be proportionally higher. The general pattern of companies on the lower levels of automation would be to have proportionally higher direct production costs and lower indirect overhead costs.

On level 3 (stand-alone CNC machines) in order to make such machines economic, the company will probably need to be used more intensively, this may involve 2 shift working, and will probably require a production control system that can integrate the CNC machine(s) with the rest of the machine shop. Although the justification for CNC technology is often based on direct labour savings, with multi-machine operation where one operator can control more than one machine, in practice, in the companies visited by the author this is not always easily achieved, and the main advantage tended to be higher quality output and increased productivity. Once a company acquires CNC there is the need for part programming; hence hardware, software and programmer costs are incurred. The way the programming is conducted in the company may affect the costs with either all programming being done centrally, or with the operators themselves carrying out part of this task. The need for computer aided design is also likely to arise and possibly the need for computer aided manufacture. Charges for external services such as consultancy advice may also be needed. Maintenance costs will also rise due to the increased complexity of the machines. The level of inventory will be expected to decrease due to a reduction in production lead times, and less rework and scrap due to greater machining accuracy. An interesting point arising from discussion with managers at a leading machine tool supplier (the CM Machine tool company), was that in terms of technological change, the jump from manual to CNC technology is often a more difficult task for many companies than from CNC to more advanced systems such as MMS, due to the need to build up the initial skills base and supporting technical and organisational infrastructure within a business.

At level 4 the economic use of the machines will probably require their intensive use and necessitate 3 shift operation, and the ability for minimally manned operation will facilitate this. A problem at this level is that given the high production rate, the company may have only a few such machines, so that in the event of a break down the company is very vulnerable, hence the need for preventative maintenance. While at this level the relative proportion of direct labour may have decreased, this may be offset by the increase in indirect costs, such as managers with specific technological skills and greater computing costs in terms of programming and maintenance. It is likely that the company will need a more sophisticated materials control system, and a computer based one such as MRP may be installed. Computer aided design will almost certainly be needed.

On levels 5-6, the large capital investment required and the need to make effective use of the machine(s) in order to achieve a satisfactory payback on the investment will mean that the materials and production scheduling systems of the company with need a high degree of control. Integrating these machines with other machines which are not of the same level of automation within the production system may also cause problems. Although direct labour will be reduced, operators will need to be more highly trained. The more advanced technology machine(s) will enable the company to offer new products and better delivery dates as a result of reduced production lead times. Perhaps greater amounts will therefore be spent on marketing and administration to achieve these sales, thereby changing the overheads structure of the firm. The general trend in the cost structure of a company at the higher levels of automation would be to have proportionally lower direct production costs and higher indirect overhead costs. An important aspect of moving to higher levels of automation is the emergence of computer integrated manufacturing (CIM), that is the convergence of what were previously discrete elements of advanced manufacturing technology. This involves the linking of the design, management information and production systems of a company and usually requires considerable organisational adaptation.

In summary, within this chapter the author has developed a basic framework in terms of levels of automation and related this to how the cost structure of a firm may vary as it progresses through different levels of technology.

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CHAPTER THREE

THE TECHNICAL, ECONOMIC AND ORGANISATIONAL ASPECTS OF NEW MANUFACTURING TECHNOLOGIES

Preamble

This chapter reviews contemporary literature on the introduction of modern computer-based manufacturing technology. The chapter places literature on the subject of its introduction into three general categories: those which stress the technical aspects of the implementation problem and which favour a procedural, methodological approach; those which focus on the organisational issues and stress the importance on getting the right match between the technology and the organisation, and literature on the economic justification of the technology and whether conventional financial appraisal techniques are suitable for evaluating such technologies.

3.0 Introduction

That the introduction of new technology is a complex task, is well illustrated in the case of AMT, where despite its proven potential its for transforming manufacturing performance, there are many accounts of where new investments, particularly in very sophisticated systems have been a failure. These were well summarised by Cane (1985):

> 'The level of success in the application of the most sophisticated technologies such as computer integrated manufacture, flexible manufacturing systems, manufacturing resource planning has often been abysmal'

Three main areas were highlighted as being responsible for high technology failures:

(1) Over-enthusiastic technologists have persuaded general management to invest in technological solutions that were not the answer to their real business problems;

(2) Many firms have succumbed to the 'Peddlers of that cloud called the factory of the future', with the result that many have tried to make too great a leap in manufacturing technology;

(3) Industry cannot rid itself of the "work study syndrome" and its preoccupation with localised work improvement rather than overall systems. Too much technology has been placed piecemeal in Victorian environments in preference to an overall plan for the manufacturing business.

In a US survey (Works Management, 1988) of 433 MRP installations (Materials Resource Planning), nearly 30% thought that systems fell short of expectations, with half of these considering the investment a failure. This finding was supported by a survey of

170 UK firms conducted by Cranfield Institute of technology, where 20% of MRP users felt they had received 'zero to low payoff' from their investment. The complex multi-disciplinary of the adoption of new technology is well borne out by the study by Fleck (1982) who in discussing the specific case of robotic adoption identified thirty factors relevant to individual firms. The important point was the diverse nature of these factors covering technical, economic, organisational and labour aspects of the problem, and in particular highlighted their interrelated nature.

3.1 Organisational Aspects of the Introduction of New Technology

Of the many factors involved in the introduction of new technology, the organisational aspect has probably received the most attention and there is a large body of research on, for instance, microelectronics and numerically controlled machines tools (for example: Boddy & Buchanan, 1982; Noble, 1979; Sorge et al, 1983), together with the study of innovation within organisations. Previous studies of the process of innovation have been of two main types; firstly those which tried to identify the factors which lead to the successful adoption or development of a new innovation by an organisation, and secondly those which attempted to understand the the process by which an innovation diffuses through industries and organisations. Such studies have identified a large number of factors affecting innovative performance and while individual researchers many attach different weighings to factors, there is general agreement that;

> 'Analysis of past technological innovations reveal a number of factors all of which appear to be present in many successes, and one or more of which are found to be frequently absent in failures' (Twiss, 1974, p.3)

In an article published in the British Institute of management journal in 1984 these were listed as :

- Senior management must be committed
- Innovation must play a role in the company's long term corporate strategy
- Senior management must accept risk
- An environment must be created in which entrepreneurship can flourish
- These must be good co-ordination between in-house functions
- Companies must retain gifted and committed entrepreneurs
- There must be effective coupling with external sources of expertise

In the particular case of manufacturing innovation, Bessant (1982) reports the following factors as facilitating success

- Presence of technically orientated, informed management
- Effective planning and control of projects
- Innovation strategy including a portfolio of projects
- Greater consideration of training needs
- Use of participative design and introduction strategies

Such studies highlight the wide variety of factors both within and outside an organisation affecting successful process and manufacturing innovation and has led to the concept put forward by Bruan (1985) that there is a "constellation of factors" affecting adoption. This is also supported by Bessant (1982) who argues that there is '....a growing emphasis upon the fact that it is the combination of factors which are important rather than a single element' and suggests that the important factor is the way in which they are combined within the firm, implying an order of priority and giving rise to the notion of manufacturing innovation being a *directed activity*. In developing this idea further at the level of the firm Bessant puts forward the concept of "design space" as a representation of the options available to an organisation involved in technological change as shown in figure 3.1.

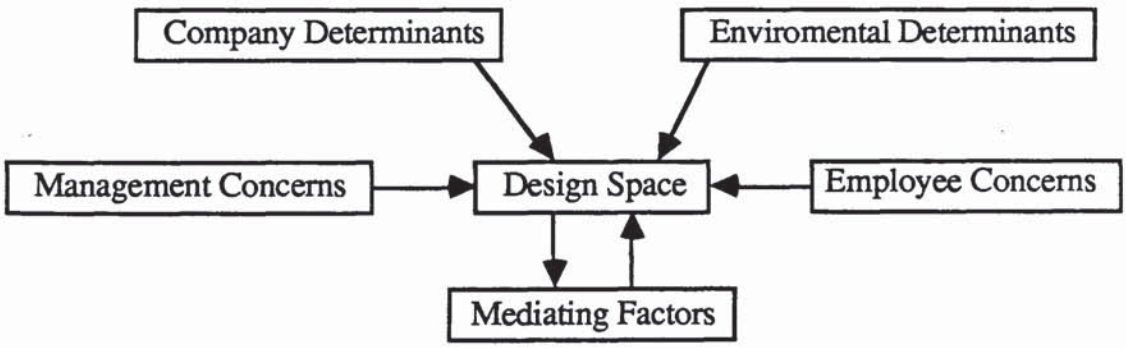

Figure 3.1 Bessant's Concept of Design Space

The design space represents the degree to which the technology lends itself to being adapted to fit its organisational context, rather than being fixed as in the view of technological determinism. Bessant argues that the contingency approach to the introduction of new technology offers the best descriptive theory of the "types and extent of choices open to managers and other decision makers within the firm". While the model is useful in this respect by assisting in defining the problem, it is limited in providing insight into its solution. To argue that "it is impossible to prescribe a single best solution to a given problem because the effects of so many variables....must be taken into account" is true but does not really assist an engineer who must eventually specify an operational system.

Carter and Williams (1957) in their study of industrial innovation linked the "technical progressiveness" of the firm to its "general quality" and identified twenty four parameters of progressiveness, including: effective internal communication and co-ordination, a deliberate survey of potential ideas and rapid replacement of machines and having scientists and technologists on the board of directors. Burns and Stalker's (1961) work on innovation management later identified two distinctly different types of company organisation: organic and mechanistic. They reported that the mechanistic form is appropriate to an unchanging environment and stable conditions and that the organic form is appropriate to changing conditions, such as the management of technological innovation. This is compared in figure 3.2.

Mechanistic	Organic
- Problems/task broken down into specialist roles	- Problems not broken down/divided
- Each sees task as distinct from task of whole, as if each were a sub-contractor	- Individuals have to perform specialised task in light of knowledge of tasks of whole
- Precise definition of technical methods, duties, powers in each functional role	- Jobs lose formal definition in terms of methods, duties, powers - continually redefined through interaction
- Vertical integration within management	- Integration lateral as much as vertical

Figure 3.2 Comparison of Mechanistic and Organic Organisations

In looking at the explanations of innovative success, Project SAPPHO carried out at the Science Policy Research Unit (1973) at Sussex University researched forty three pairs of innovations and provided evidence in support of the project champion hypothesis, identifying four roles which influenced the probability of successful innovation:

Technical Innovator - Made the major contribution on the technical side to the design or development of the innovation.

Business Innovator - Responsible for the overall project process

Chief Executive - Head of the company, MD or CEO

Project Champion - Actively promotes the progress of the project through its critical stages

This is supported by others such as Avison (1984) who argues that "the weakest element in a company's business is not the level of technology it uses, but the key people who manage the introduction of new technology and determine whether or not it is a success". A pioneering study into the decision making process of innovation was that by Rogers and Shoemaker (1971) who put forward a five stage process as shown in figure 3.3:

(1) The Awareness Stage - At this point the individual learns of the existence of the new idea, but lacks any kind of information about it.

(2) The Interest Stage - The individual becomes more interested in the idea and consciously seeks out further details

(3) The Evaluation Stage - The individual considers how best the idea could be applied to the present or future situations and whether or not to try it out

(4) The trial Stage - At this point the individual actually applies the idea on a small scale so that they may carry out tests and see if the idea can be incorporated in their own situation

(5) The Adoption Stage - At this stage the individual takes up the new idea completely

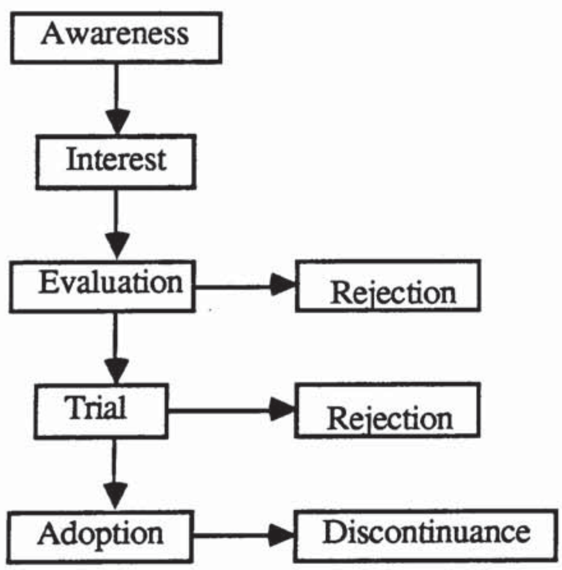

Figure 3.3 - Rogers and Shoemaker's (1971) Decision Adoption Process

Other researchers have put forward alternative models of the adoption process (ie. Bessant, 1982; Nabseth and Ray,1974) but in general these have followed the format of a series of sequential steps. Bessant in addition lists the stimulus which may be responsible for bringing the attention of a company to a new innovation:

- Rational development form existing work already being carried out

- Review of the state of the art technology as a response to an identified need within the company

- Promotion by outside agencies, government, trade associations or suppliers

- Awareness that adoption was already being undertaken by a competition

3.2 Technical Aspects of the Adoption of New Technology

Literature discussing the technical aspects of advanced manufacturing technologies as they have diffused throughout industry can often be placed into one of two categories: those which offer prescriptive methodologies for implementing such technologies within an organisation, and those which provide case study material discussing the experience of individual firms. Much of the latter is unstructured and case specific, but the former is well developed and contrasts markedly with the organisational aspects discussed in 3.1. An example of this is in the case of robotics technology as shown in figure 3.4. Here the authors are generally in close agreement, all advocating structured methodologies based on a sequential process. In these stages no mention is made of any of the non-technical aspects of the effects of introducing new technology in the same way that the organisational literature tends to underplay the technical aspects of the implementation process. The technical approach in its avocation of a structured approach also conflicts with the organisational literature,which argues the the complexity of the adoption process requires an unstructured flexible approach which can be adapted to a problem situation as it evolves. Parallels with these approaches in figure 3.1 can be found in the literature relating to numerically controlled machine tools and computer aided design. The point being that they tend to look at the implementation of new technology on a standalone basis, without looking at the overall manufacturing task of a company and its business objectives.

Tanner (1976)	Warnecke & Schraft (1982)	Teale (1981)
review state of the art	define area of study	prepare automation strategy
carry out initial application survey	carry out rough analysis of each workplace	implement support organisation
consult with robot manufacturers on applications	select suitable applications	sell proposals to workforce
select simplest job first	carry out detailed analysis of the selected applications	get some basic knowledge
study job in detail	prepare system specification	get some basic knowledge
design a system	design system	identify, prioritise and select applications
implement a system	implement system	implement first system

Figure 3.4 - Technical Approaches to Robot Implementation

In contrast, Parnaby (1979, 1984) from a study of Japanese manufacturing systems states that the design of flexible manufacture involves a "shrewd and professional combination of new technology with methodology which develops the adaptive capabilities of people and uses simplified systems and procedures". He links this in particular with organising for innovation and "combining manufacturing systems design skills within a framework of business strategy appreciation". He puts forward five basic stages common to all problems of flexible systems design.

(1) System 'steady state' or average performance design, starting at the end of the process and working back, each sub-system is designed using detailed input-output analysis. A preliminary simplification into basic key functional needs of homogeneous cell elements and their interactions starting from a simplified conceptual design is required.

(2) Dynamic design of each cell or module based on what if questions about disturbances to product volumes, product mixes and machine reliability

(3) Definition of all control functions and their information and exception report needs.

(4) Control and information-flow systems design using a hierarchical multi-level approach - top down planning

(5) Design of the task force team and procedures for performance improvement.

The principles of Parnaby's approach, which call for a consideration of the total manufacturing process conflicts directly with the workplace, standalone emphasis of the authors described in figure 3.4. However, the total system perspective has gained increasing attention as progressively more complex manufacturing systems are being installed in industry.

3.3 The Economic Appraisal of Advanced Manufacturing Technologies

Paralleling the technological innovations in manufacturing, those responsible for their instigation have the task of quantifying economically their effects, and in response a large body of literature has arisen concerned with various aspects of this task. These have ranged from academic journals and conference proceedings to management-orientated magazines, technically focussed trade journals and governmental sponsored reports. Although the majority of these reports can legitimately claim to make some useful contribution to discussion within the area, most of the literature can be placed within one of four categories:

(1) Identification of the characteristics that make new production technologies difficult to evaluate with traditional economic justification techniques.

(2) Provide a critique of the inadequacy of traditional financial justification techniques. These papers argue that contemporary cost accounting theory is unsuited to evaluating the performance of modern production technologies in which direct labour costs are a proportionally smaller part of total manufacturing costs,

(3) Strategic Considerations; These papers often seem to suggest that companies abandon the use of quantitative economic evaluation techniques, and instead base their production technology investment plans upon strategic considerations

(4) Evaluation Techniques; These papers give a variety of methodologies by which companies can conduct an assessment of the economic viability of proposed new investments.

3.4 What Makes Modern Production Technologies Difficult to Evaluate?

Despite the increasing volume of literature on the subject, many of the problems involved in manufacturing economics are not new. Essentially they can be placed into two broad groups. There is the problem of investment appraisal - how to cost justify new investments in production plant. And there is the problem of cost accounting - what costing systems to use and what information to collect to decide how products should be priced, resources distributed, manning levels determined, what machines should be used for a particular task. These problems are interrelated and indeed, difficult to separate. Methods for dealing with these problems have been developed over a large number of years, and established engineering costings texts can be found in most libraries.

The question thus arises is whether the set of technologies often referred to under the 'blanket 'term of Advanced manufacturing technology, "AMT", really does signify a distinct break from previous experience. That this is indeed the case, is argued by Gold (1982) who argues that AMT investments are not 'incremental' in a traditional sense but represent significant advances in technology. Since "synergy" and integration are the main benefits then neither the or purchase and operational performances should be assessed through traditional methods. Heath (1985) comments in a similar vein:

> 'Traditionally suppliers of manufacturing equipment, such as machine tools, have tended to provide equipment on a stand alone basis. It was important for the salesman to relate to the production process, and to communicate with the production engineer at this level, ie. to sell the equipment very much on the basis of its technical capabilities'....'we believe that leading suppliers in the factory automation market will move away from this stand-alone focus (as many are already) and will respond to increased user demands for a more a more integrated systems approach to broader automation requirements'...'It will be increasingly difficult for investments in manufacturing technology to be viewed not as standalone solutions to comparatively simple production problems, and the high level of investment that will be required may well force a change in the nature of investment decisions and practices'

One of the key problems identified within the literature in the economic evaluation of AMT is that of quantifying the 'intangible' benefits which are suggested as arising when such technologies are used. The list includes factors relating to increased sales, higher quality, shorter lead times, lower inventory levels, reduced scrap & rework, production flexibility and an improved company image. Initially, arguments were put forward which suggested that such 'intangibles' have to included in the investment decision process almost as an 'act of faith', in anticipation that their benefits would be realised. (New,1985; Sheridan, 1986; Kaplan,1986). A problem in evaluating intangibles is that they may not be obtained directly within the production unit, but elsewhere within the company. In addition, the point is made that the time lag between investment and savings often shows as an operating variance and not as an investment benefit.

In contrast, other authors suggest that if intangibles can be identified, then techniques are available to assist in the quantification (Catton,1986; Primrose & Leonard, 1985, 1986, 1987). Primrose and Leonard in particular at UMIST have been responsible for the publication of a large number of papers on the subject of quantifying intangibles. Their work has resulted in a computer program package called IVAN which is commercially available. This functions interactively by the user assigning cash values and weighings to a large number of variables (over 100) including intangible ones. The program then conducts a discounted cash flow calculation to test the viability of the investment. The author has used the program, and although it does represent a useful attempt at quantifying intangibles, it suffers from the problem that many complex financial analytical techniques do, simply that there are too many data inputs. Few companies, will have the time and resources available to supply such a large amount of data with sufficient accuracy. However, the idea that intangible benefits can be analysed through the use of a structured decision model one is a valuable one.

3.5 Problems with Conventional Cost Accounting Techniques

Literature which provides a critique of conventional cost accounting is considerable. A frequently cited author is Kaplan (1983, 1984) who suggests that the accounting profession will need to develop new measures of evaluating manufacturing performance, which better reflect the economics of highly automated factories. The essential idea of Kaplan's thesis is that contemporary cost accounting practices are based upon the mass production of a mature product with known characteristics and a stable technology. However, as progressive companies introduce more automated technology with higher fixed costs and lower variable cost, minimal direct labour, and small batch production of a variety of products or parts, the assumptions of current cost systems become increasingly irrelevant. Kaplan observes that job shop operations usually assign an overhead absorption rate based on direct labour hours and comments 'As the direct labour content of a product shrinks through the more effective use of fixed investment, firms are finding that their total cost per direct labour hour can be in excess of $50 even though only $10 of this represents actual costs' (Kaplan, 1983). He suggests another problem is whether labour should be considered a fixed or variable cost. He concludes that with the use of advanced manufacturing technologies, companies will be more concerned with developing product strategies that emphasise innovation, customisation and quality. In such an environment, production performance measures based on cost minimisation are viewed as inappropriate and argues that new performance indicators will need to be devised that can evaluate non-traditional and semi-quantitative factors. These include product leadership, manufacturing flexibility, delivery, quality, inventory costs and productivity.

The longer term nature of AMT investments and the inter-relatedness of the technologies are the basis for criticisms of the Payback method of analysis, although it remains the most commonly used method by companies (Pike, 1983). While the inadequacies of the technique are well documented, being quick to produce and readily understood by non-financial management in many companies, particularly smaller ones it still remains a favoured method. Although it is generally recognised that discounted cashflow techniques such as net present value and internal rate of return provide a better indication of the likely return on an investment by taking into account the time value of money, an issue raised by Finnie (1988) is that discounting calculations can also be prone to bias appraisals against longer term projects. Since the present value of £1 next year will always exceed the present value of £1 due further in the future for interest rates greater than zero, the use of discounting must favour projects with rapid payoffs over projects with deferred payoffs as may be the case with the introduction of new technologies. Finnie however argues that while the devaluation of future cashflows with discounting is undeniable, this will not have a particularly severe effect unless high rates of discount are used. What should be an appropriate rate of discount in such evaluations is a recurring theme. Swann (1988) shows evidence that UK companies use rates varying from 5% to 32% with an average (in money terms) of 18.5%. By comparison, in the USA it varied between 10% and 40%, with an average in money terms of 17.1%. Kaplan (1986) suggests that the rates used by many companies in the USA appear to be overestimating the cost of capital. The measurement of this return for UK companies is discussed by Samuals (1986) who shows from an analysis based on rate of return secured by investors, that the rates are considerably less than the 18.5% hurdle rate, even allowing for inflation. While there are undoubtedly valid criticisms as to whether DCF can fully evaluate all aspects of AMT investments, its conceptual basis is well established, and DCF does represent a genuine advance over payback and purely subjective appraisal methods.

Gold (1982) in contrast, suggests that the adoption of robotics and other programmable automation technologies alters the fundamental productivity relationships within a business to the point that localised appraisal of discrete projects using techniques can provide misleading results. He argues in discussing the use of robotics that the technology alters the interacting components of productivity relationships as shown in figure 3.5.

The following changes are said to take place:

(i) The ratio between fixed investment to direct labour input increases

(ii) " " " " man hours to unit output decreases

(iii) " " " " productive capacity to fixed investment decreases

(iv) " " " " direct materials to unit output may increase or decrease, but will change

(v) " " " " indirect manhours to unit output increases

Aston University

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Figure 3.5

The Network of Productivity Relationships in Manufacturing (Gold, 1982)

Gold makes the important point that existing appraisal methods are unable not only to take adequately not account the above, but also their 'inter-connectedness' and cites the following:

> '....mechanising some manual operations would first affect the ratio of activity - utilised fixed investment to manhours. This would tend to reduce man hours per unit of output, while the attendant increase in fixed investment might alter its ratio to capacity. And if the innovation reduced scrap rates, it would decrease the materials input volume per unit of output'

3.6 Strategic Considerations

A line of argument which has featured in the debate surrounding AMT, is that since conventional cost appraisal systems find such technologies difficult to evaluate, then less emphasis should be placed upon the results of such appraisal systems. Instead investment in AMT should be seen as part of a longer term strategic necessity on the part of a firm if it is to remain competitive. The arguments usually put forward to suggest this view include:

(1) The present state of knowledge makes it difficult to produce reliable cash flow forecasts and cost control standards as can be done for existing production technologies

(2) In many cases spurious financial justifications have been contrived to circumvent existing financial evaluation techniques

(3) Many important benefits from advanced technology, usually referred to in the literature as "intangibles" are not readily susceptible to precise quantification.

(4) The "inter-relatedness" of such technologies means that the benefits of the investment will be realised throughout the firm, not just in the manufacturing unit.

The development of company strategies within which manufacturing policy can be formulated has been the subject of discussion for some time in academic and managerial journals. The author of a survey by Woods (1985) report that 37% of firms investing in new technology employ no formal method for evaluating investment in new technology, and comment that the firms studied by them appeared to be more interested in 'subjective' assessment than formal appraisal techniques. Articles such as those by McDonald (1985) suggest that AMT should be introduced as part of a total operations strategy aimed at increasing overall business competitiveness. One of the problems with such papers is that guidelines for applying their ideas are not offered. While it is difficult to disagree with the general principle that proposed new investment in AMT should contribute to an agreed company strategy, surely this should be the case with any managerial decisions. There appears to be the implicit assumption that the realisation of a strategic objective such as increased market share will have beneficial economic results. This however, is a false assumption, as it is perfectly possible to envisage a scenario where strategic objectives such as increased market share may be achieved, but are unable to yield satisfactory, or any, profits. While Strategic objectives should have a significant role in investment decisions, they should not be used in isolation, but in combination with other financial evaluation techniques. One aspect of the 'strategic' approach that is usually overlooked in discussion on the subject is that for many smaller and medium sized manufacturing firms such notions as 'company strategy' are of limited relevance, where investments are often made on the basis of what is required simply to keep daily production going.

Aside from the issue of methodology, the importance of the decision making process within firms needs also to be stressed. Traditional demarcations within manufacturing organisations, especially between production engineering and finance has been blamed by a number of authors as accounting for the UK's disappointing take up of AMT compared to its major industrial rivals. In particular, the dominant position in many companies of accountants , to whom the "bottom line is sacrosanct" (Hastings,1984) and senior managers who lack an appreciation of AMT and the importance of indirect and difficult to quantify benefits. Heath (1987) comments:

> 'It is a well recognised feature of British Management that the "best route to the top" is through finance and marketing, and production engineering interests are poorly represented at senior management levels'

Senker (1984) and Skinner (1985) make the point that production managers are often excluded from the strategy formulation process, while having responsibility for drawing up the specification and justification of projects. Apart from such demarcations, other authors point out that the accounting methods used in a firm does not always determine in practise how the appraisal is actually carried out, and the stated procedure can be circumvented in favour of a considered judgement , thus highlighting the "political" nature of major investment decisions. For example, Gerwin (1982) in his study of the implementation of flexible manufacturing at Caterpillar points out that:

> 'Only a veneer of of objectivity surrounds the adoption decision for major technological innovations'. .

and quotes Bower in stating

> .'..capital investment evaluation is a process of study bargaining, persuasion and choice, operating at many levels of the organisation and over long periods of time'

Similar sentiments were expressed to the author by a manager at a large West Midlands vehicle manufacturer during a discussion on their machine justification procedures:

> '...regardless of what the numbers show, investments can be made at the whim of a manager provided he has enough clout to get his way'...'we've got a whole load of advanced equipment just standing idle, because it doesn't suit what we're trying to make, but was purchased because one manager *thought* it was what we needed'.

3.7 Summary of Evaluative Techniques

In response to the perceived need for techniques with which to evaluate manufacturing investment, a variety of such techniques have been put forward. While not an exhaustive survey, the purpose of this review is to identify the main approaches and to comment upon their particular strength and field of application. Meredith and Suresh (1986) provide a useful classification system of these methods which will be used here, and is outlined in figure 3.6.

Figure 3.6: Classification of justification methodologies (Meredith & Suresh 1986)

3.8 Economic Methods

Payback - This probably the easiest to understand and is simply calculated as the initial investment outlay divided by the average annual cost savings resulting from the investment. Typically a payback period of two years or less would be acceptable. Payback however, does not take into account the time value of money, nor the costs of savings achieved after the payback period. It is therefore immediately biased against longer term investments. A survey by Pike (1982) of of investment practices in large companies in the early 1980's showed that four fifths of the 149 respondents used the payback method.

ROI or Accounting Rate of Return - This is another comparatively simple method of calculation. It uses the ratio of net profit/capital employed. Profit is normally averaged out over the anticipated life of the investment, with no account being taken of the time value of money. Although ROI can give a useful analysis to judge the past performance of a business, it tends to discriminate against projects of less than ten years.

Discounted Cash Flow (DCF) - Discounted cash flow analysis is a preferred method of analysis since it recognises the time value of money and takes into account expected future cash flows. There are two major applications of the DCF principle; the Net Present Value (NPV) and the Internal Rate of Return (IRR). The latter technique is closely related to ROI but is an attempt to determine a 'real' discounted rate of return (taking into account the time value of money) and this rate can then be assessed to see if it is acceptable to the company. The NPV is generally considered to be a more realistic technique, and the calculations are used to assess whether a project will provide a negative or positive return (expressed in £). The flows of money are discounted during the period using a rate specified by the company. (This rate normally equates to the company's cost of capital).

3.9 Analytic Techniques

The analytic techniques described here are again mainly quantitative, but tend to be more sophisticated than the economic approaches. They also tend to include more information and often deal with issues such as uncertainty and multiple measures and effects. Their advantage is that by taking more factors and subjective judgments into account they are better able to reflect reality as perceived by knowledgeable managers. Their disadvantage is that more data is required, and the analysis is considerably more complex and time-consuming.

Value Analysis: This technique described by Keen (1981) was primarily developed for assessing technical innovations. It is essentially a two stage process. During the pilot first stage the project is viewed as an investment in R & D rather than as a capital investment. In this stage the *value* to the firm is determined either quantitatively or not to see if this is acceptable or not. If so, the pilot investment continues. In the second 'build' stage, assuming the pilot stage was satisfactory, the expected cost is considered first and then the expected benefits were evaluated for acceptability. The main strength of this technique is claimed to be the separation of the costs and value derived, and to enable managers to initially ascertain if the value of the benefits is worth their cost.

Portfolio Analysis: The scenario for using portfolio analysis arises where a number of projects are competing for limited capital funding. The essential idea is to identify a number of projects which maximises value to the firm or minimises risk of capital subject to achievement of a certain level of value. There are basically three types of model: non-numeric, scoring models and programming models. All three are described in Meredith and Mantel (1985).

Non-Numeric - These models are justified as the name implies on the trade-off between costs and benefits within which there is claimed to be a case for exemption from the normal evaluative process. These would include the "sacred cow' and 'operating necessity' scenarios.

Scoring models - There are a large number of such models, the simplest being the 'unweighed' model where a set of relevant factors is selected and one or more raters score each project on each factor. If a simple linear measure is employed scoring on a scale of 1-5 then an unweighed total is given. Summing its values gives a ranking of the projects. The model can be extended to a weighted model by assigning weights on each factor to indicate its relative importance to the firm, thereby developing a 'weighted factor scoring model'. Usually the weights are normalised to represent the proportion of total weight according to each factor. Such models if used in appropriate situations can be useful, their main problem is the difficulty of assigning ratings to alternatives for ambiguous criteria. Drayson et al (1986) describes the situation in a large food company where the introduction of a stand-alone robot for packaging sweets was found to be uneconomic on the conventional two-year pay-back costing procedures used in the company. However, the environment in which the robot was to operate was considered unpleasant by the workforce, and by designing a weighted scoring model which gave a cash equivalent value for the unpleasantness of the environment, the introduction of robotics was shown to be economically feasible.

Analytical Hierarchy Process - This technique developed by Saaty & Kearns (1985) is claimed to correct for the often-found inconsistency in human judgement when evaluating projects on various factors. The AHP procedure allows the rater to compare projects *against each other* on individual factors to ascertain their scores. It is suggested that more accurate estimates of the rankings can be obtained by this pairwise comparison method.

Programming Models - A number of programming models can be framed using weighted factor equations. Those projects maximise the set of project total weighted scores subject to constraints on various resources such as capital and facilities.

Risk Analysis - The typical approach to risk analysis is to simulate the type of project under consideration in terms of the particular variables of interest, ie. benefits, yields, costs, etc. Cumulative distribution functions are determined for each variable of interest showing the probability of achieving a certain profit, yield, return on investment, etc. Various proposed investments can be simulated beforehand and the results compared. Using the concept of stochastic dominance as described by Whitmore and Findlay (1978) the less favourable options can be discarded.

3.10 Strategic Justification Approaches

The strategic approaches tend to be less technical than the two previous categories, though they are often used in combination with them. The advantage of the strategic approach is that it can be linked directly to the objectives of the firm. Their disadvantage is that they can sometimes be used too easily to override unfavourable financial indications from other sources. Four main approaches tend to used.

Business Objectives - The justification of a project because it fulfils a firm's business objectives is clearly a strategic approach. 'Key indicators' can be established to measure how well these objectives are being attained. For example, automation may result in shorter production lead time and thereby allow better customer service, which may be a strategic business objective of a company in a very competitive market. The image of 'progressiveness' that automation gives to a company can also be of importance in marketing the product.

Technical Importance - This justification is that investment in a particular project, despite little or negligible immediate returns is a prerequisite for an important follow-on activity. This argument is often used to justify a firm gaining some experience with a particular type of machine or process on the grounds that it is likely to play a larger part in the firm's future.

Competitive Advantage - This approach suggests that an investment may be needed to gain or maintain a competitive advantage in its market. There is evidence to suggest that this is the case with some investments (Dodgson, 1987).

Research & Development - Treating a project as an R & D investment admits that the project may be unsuccessful, but that it holds sufficient long-term potential to justify the investment. The essential point is that if successful the project will more than pay for the ones that were not. Without risk nothing would be gained, and indeed the firm could be left behind by others who did take the risk.

3.11 Summary

While the advantages of discounted cash flow calculations over Payback procedures have been discussed over many years in both engineering and accounting journals, the majority of manufacturing firms still do not use a formal evaluative technique for their investment proposals. In such a situation, the complex *'analytical'* and *'strategic'* techniques discussed can become irrelevant except for the minority of (usually large) companies with the time and resources to provide the necessary data inputs. Finnie (1988) makes the useful point that the shortcomings of many financial evaluation techniques are more likely to represent shortcomings in the management of the investment appraisal process within companies.

The reality of manufacturing for the majority of smaller to medium sized firms companies is that of ensuring their day-to-day existence, with limited attention being given to developing the firm's 'strategic objectives'. Those putting forward new financial appraisal techniques should ensure that they do not become divorced from the reality of the manufacturing situation. The reason why many firms continue to use such 'primitive' appraisal techniques as payback is that it is suited to the dynamic environment in which many find themselves, where the horizon of the order book does not extend far into the future, and large fluctuations in demand are commonplace. In such firms most investments are expected to pay for themselves inside two years and the payback method is seen as reflecting this. However, set against this is the fact that as such companies find themselves needing to invest in more advanced systems, they will have to face up to the longer payback periods often incurred where investment takes on a more strategic dimension.

Chapter 3 References

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CHAPTER FOUR

THE USE OF COMPUTER SPREADSHEETS TO DEVELOP FINANCIAL MODELS OF MANUFACTURING FIRMS

"Man is still the most extraordinary computer of all"
John F Kennedy (1917-1963)

Preamble

This chapter discusses the techniques available for financial modelling, and why the use of a computer-based spreadsheet was found to be most suitable for the purposes of the research. The literature relating to financial modelling of firms is assessed to provide guidelines for effective model design. The subsequent financial models developed for the research are then explained.

4.0 Management Information and Models

The techniques of providing information for decision making in business, characterised by such terms as Management Information Systems (MIS) and Decision Support Systems (DSS), have in recent years become an area of rapid growth in organisational activity. The reasons for this are twofold; firstly the rapid developments in information technology enable organisations to collect, analyse and communicate data on a previously unseen scale. Secondly, the growing complexity of the modern business and the environment in which it exists.

The original development of computer hardware led to physically large, well secured computing machines isolated from the users. Access to these machines was restricted to the system analysts and the computer programmers. Most organisational managers had to enlist the skills of these people in order to apply computing facilities to solving their problems. Such approaches were time consuming and the analyses that resulted sometimes inaccurate. The software then available required a unique computer program to be written for each analysis. The code in which the models were developed can often be difficult to verify and costly to generate and modify. Subsequent developments of higher level programming languages such as *Fortran*, *Pascal* and *Basic* assisted in these tasks. However, the generation of code programming computers to analyse the desired models was an inefficient way to operate.

Both of the environments required highly sophisticated technical support. In the late 1970's the introduction of micro-computer technology radically altered the situation. This technology soon resulted in the hands-on availability for nearly anyone who had a need for computer power. In parallel with the hardware developments, software was developed which greatly enhanced the ability of the individual user to develop and analyse custom designed models. The early spreadsheet packages like *Visicalc* and *Multiplan* were key software packages in this stage of evolution. These were augmented by file management and database management packages which enabled management to collect and organise data to which they would not otherwise have access to. The business environment in which small and medium sized firms find themselves is often a dynamic one, with fluctuations in demand and the need for effective planning of the use of resources. Microcomputers and the financial software available are a powerful tool for such firms to have a better understanding of their business environment, which previously was available only to the larger firm. Also, such technologies allow models to be developed more rapidly, and experiments conducted to evaluate the outcomes of alternative courses of action without the need to alter the real system under consideration.

4.1 Modelling Methodology

A key stage in the research process was the selection of a suitable method for modelling the financial data derived from firms, into a form where the objectives of the research could be tested and conclusions drawn. In achieving these objectives it was essential that a methodology was adhered to, so as to ensure that the subsequent model developed was systematic in design and was able to effectively test the aims of the research and was verifiable. A large volume of literature is currently available offering advice in this regard, for example: Gershefski (1969), CAET (1979), Sherwood (1983), Bhaskar et al (1984).

The essential stages in the modelling methodology were identified as:

(1) Problem identification

(2) Selection of modelling technique

(3) Selection of modelling Hardware and Software

(4) Review of existing financial models

(5) Model development

4.2 Problem Identification

Although the aims of the research have already been discussed, it is important to ensure that the method chosen by which to conduct experiments to test these objectives will provide valid results. In this research, the aim is to analyse the economic effect of of new investment upon overall company performance. The data supplied by firms will be largely numerical and presented in an accountancy-type format. The modelling medium chosen must thus be able to manipulate a relatively large volume of financial data in a way, that meaningful insights can be obtained. Key problems which needed to be considered in developing the model are:

(1) Ensuring that the hypothetical automation changes in each firm being modelled were feasible, and could be represented in economic terms which are accurate enough to produce valid results.

(2) Deciding upon appropriate levels of model detail. An oversimplified model may leave out potential crucial factors, while an over-complex model will be unwieldy to use and key variables may be difficult to identify in a mass of detail.

(3) In this research, time is an important variable, since it is the effects of change over time that is being modelled. The model must thus be able to replicate the time horizon of the firm and perform experiments at suitable time intervals.

4.3 Classification of Modelling Techniques

The term *model* is a generic one and is often taken to include a wide variety of constructions. What is important to the potential model user is that it is possible to identify the different ways of generating and exploiting the relationships between decision variables, so as to determine the most appropriate type of model for a specific context. This will depend upon many factors, including the mathematical relationships between variables, the objectives of the user, the extent of control over decision variables, and the degree of uncertainly within the decision environment.

Figure 4.1 depicts a classification of modelling approaches. Non-mathematical models cover a whole range of different types, such as three dimensional solid state modelling in wind tunnels and two dimensional models such as maps or engineering drawings. Mathematical models are representations of the item to be modelled in mathematical

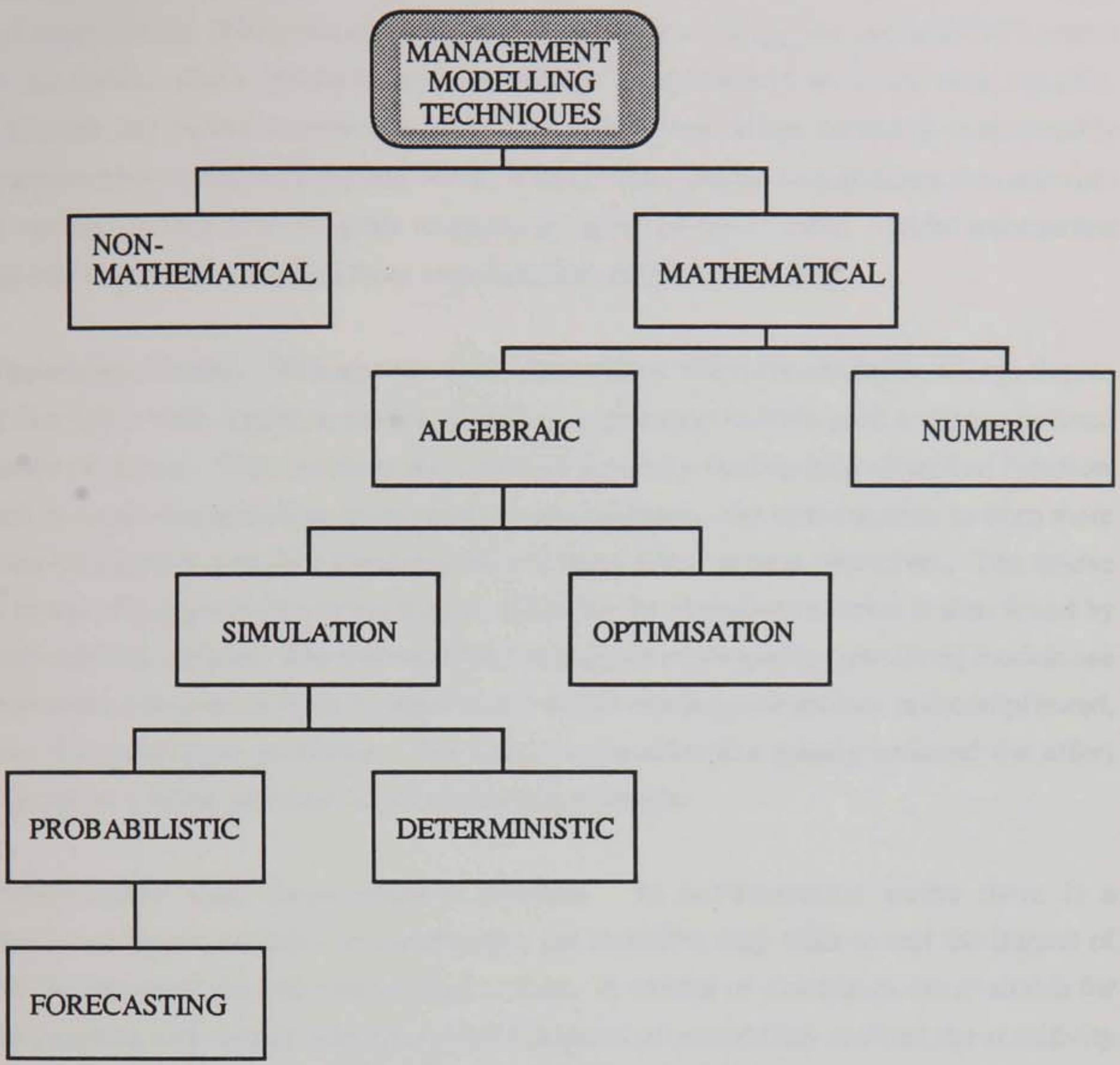

Figure 4.1 Classification of models

terms. Numeric models are represented by fixed values, ie. a balance sheet is a numeric model of the financial state of a company. The relationships of the variables of assets and liabilities are fixed at a point in time. To represent the situation at another point in time necessitates the construction of a fresh model. In contrast, an algebraic model would use symbols to represent the variables on the balance sheet, thus changes in any variable over time will not change the structure and therefore the validity of the model. The majority of financial decision making applications usually employ one of the following of the sub-family of algebraic modelling approach.

Simulation - Simulation models are the most commonly used form of financial model, typically used to answer the 'What if' type of question. This usually involves the modeller creating a hypothetical situation in which certain environmental factors apply and examines the effect of a particular course of action. Often, the modeller will search for an action which produces a result which is considered as being near optimal. Although any model involves a degree of abstraction, if the model is a reasonably accurate representation of the real world, it should be possible to determine the outcomes of various courses of action prior to implementation of any of them. Useful information can still however, be derived from even the most simplified models.

Optimising Models - Whereas the simulation model offers the modeller a large degree of flexibility with regard to choice of action, optimising models seek a unique optimal course of action. This involves the modeller formally stating their objective function, such as profit maximisation, sales revenue maximisation, cost minimisation or even more complex function possibly involving two or more simultaneous objectives. The course of action which gives rise to the highest value for the objective function is then found by mathematical analysis. The mathematical techniques employed in optimising models use systematic solution methods or algorithms, which can be quite tedious and complicated, even for quite basic problems. The use of computers has greatly reduced the effort required in making practical use of optimising methods.

Probabilistic and Deterministic Models - In environments where there is a significant degree of risk and uncertainty, the modeller may wish to test the impact of such factors upon the outcome of their actions. A variety of techniques are available for this purpose, and usually attempt to model aspects of uncertainty and test the sensitivity of the output data. The techniques can be broadly classified as probabilistic modelling, which can be contrasted with deterministic modelling in which single (certain) values are assumed for all input data, thereby producing single values for the output data. Thus, deterministic models do not specifically allow for risk and uncertainty within the modelling process, although some "understanding" of model sensitivity can be obtained in deterministic simulation by varying the assumed values of input variables.

Forecasting Models - Modellers often require to know how a particular variable is going to behave at some time in the future. A model can therefore be developed by identifying such a relationship by observing behaviour between variables from previous experience or in similar situations. In simulation modelling, the main interest is in following the path of the generating process. Forecasting models however, aim to identify statistically significant relationships between variables and to produce data which can then be fed as data into simulation or optimising models. For the purposes of this research, simulation techniques were selected as most appropriate. This is because developing a series of financial company models , in order to analyse the economics of using different levels of automation over various time periods creates a "hypothetical" situation and uses the "what if" type of question for which simulation techniques are most suitable. The nature of the research problem means that there is unlikely to be an "optimal" solution, and it is difficult therefore to assign probabilities to the variables involved.

4.4 Selection of Hardware & Software

The selection of hardware and software facilities for modelling are in many respects intimately linked, and were subject to the availability of facilities at the University. At an early stage the decision had been taken in regard to the choice of hardware to use a microcomputer, since the VAX mainframe computer at Aston was unable to run the *Excel* spreadsheet software chosen for modelling. Microcomputers are also more likely to be representative of the type of computing facilities found in smaller to medium sized companies. The proliferation of microcomputers in industry, often relatively cheap "all in" packages costing only a few hundred pounds has meant that they are rapidly becoming a "common tool" and leading to the situation where a large number of managers, even in relatively small companies are "computer literate". It was also possible when developing the models, that the need would arise for a company to be given a demonstration of the their operation and microcomputers are reasonably portable.

The microcomputer selected for running the software was an *Apple Macintosh SE* with a 20 megabyte internal hard disk. A key factor in the selection of the system was the "user-friendly" design of the *Macintosh* environment. An IBM-compatible system was considered for modelling and although such systems are more of an "industry standard", the user interface was not considered as "user friendly". The *Excel* spreadsheet program selected for the modelling is available in different versions for both Macintosh and IBM-compatibles, and so any model developed on a Macintosh system could be translated on to an IBM-compatible system.

The criteria for the selection of the software was guided by the need, that it be suitable for running simulation type financial models which could be modified easily, to allow for the variations between different companies being modelled. The author did not have an extensive knowledge of computer programming, so a "user-friendly" modelling interface would be of assistance. The models would also be shown during their development to company managers who may have a limited knowledge of computing. Software in which the numerical data and logic relationships within it can be easily traced, would assist in making the program better understood by the layman.

Four classes of software were identified as possibly fulfilling the above criteria:

(1) Relatively cheap and simple spreadsheet packages, such as *Visicalc*, *Supercalc* and *Lotus 1-2-3*

(2) Rather more expensive but sophisticated spreadsheet packages such as *Excel*

(3) A high level programming language such as *Fortran* or *Basic*

(4) Financial Modelling Packages with Separate Logic/Data

4.5 Simple Spreadsheets

Simple spreadsheets were first developed for microcomputers, and were the first type of financial planning package based on the use of a VDU for input and output. Spreadsheet packages offer the electronic equivalent of a large piece of paper divided into a matrix of rows and columns. Typically 63 rows by 254 columns is the size of the spreadsheet offered although hardware memory may affect its usable size. A complete matrix of cells is naturally far too large to be shown on a VDU and thus a portion of the spreadsheet must be chosen for viewing at any one time. Conceptually therefore, the VDU can be considered as "movable window" which can be used to view any chosen portion of the imaginary piece of electronic paper.

Effective cognitive coupling is one of the important factors for the widespread use of spreadsheets. The way an accountant would traditionally layout a financial plan is closely reproduced in spreadsheet packages: he can think in terms of a sheet of paper with columns and rows when he is defining the logic and inputting data, this appears on the VDU screen as how the computer holds and manipulates the data. The printouts also show the data in exactly the same way as it is displayed on the screen.

An advantage with spreadsheets is that they are extremely easy to get started with, although with the "cell" logic specified in algebraic form, it can be difficult as a model grows larger for someone other than the model creator to understand the model quickly. Supporting documentation can, however, greatly assist in this task. A characteristic problem of spreadsheets is their potential vulnerability to mistaken adjustments by other users, so protection facilities need to be built into a model. From this it can be seen that one of the major roles of spreadsheets is for the users of the model to develop their own model, and to use it for repetitive work on a series of relatively simple calculations. Since recalculation is relatively fast, many repeat calculations with different sets of data can be quickly performed.

The original basic ideas behind all simple spreadsheet packages, came from the *Visicalc* package, of which 250,000 copies are estimated to have been sold. The *Visicalc* package was originally written for the APPLE II microcomputer by Visicorp of San Jose, California, and its popularity was in part responsible for the success of the Apple in the business sector of the microcomputer market. However, one result of this success was that many other software houses produced their own spreadsheet packages with various embellishments, usually incorporating the syllable "calc" in their title, such as *Supercalc*. Several are basically simplified versions of the original *Visicalc* package, but others offer various improvements upon the original package. An example of this is *Lotus 1-2-3* which because it runs on IBM microcomputers and compatible systems is probably the most widely used.

There are however, several limitations built into simple spreadsheets by their original design. One major limitation is that while several of the simpler spreadsheet packages can support approximately 16,000 cells, in practise only a fraction of this can be used before the microcomputer's Random Access Memory (RAM) runs out. Nevertheless, such a working area is usually ample for most calculations, although generally the larger the model the slower the speed of calculation. This partly due to the fact that when a change is made to a model, the spreadsheet recalculates all the data in the model regardless of whether it is affected by the changes made. With larger applications the delay during calculation can become irritating to the user. Other more serious limitations with many of the more basic spreadsheet packages are that:

(1) each spreadsheet model operates in isolation, meaning that two models cannot be consolidated, and the spreadsheet files cannot be linked to other software applications.

(2) the output facilities are usually very limited, with report writing being confined to printing out the entire model displaying either figures or the logic formulae

(3) links with graphic packages are often not available (or very limited) which prevents illustrating reports

(4) even if the information required in the model is already stored in the computer, it still has to be input initially to the program through the keyboard unless a database link is available.

4.6 Sophisticated Spreadsheets

Although they operate on the same basic principles as the cheaper spreadsheets, the more sophisticated spreadsheet packages such as Microsoft's *Excel* and Ashton-Tate's *Full Impact* which have appeared during the last three years, represent very powerful pieces of software which offer considerable improvements on earlier spreadsheet packages. Using *Excel* as an example, the advantages of sophisticated spreadsheets packages are that:

(1) The user interface uses a series of pull-down window menus, and selection of functions can be made with a "mouse" making it quicker and easier to use

(2) The spreadsheet is combined with a business graphics program which allows data to be presented in a variety of chart formats. Such spreadsheets also have a variety of database functions, which make it easy to organise, file, sort and retrieve any data in the spreadsheet

(3) The problems of limited computer memory are largely overcome, since space in memory is more efficiently used by reserving it only for those spreadsheet cells carrying data. Recalculation time resulting from changes is also cut by the software recognising only those cells which need recalculation

(4) Multiple spreadsheets and charts can be displayed and linked simultaneously on the screen. This allows the user to consolidate and organise data from multiple spreadsheets and charts. These can then be linked together into a single report. Permanent links can be made between spreadsheets, so that changing a value in one changes them all.

(5) The output from the spreadsheet can be adjusted to print out only part of the spreadsheet. The visual presentation of the spreadsheet can also be customised

(6) The availability of network versions of *Excel* facilitates the use of spreadsheet models throughout a company.

(7) The macro program recorder allows the user to automate easily repetitive tasks such as updating monthly budgets. Instead of programming a complex macro program, the user can simply perform the desired actions, which will be recorded and built up as a macro program

(8) The *Excel* spreadsheet has over 100 built-in financial, mathematical and logical functions which can integrated into models. In particular logical relationships in cells can be given names to make them easier to follow, for example: REVENUE=SALES*PRICE, rather than: B1=B2*B3

4.7 Programming Languages

The use of the Basic and Fortran computer programming languages was considered for modelling purposes. Procedural languages by existing in List form implicitly define the sequence in each step of a calculation is performed. The modeller thus has close control of the calculation process to an extent that is not available in spreadsheets. Such languages can also be used to develop highly interactive programs which for example, may prompt the user for data input through a series of questions. Their main disadvantage from the point of view of the research was that this author had only a limited experience of these using these languages, and that they did not not really offer any significant features that were not offered by sophisticated spreadsheet packages. In addition, the research models would need to be demonstrated and explained to firms providing the data, most managers would be unlikely to have an in-depth understanding of these programming languages, while the logic and design of spreadsheets makes the models developed easier to understand.

4.8 Financial Modelling Packages

In spreadsheet packages, the data and the logic are intimately linked together. With financial modelling packages such as *MicroModeller*, *Micro-FCS* and *MasterModeller*, separate logic packages keep the model logic and data separate. The reason for this is that the logic may apply to several sets of data, for different sections of an organisation or the data from different experiments with the logical model. In-built financial and statistical routines together with the availability of report generators and the ability for the modeller to write their own sub-routines make this sort of package more of a modelling tool for large and complex models than spreadsheet models. Indeed, packages such as *Micro-FCS*, were derived from mini and mainframe versions, and their use is still mainly confined to large organisations. For the purposes of this research such packages were not considered as offering any particular advantages over the use of spreadsheets. The availability of these packages at the University was also limited, and they were reviewed by obtaining sample packages from their suppliers.

In summary, from the categories of software reviewed, the sophisticated spreadsheet package *Excel* was selected as the modelling tool. This was considered to offer sufficient features in order to be able to design and develop models that could test the research objectives. The key factors in its selection were the ease of its user interface, its ability to link and transfer information between multiple spreadsheets and the fact that the logic of spreadsheet design makes models easier for managers in participating companies to understand, many of whom had a limited experience of computing.

4.9 Review of Spreadsheet Financial Models

Despite the large volume of literature explaining how spreadsheet software can be used for a variety of general financial applications, there is little published on the the specific subject of capital investment appraisal and modelling its wider effects on company profitability. This is understandable, since companies will often want to keep their methods of financial evaluation and modelling confidential. The work of three authors who have published papers in this area is outlined below. However, this lack of information does make it difficult to evaluate whether companies are using suitable methods of investment appraisal and how useful were the models used. Such information would undoubtedly assist in the drawing up of guidelines for successful model design.

Earnest (1987) working at Georgia Institute of Technology, describes a spreadsheet application program for capital investment justification. The model was originally developed using the advanced version *Visicalc* spreadsheet on an Apple III personal computer. The limited memory space available on the Apple III and limitations of the Visicalc software package led to the transfer of the program to the Microsoft *Excel* package running on a Mackintosh Plus microcomputer. Earnest also states (p.342) that the "...friendly user interface and speed of the Mackintosh along with *Excel's* advanced spreadsheet capabilities were the main reasons for not implementing this template on an IBM using *Lotus 1-2-3*".

Etemad et al (1987) give an account of a financial model developed at University College, Swansea to assess the economic viability of setting up a small factory in South Wales to produce a pelletised fuel from commercial and colliery waste. The author was able to meet with the research group to discuss their findings in January 1988. The model is based on *Supercalc III* spreadsheet software and was used as part of a business plan submitted to the Welsh Development Agency for a regional grant to start up the business. Essential to the success of the business were the relative prices of the two principal feedstocks. The model was able to analyse the financial viability of the business in relation to change in the costs of these variables. The results of the model showed that the cash flow of the business would be under considerable strain in the event of any delay in the plant becoming operational.

Since the engineering required would involve a considerable degree of novel design, there was a high probability that delays and cost overruns could occur and it was decided not to proceed with further development. However, the model was able to demonstrate effectively how a custom built model can assist the smaller business in making decisions.

Hundy and Hamblin (1986, 1987) describe the problem that can arise within a company in introducing new technology when an engineer having developed what seems to be an excellent project is told by the financial function that the scheme does not pay off. The problem is often a lack of communication; the engineer may be unaware of accounting principles, while the accountant may lack knowledge of manufacturing technology and the long term benefits of investing in new technology. Ideally, the manufacturing engineer should be able to assess easily the consequences of their proposals in financial terms to try out alternative solutions to a problem. Recognising this problem among their own engineers, the Ford Motor company, in collaboration with Cranfield Institute of Technology, have been running week long course to train Ford engineers in appreciating the financial dimension of engineering projects. Part of the course involves the use of a series of spreadsheet models devised by Hundy and Hamblin to perform risk analysis on manufacturing investments using NPV and IRR. The author was able to meet with them in December 1988 to discuss their findings and it was reported that over 300 engineers in Ford of Europe have been through the course, with many now using the principles in their daily work and employing spreadsheets in project evaluations. This helped to confirm the valuable communication benefits of spreadsheets and their selection as the modelling technique used in the research.

4.10 Problem Specification

Since the aim of the research was to model the economic effects of a new investment over a period of a given time horizon, a simulation type modelling technique was identified as the most suitable for this task. A key stage in the design of any financial model is the preparation of the modelling specification, it is during this stage that the problem to be modelled is analysed in detail and the precise logical relationships are worked out. Ideally once a good specification has been prepared, the technical aspects of model design, programming, testing and experimentation should proceed more smoothly. Setting out a good specification is however, not a straightforward task since many business problems are inherently complex, and even those which at first sight appear to be relatively "simple" often turn out to less so, when the underlying logical relationships have to be identified. From the author's experience the modelling specification is a creative, problem solving exercise, which usually requires more time than initially anticipated, but which usually gives a deeper insight into the nature of the problem under consideration.

In initially preparing the specification two key questions arise - who is going to use the model? and what is the model intended to show? In this research while the author was intended to be the main user of the models, the management in the case study companies being modelled would need to be shown the models and understand them in order to supply the necessary information. They also requested that copies of the models and instructions on how to use them be documented and made available to them, and this also had to be taken into consideration in model design. Defining the requirements of the models was also difficult, since usually the initial objectives of a model are vague rather than precise. Before approaching the companies for information several prototype models were developed to acquire expertise with "Excel" and to try and clarify the ideas of the author. It was also important that when companies were approached for information, that the author had some basic models prepared to demonstrate the ideas behind the research methodology rather than just talking about a set of "hypothetical" models. It is in discussing "company models" that the author first encountered one of the problems of the academic/industry interface. Being smaller companies few of the managers in them had graduate level training and had reached their current position based on time served experience. While this provided an in depth knowledge of their respective businesses, few had experience of dealing with such conceptual ideas as "modelling" and only limited knowledge of spreadsheets. In seeking their cooperation, it was felt important to try not to come across as purely an "academic" with little grounding in the "real world". The use of spreadsheets were of considerable assistance in this respect, since the models were based as much as possible on the standard financial operating data used within the firm. By transporting the computer to the companies and demonstrating the prototype models, managers were able to see for themselves what the objectives of the research were and could relate this more easily to the situation within their individual business.

From the prototype models and the feedback provided, the author was able to begin the process of adapting them to fit the companies under consideration. Wherever possible, the models were designed to use a similar format to financial information already used in a company, such as an operating budget. Much supporting company documentation was also obtained relating to previous capital investments and their justification. One of the problems encountered in specifying the models was, sometimes, the reluctance on the part of managers, to make an "estimate" to quantify particular items of detail on which information was not readily available. This does not reflect any inherent inability on the part of managers to make a decision, rather it reflects that the question is genuinely a difficult one to answer and considerable time would be required before a good answer is obtained. The process of agreeing the information to be included in a model is a difficult one, which requires considerable tact and an adequate amount of time. Whilst discussing the information needed with management, one of the key skills in modelling is to assess the level of detail required, since it is important to prevent the information requirements from becoming too complicated.

There are two approaches to modelling a company which can be termed "top down" and "bottom up". The "top down" approach looks at the total organisation and seeks to build a model of its total behaviour by providing full and detailed links between functions and activities. Conceptually, the top down approach is logical but in a practical context is difficult to apply, since gathering all the information is a time consuming process and the eventual models are large and not easy to use. The "bottom up" approach as the name implies adopts a building block approach, beginning at the lower, operational levels of an organisation by modelling discrete activities. The individual models are made open ended so that they can be linked together with models of other activities, thus progressing towards a "total" model. The problem with this approach is that in building models up from the bottom, vital areas of activity may be overlooked or of building discrete models that do not interrelate as intended. The approach taken in the research was to adapt a mid-point one, where models are built from a base upwards but within a predefined framework to which each is intended to contribute.

In designing the models a number of techniques were found to be of assistance in discussing the specifications of the model with managers:

Flow Diagrams - The purpose of flow diagrams to represent pictorially the overall logical structure of a model as shown in figure 4.2. Within each block there is a brief description of a particular process and the blocks are connected by arrows which represent the transfer of intermediate results from one block to the next. The first draft of a flow diagram is usually a tangled web of blocks and crossing lines, but with successive redrafts, the logical flow begins to take shape. The use of such diagrams was an integral part of the problem solving process and was found to be an effective tool in working with managers to design a model. When drawing flow diagrams the following points needed to be borne in mind; what information is passed from block to block, what functions are performed within each block, and what information is produced as a result of the functions represented by each block. Flow diagrams were also drawn in a hierarchy of levels, where for example, the highest level diagram might show separate modules in a complex model such that each individual block is then exploded onto its own lower level flow diagram. For example, the forecast sales revenue block in figure 4.5 could be broken down into individual product groups.

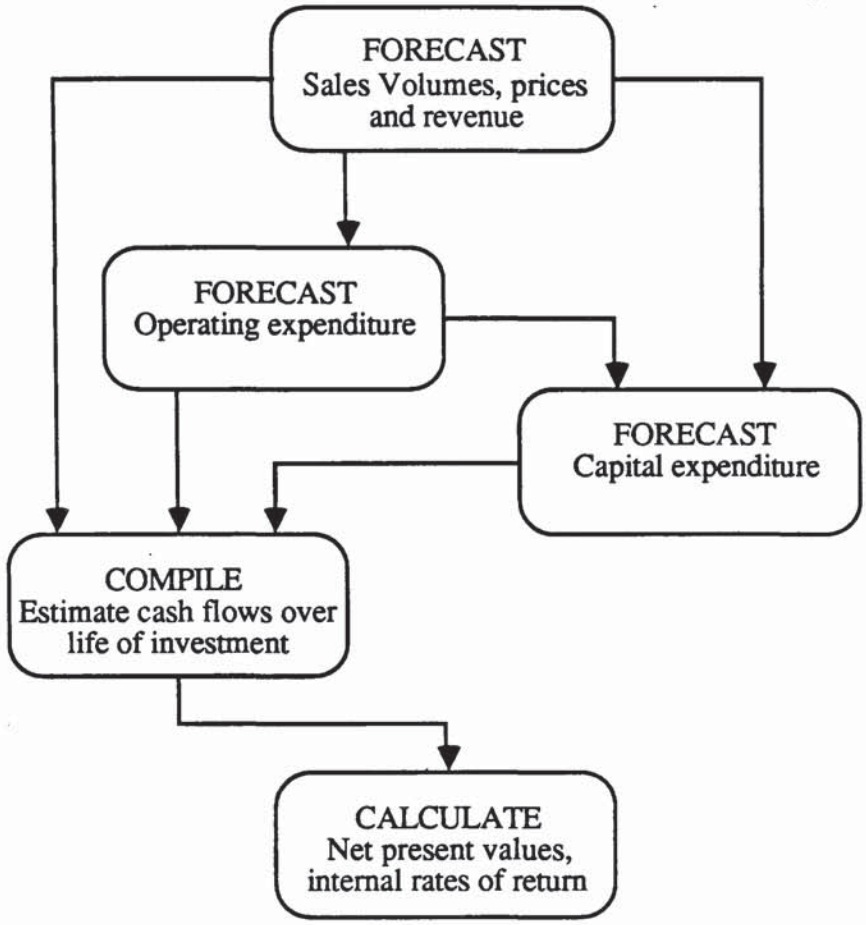

Figure 4.2 Flow diagram of a simple investment appraisal model

Tree Diagrams - A method to relate the items on the output reports to the corresponding input requirements is to compile a tree diagram , an example of which is shown in figure 4.3. This involves first listing the requirements of a given output report and then working backwards to identify where the information required comes from. For example, the sales revenue in the model will made up from the unit price multiplied by the sales volume. The sales volume can then in turn be analysed at a lower level. By adopting this process, it is possible to analyse each item into its fundamental components and provide a better understanding of a problem.

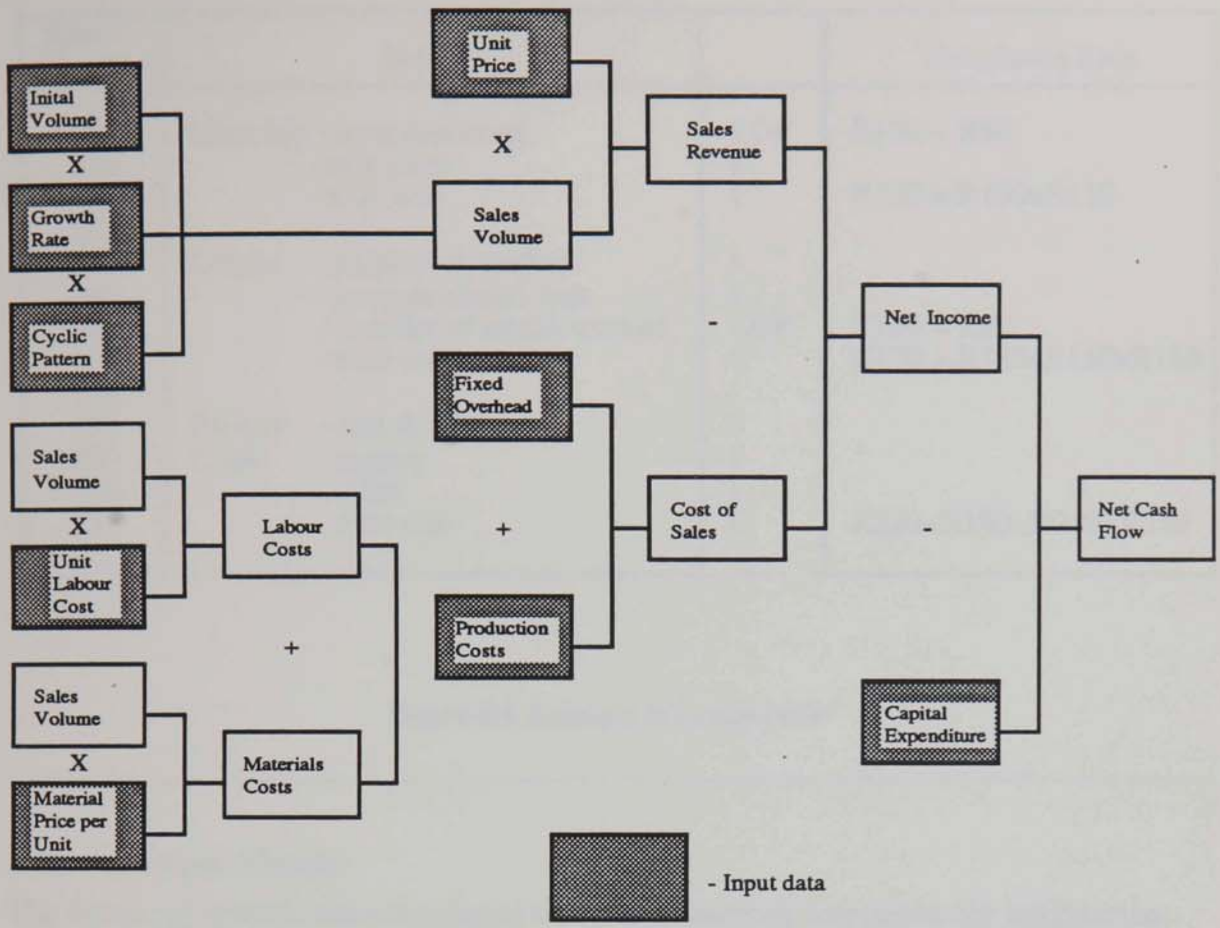

Figure 4.3 Example of a tree diagram

Rules Tables - While the objective of the flow diagram is to show the overall logical flow of information of a model, it does not show the calculation rules. These rules, while shown in the tree diagram, are often hard to follow. To define the rules in a more intelligible manner, rules tables can be used, an example of which is shown in figure 4.4. The benefit of this format is that it requires the modeller to define the complete logical solution to a problem, by stating whether data is to be input (I), Calculated (C) in which case there must be a formula, or copied (COP) in which case the reference from which the data is to be obtained must be given. Listing all the inputs in rules tables before the model is set up ensures that a compete solution is identified. Another benefit of rules tables is that they are a good means of documenting a model and are an effective aid in communicating the logic of the model to others. Having set up the model, the rules table are also useful for identifying any errors that may have occurred.

Row Number	Item		Calculation Rule
100	Materials - units produced	COP	R100 = R50
110	- unit price	I	
120	- total cost	C	R120 = R100xR110
130			
140	Labour - number of workers	I	
150	- average annual cost	I	
160	- number of weeks worked	COP	R160 = R20
170	- total cost	C	R170 = R140xR150xR160
180			
190	Factory - rent & rates	I	
200	Costs - engery	I	
210	- other	I	
220	- total cost	C	R220=R190+R200+R210

Figure 4.4 Example of a rules table

4.11 Prototype Models

The following models were developed before approaching companies for information:

(1) The ***Investment Analysis model*** - for calculating the cashflows of individual investments and using discounted cash flow techniques, gives the net present value and internal rate of return. This model also has an interactive interface so that the user is taken through the data inputs automatically and prompted for data.

(2) The ***Financial Impact Analysis Program*** - was developed for analysing the financial effects of introducing a new product on a company and also take into account depreciation. This model again uses an interactive interface to prompt the user for required data inputs.

(3) The ***Detailed Company Model*** - based on a series of linked spreadsheets using a standard operating budget and cash flow format, which were also linked with a balance sheet and financial analysis features. This model is able to project investments over several years was designed to be extremely flexible, so that it could be adapted to the needs of individual companies.

(4) ***Machine Based Absorption Model*** - This model, discussed in chapter 5 was developed in collaboration with the financial director of a company rather than being developed beforehand, and allocates company overheads on a machine based recovery system rather than the labour based one commonly used in industry.

In developing all the spreadsheet models the author tried to ensure that they conformed to general accounting principles. The *investment analysis spreadsheet*, an example of which is shown in appendix 4.1, was developed for preliminary analysis of the cash flows of a potential investment using DCF techniques. The spreadsheet was designed with an interactive macro driven routine so the user can feed data into the model without requiring an extensive knowledge of the Macintosh or of *Excel*. This approach would enable the managers in the case study companies to easily use the model for themselves. The macro, (which is a facility for listing a series of instructions for the computer to obey, similar to that in a program of a computer language such as BASIC) is first loaded onto the screen and instructed to run by means of the "drop down" menus which are a feature of the Macintosh computer interface. Prompt boxes provide interaction to inform the user when and if data has to be entered, an example of one is shown in figure 4.5. The macro automatically opens the spreadsheet and guides the user through the data input phase. After data has been input correctly the macro saves the input values and calculates the result. The macro then prompts the user to ready the printer and then prints the spreadsheet showing the results. The user is also asked if he requires a graphical printout of the results using either net present value, as shown in figure 4.6, or internal rate of return as shown in figure 4.7. An advantage of the model is that the user can quickly manipulate any desired variables to perform a sensitivity analysis.

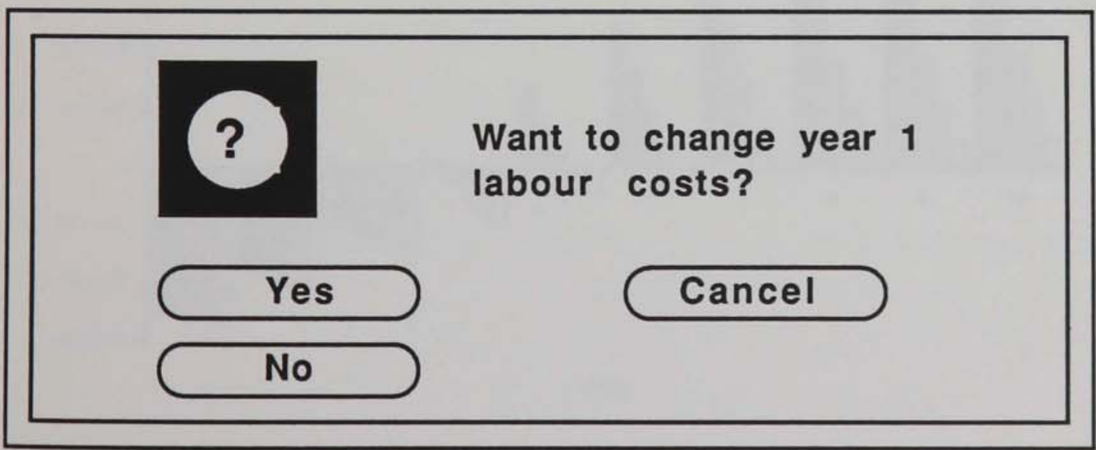

Figure 4.5 Example of a user prompt box

The advantage of using a macro driven interface is that it prevents the user from inadvertently altering formulas during data input. After printing is completed, the files are closed and the user regains control of the computer. The spreadsheet has five sections requiring input, an example of which is shown in appendix 4.1. Appendix 4.2 shows the logic printout of the spreadsheet and appendix 4.3 show the logic of the macro program. The first requires data on initial capital and non-capital start-up costs, against which any equipment sold off and grants obtained are offset. Section two quantifies the additional operational cost of the new investment, while section three takes into account the potential savings offered by the investment. Section four provides a facility for calculating the revenue from the number of product units sold as a result of the investment and also includes basic tax and capital allowances calculations, although this is clearly a specialist area. Section five requires the user to define the range of required rates of return over which the net present value will be calculated. Several companies discussed in chapter 8 who were not able to supply information for detailed modelling of their businesses were able to provide information relating to specific investments and where possible the author has carried out a DCF analysis using the *investment analysis* model.

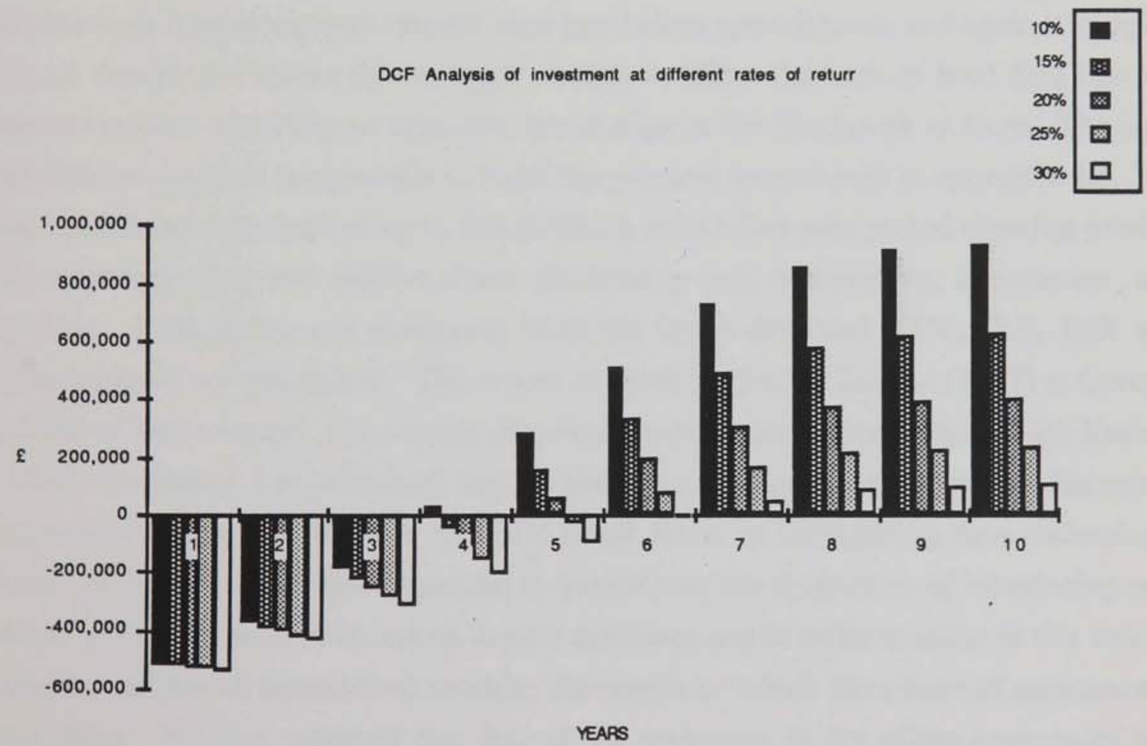

Figure 4.6 Example of graphical printout of DCF analysis using net present value

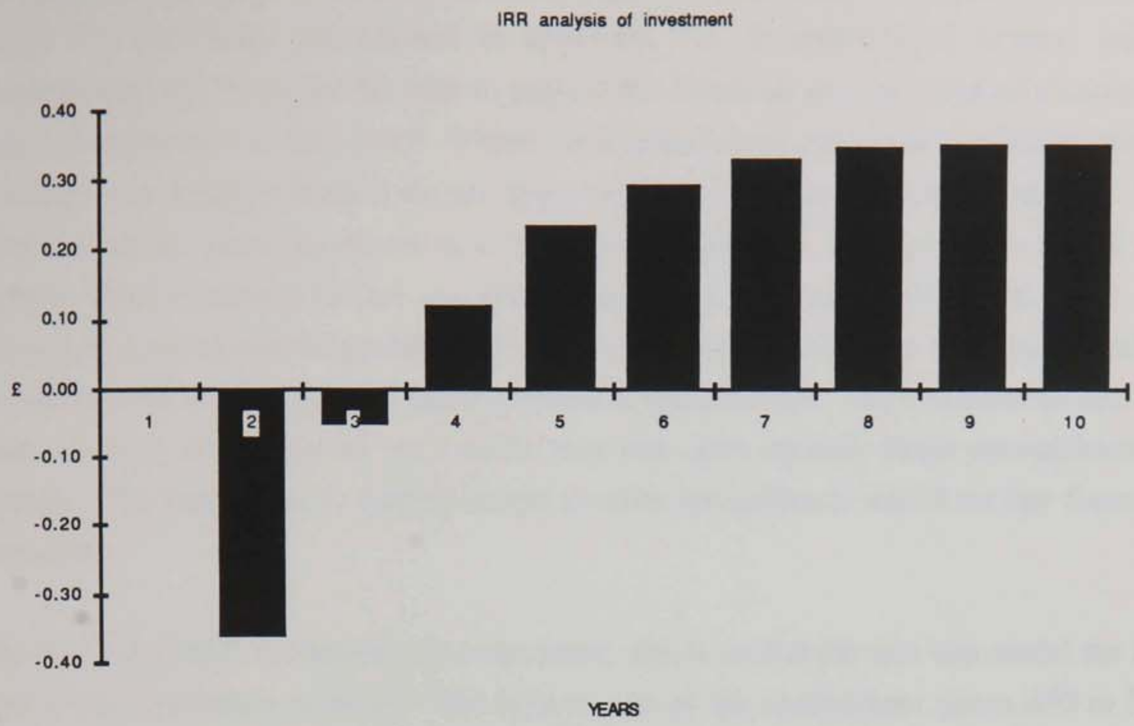

Figure 4.7

Example of graphical printout of DCF analysis using internal rate of return

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The *financial impact analysis* model uses two linked spreadsheets, and again is coupled with an interactive macro driven input routine to allow the user to feed data into the program without requiring an extensive knowledge of the Macintosh or Excel. The input spreadsheet is shown in appendix 4.4 and the printout spreadsheet in appendix 4.5. The program offers an analysis of up to five products over a five year period showing product cost, expected sales and market share, equipment cost, receivables, inventories and payables. Cash flows are generated from the input data and NPV, IRR, ROI and payback period are calculated. The model is based on that by Earnest (1987) at Georgia Institute of Technology. As a result of correspondence and conversations with Earnest in 1988, the author was informed that he had been working on an academic/industrial programme run by the institute to assist small firms in introducing new technology. Several of the firms had been interested in quantifying the economics of introducing new product lines as a result of investing in new machines and in order to assist in this task he devised a number of spreadsheet models, the results of which have been of assistance in these firms. He also reported that few of the managers in the client companies had experience of micro computers and DCF techniques and the macro driven interface was found to be of assistance in overcoming this problem. The experiences of Earnest helped to confirm the approach taken by the author in the research.

An outline of the structure of the *Detailed Company Model* used in chapter 7 is shown in figure 4.8 and fully reproduced in appendix 7.1. It consists of several linked spreadsheets which enable the user to project the financial performance of a company over a time horizon of four years. Within each spreadsheet, the operating budget (profit and loss) on a monthly basis is shown and is linked to a monthly cash flow model. The results of all the years are shown in a summary spreadsheet. This in turn is linked to a balance sheet summary linked to a spreadsheet used to calculate financial ratios. An advantage of using linked spreadsheets is that it enables models to be modular in design, so that the user can remove and insert alternative spreadsheets. The complete model also does not have to be opened up, and the user can open up only those spreadsheets of interest. The model can be further linked to other spreadsheets which set key financial variables.

The year one (1989) spreadsheet has two parts; this is so that the user can model the first year of an investment in detail. The bottom part of the spreadsheet (rows 470 to 762) shows the planned financial projection of the operating budget and cashflow of a company, taking into account the costs benefits upon overall performance of, for example an investment in new technology. A key feature of the model is that it provides a *What-if* facility. The top part of the spreadsheet (rows 1 to 466) has the same format as the bottom and copies values across from it, but has the facility to enter a percentage difference from the plan below each cost category.

For example, in the base model shown in appendix 7.1, the planned sales figures of general cartons in January 1989 was £198,000. To find out the effect of a 10% reduction in this value on the net profit and hence on the cashflow, the user would enter "-0.1" in the *What-if* facility (row 26, column C) and the result would be calculated and shown in row 16, column C. Although, the model has the capability to vary all the values in the plan, it is not suggested that this facility would actually be used in all cases, since many of the cost categories contain very small figures. Instead, the user can set the model so that a change in one cell is copied to all other cells automatically, and so the user is able to tailor the model to suit the level of detail required. For example if the user wished to specify that all the materials costs values (rows 83 to 92) would be 5% lower than plan throughout the year, the user could set the model up so that for example, a "-.5" entered in row 97, column C, would be copied across the rest of the cells in the materials category.

Starting in year 1 the user inputs the figures for the predicted operating budget. The cash flow is calculated automatically, although the finance payments for an investment are input manually. Having set up the year 1 operating budget, the spreadsheet automatically

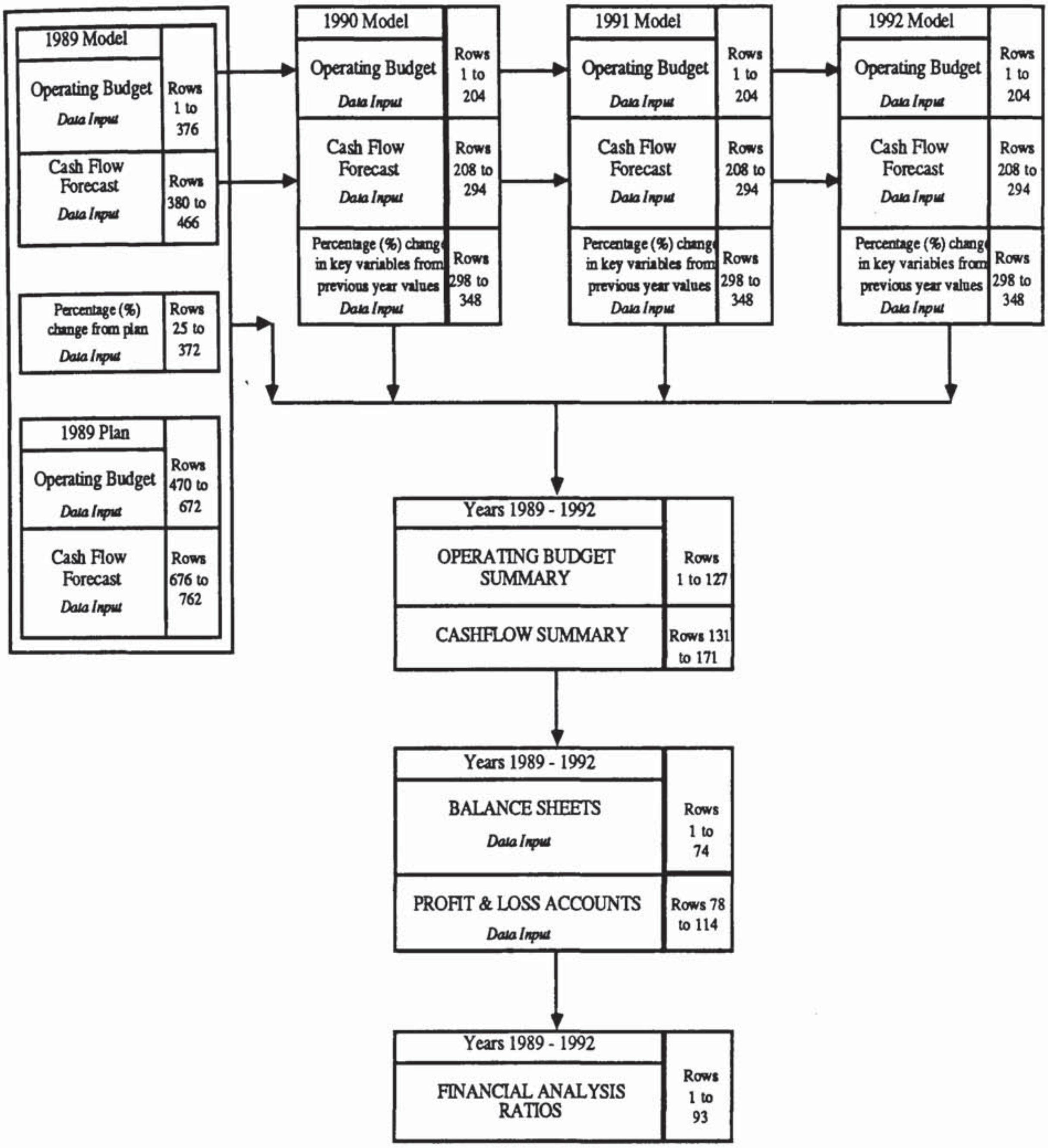

Figure 4.8 - Structure of Detailed Company Spreadsheet Model

copies across key financial items from the closing stock and WIP from year 1 and the closing balance to the following year, with subsequent years transferring values likewise. Years 2 to 4 (1990 to 1992) are projected on an annual basis by means of the parameter change facility at the bottom of each spreadsheet (rows 298 to 348). For example, the

1990 sales figures (rows 16 to 21, column C) are projected by copying across the values from the 1989 spreadsheet (same reference) and multiplying by a user defined value in rows 302 to 307, column E. This figure is derived from a specified value of growth, or decrease and a value if required to account for inflation. For example, if sales of a particular product were £100,000 in year 1 and expected to be 15% higher the following year, the user may enter a general figure of 10% in to account for inflation and a 5% real growth factor. The advantage of this is that in many companies the relative effects of inflation on different parts of its costs may be different., ie. material costs rising faster than sales turnover, and the model is able to reflect this. While years 2 to 4 are therefore calculated by a single value of change from the previous year, instead of monthly values, the user can if needed easily adapt the model to reflect this instead.

The financial ratio model shown in appendix 7.8 offers the user the ability to monitor changes in key company financial ratios as the business acquires more advanced technology. For example, more productive machines should offer the company the opportunity to reduce manufacturing leadtimes, which in turn would be expected to improve the number of stockturns per year. Improvements in stockturn over a number of years should be reflected in the financial ratios of the firm. Other ratios such as the net assets employed relative to sales, would also be expected to be show changes as the company becomes more capital intensive.

Since for many smaller companies, when financing new investments, the strain upon the cash flow can be considerable, the model has built-in logic feature which enables the user to test the effect of varying the credit periods given and taken by its debtors and creditors. This feature is shown on rows 210 to 218, column H of the 1990 to 1992 spreadsheets in appendix 7.1. For example, if a company has 80% of its debtors paying within two months and the remainder within three months, the model would be adjusted to reflect this. The user, by varying the relative percentages, ie. 90% within two months, 10% within three months, is able to see the expected improvement that would occur in the company's cash flow position and relative sensitivity of the cash flow to % changes in credit terms. Likewise, the model is able to show the effect of varying the period of credit that the company takes itself in rows 211 to 218, column O.

The model was designed to represent most smaller to medium sized companies, and so the structure of the model was designed with a degree of build-in flexibility to provide flexibility for adapting its use to individual firms. The model conforms to the general categories of costs found in company operating budgets but the headings can be changed easily to meet individual requirements, with any surplus rows being left blank. An advantage of using a spreadsheet modelling approach is that it can be easily adjusted to suit the level of detail required in a company. For example, while the model has the capability to show a detailed operating budget and cash flow for a company over six years on a monthly basis, most managers would be reluctant to project the company over such a long time horizon in anything other than yearly figures. However, if the company wished to model its operating budget and cashflow in sales and costs on a monthly basis for years 0 to 1, quarterly basis from years 2 to 4, and yearly in 5 and 6, the model could be set to show this Since the model was designed to to be used on a practical basis in the participating companies it has the facility to calculate VAT. However, for the purposes of evaluating new investments, while VAT will affect the cashflow of a company in the short term, it should not have an effect upon long term investment decisions, and so is not included in the models.

The method in which a hierarchy of spreadsheet models would ideally be used to project the financial implications for a business as it progresses towards higher levels of automation, is shown in figure 4.9. The production or standalone level is the level at which many firms evaluate investment in new technology and takes into account the direct effects of new investment , ie. capital cost, reduced labour costs, reduced scrap, etc. Most firms perform their justifications at this level with supporting calculations of various such factors. At this level an investment is looked at in isolation from the rest of the business, and the *Investment Analysis Model* and the *Financial Impact Analysis Model* were developed to perform discounted cash flow calculations for this task.

Should a company wish to assess the economic consequences of an investment upon overall company performance, then a more detailed overall company model could be used for which the larger spreadsheet models were set up - the detailed company model used in chapter 7, a simpler version in chapter 6, and the absorption model used in chapter 5. The advantage of these models is that they are able to project the cost effects of an investment upon overall company performance, and to project their effects over a number of years. The company model can assess the profit and cashflow implications of several ongoing investments which the company may have can take into account the important indirect effects of technological change, such as the change from direct to indirect costs, with fewer operators,but more personnel with higher technical skills. All of these may be expected to have financial implications. For example, if a hypothetical firm was considering investing in a number of machining centres, the model could be able to show the financing implications of this decision upon the cashflow and the net profit. In addition, indirect costs such as the need for programmers and greater technical expertise would be expected to increase as the company progresses in terms of automation, and it was intended to represent these in the models.

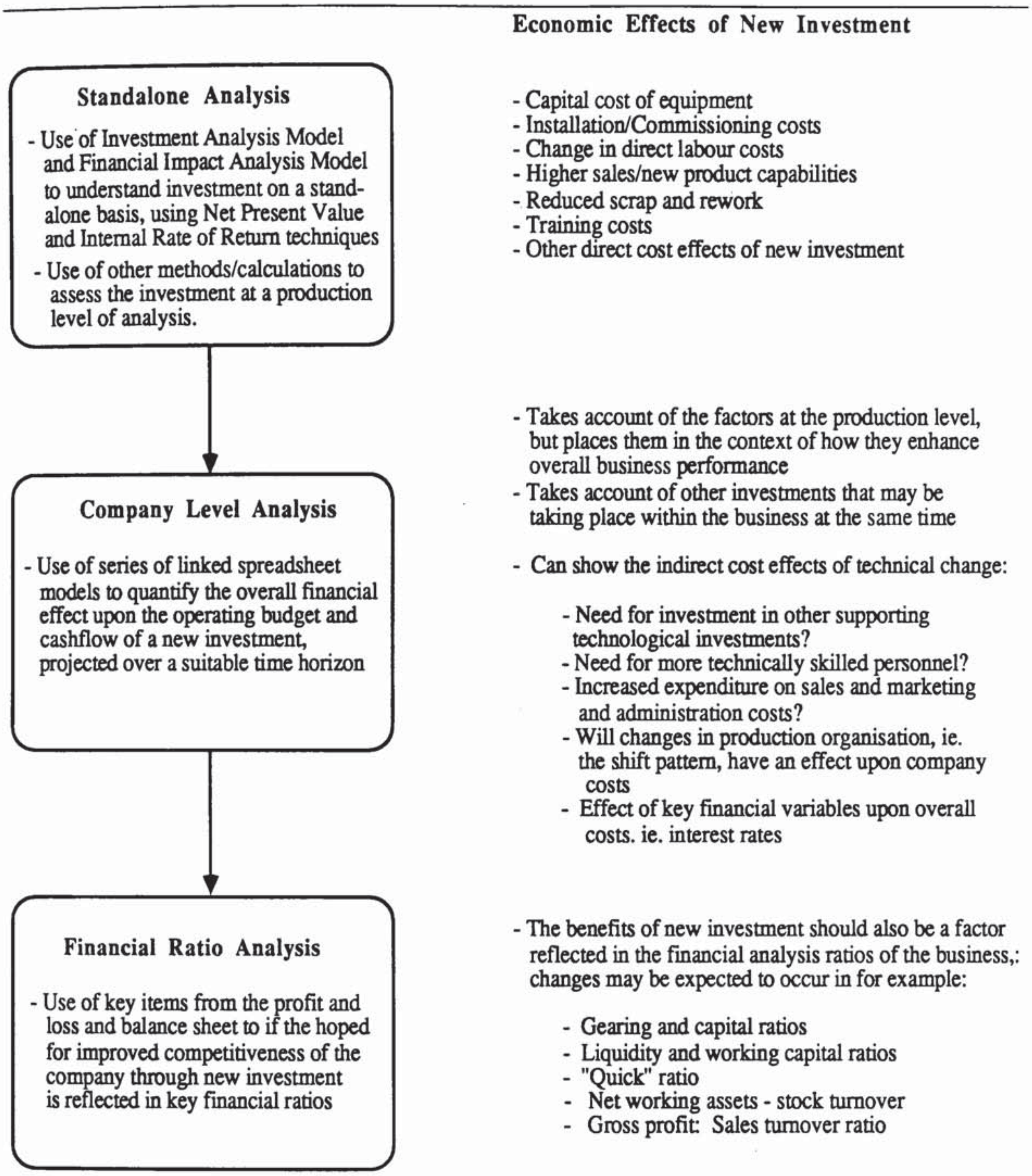

Figure 4.9 - Hierarchy of Models

By projecting the business over a number of years, it was intended that trends in costs within a business which as a result of new investment, may not be very profound in a single year, would, when accumulated over several years, together with the effects of other similar investments, become more readily apparent.

Since the objective of new investment is either directly or indirectly to improve overall business performance, their benefits should be one factor contributing to an improvement in the financial ratios of the business. For example, if a company had invested in several machining centres which would provide faster throughput, together with a computer based materials control system, one of the expected benefits may be a reduction in the level of inventory held by the company, and hence to increase the number of stockturns per annum, so reducing the demands made upon working capital. While the use of ratios should always be treated with great care, since considerable variations can exist between individual firms in the same industry, the important factor thing is the general *trend* of the ratio, and whether it is in the right direction or not. Thus, the models developed provide a structured method of assessing the effect on new technological investment upon a company form the production level , through to the overall financial performance.

Ideally, as shown in figure 4.10, managers responsible for different functions within a firm would quantify how they expected a new investment to affect that aspect of the business for which they were responsible. Through discussion with company management, the author was able to build up a series of scenarios of firms as they progressively automated and to test the effects of alternative investment decisions.

In summary, the models can be said to have two main purposes:-

Firstly, to identify and measure the effect of technological change within a company, particularly with regard to the "wider" effects of change, such as in the indirect cost structure of a business. Secondly, to demonstrate relationships between the various parts of the business and in consequence to improve management understanding of the functioning of the business and the effects of significant technological change thereon. The models were also of particular value as a research aid in as much as that they made easier the task of explaining the objectives of the study to the managers where collaboration would be essential to its success. The process was also rewarding in as much that it highlighted differing perspectives held by managers within a business, evaluated the financial appraisal systems in use and identified intangible factors which are important, yet economically difficult to quantify.

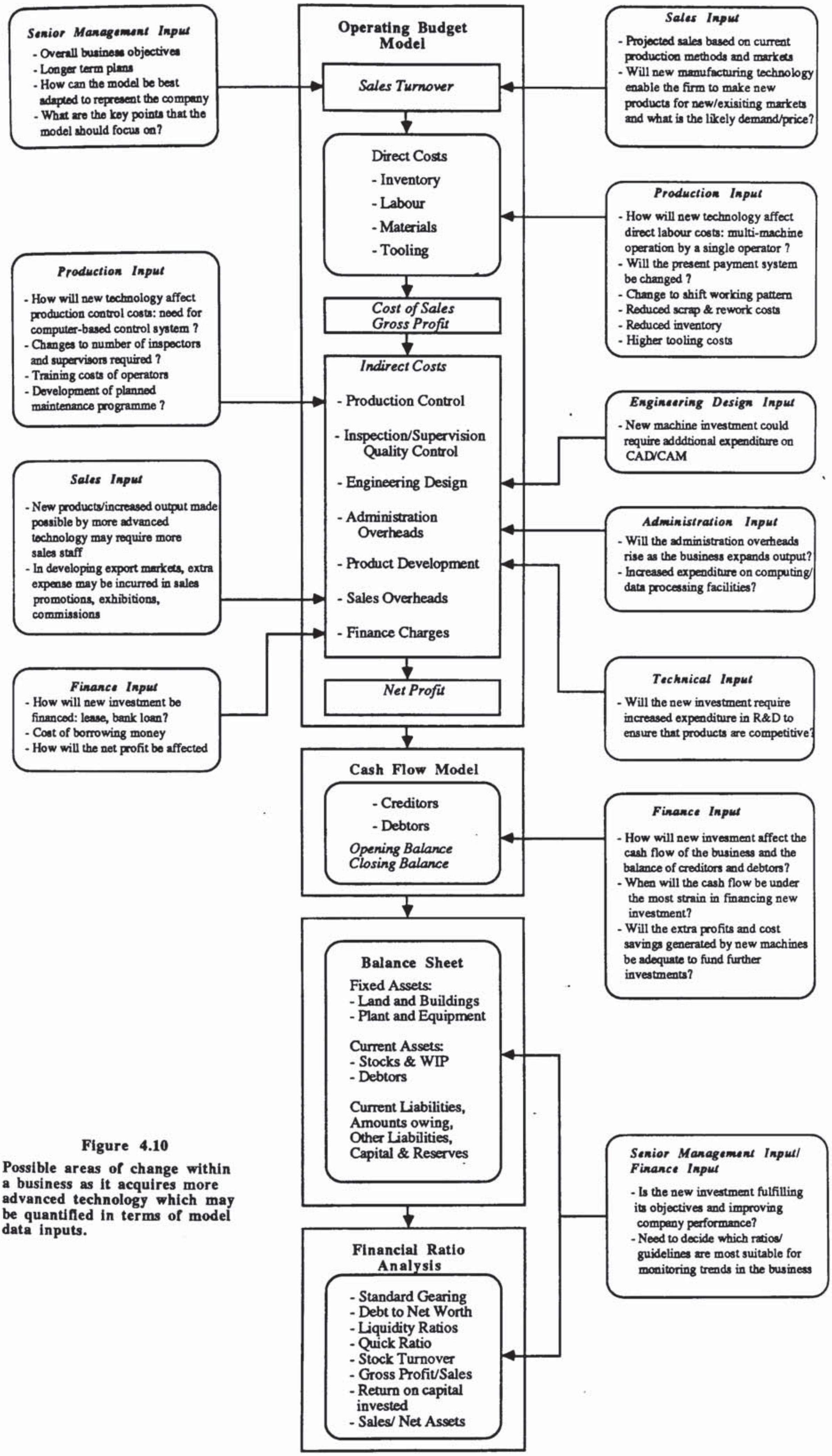

Figure 4.10

Possible areas of change within a business as it acquires more advanced technology which may be quantified in terms of model data inputs.

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Chapter Five

VHME Press Company Limited Case Study

'Despite a steady diet of acquisitions, we are a group that is focused and will remain focused. We are not a conglomerate. We understand the product and the investment in developing it'

Company Chairman

Preamble

This case study discusses the justification for a CNC Machining centre in a medium sized company manufacturing machine presses. The company had based its existing overhead absorption system on direct labour hours, but the introduction of CNC machines meant that labour was a declining cost factor in relative terms. The company was interested in developing an absorption system based on machine hours to test the effect of future machine purchases. This the author was able to do using spreadsheet based models. The company is particularly interesting as it is one of a group of companies in related metal forming operations which have been brought together by the group chairman to test his strategy of a "Total Engineering " group aided by the 'synergy' between group companies.

5.0 Introduction

The VHME press company manufactures a range of machine power presses, press brakes and cold roll forming equipment, and employs some 130 personnel. Although the company in its present form has only been in existence since 1985, it was formed by the combination of four separate smaller businesses by the chairman of the group of companies of which it is a part. In many respects, this group, which has been built up since 1982 when the first company was acquired, represents an interesting example of how traditional metal forming firms, which have of late, often been thought of as dying industries, have been restructured to become profitable again.

5.1 Background to VSN International Group

Figure 5.1 shows the present structure of the group of companies. The rationale behind the group originates from the experiences of the group chairman. While working for a large US engineering company, he was sent in 1974 to Brussels to close its loss making Belgian steel press subsidiary. However, he believed that the business and others like it could be saved if they were encouraged to export and invest in technologies which could increase productivity. The problem as he saw it, was that while their products were still in demand, the metal forming industries in Europe tended to be fragmented, consisting of numerous small/medium sized companies. Few of these on their own had a very large market share and lacked the necessary resources to reach overseas customers to market their products. In addition, their small size limited the resources they could provide for investing in more productive technologies and updating their products and they were gradually falling behind in terms of technology. This pattern of industrial structure well fitted much of traditional UK metal forming industry in such areas as the West Midlands. Furthermore, the large Japanese machine tool conglomerates backed by extensive R&D,

associated benefits and economies of large-scale production were beginning to gain a foothold in the European market. His idea was to bring together a number of smaller companies making complementary products and restructure them to form a group with a central marketing unit which would market all their products. It was intended that by sharing the expertise of individual firms within the group, a degree of *synergy* would arise and innovative new products could be developed.

Five years later backed by the then profitable US parent company, he was able to develop his strategy and was sent to London to develop the international sales unit which had been created to carry out his plan. At that time the economic recession was hitting traditional metal forming industries particularly hard in the UK and many firms were being sold at prices close to their nominal asset value. The first acquisition made in 1982 was of a power press maker, bought from the receiver. However, the US parent company was also to feel the effect of the recession and went into the red in 1984. Viewing the development of its international operations as an unnecessary expense, the decision was made to sell the business. This provided the opportunity for the present group chairman to arrange a management buyout for £2.8 million pounds in 1985.

Since the buyout the group chairman has expanded the group by one or two companies per year to its current structure shown in figure 5.1 These acquisitions have included a number of well established British machine tool makers. The present criteria for acquiring a company is that it must be involved in a metal forming industry for the automotive, aircraft, steel, railway, defence or capital goods markets. Also, it must fit upstream or downstream with other products made by the group and must have the potential to develop an export market. The idea is to create a *Total Engineering* concept, where a customer can approach the company for a complete system, which would be built up by products from several of the group companies. Previously customers would often build up a production system by purchasing individual machines from different suppliers and use their own production engineering skills to make the system work. An unforeseen side-effect of the recession in manufacturing has been that many companies, when forced to cut their overheads cut back on their production engineering staff, with the result that this capability has often been greatly diminished. When purchasing new equipment, such firms now have to consider purchasing a complete system from a single supplier.

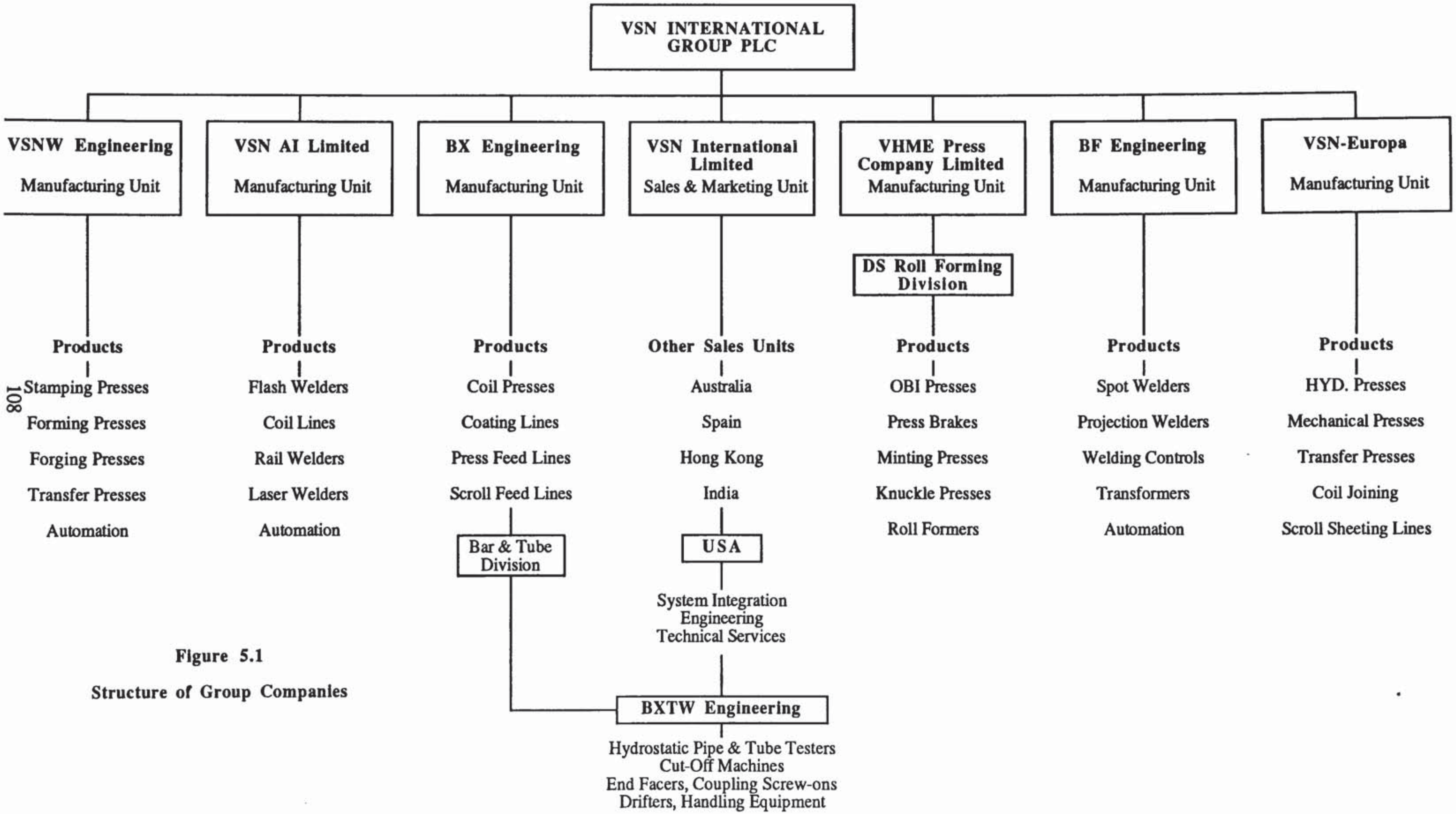

Figure 5.1

Structure of Group Companies

The group's current operations include power presses, electrical welding machines, bar and tube straightening equipment and coil processing. Once it acquires a company, the group management immediately start a drive to increase its export sales, aiming to double its turnover within 2-3 years. So far the group has been successful in achieving this high rate of growth in its acquisitions and has established sales offices in the Far East, continental Europe and in the United States in Pittsburgh and Chicago, to cater for international customers with products from all the group's companies. In this way, none of the group's subsidiaries has to bear the sole cost of setting up an overseas office itself, and the relative cost of the overseas offices to the group declines as more companies are acquired. The group chairman comments on this 'The companies we acquire generally have 70 percent of their sales in the United Kingdom and 30 per cent overseas. We reverse that ratio'. The overheads in acquired companies are also cut, although the main focus of this is tends not to be on employment since this usually has already been slimmed down during the recession, but on such things as dining rooms and company cars. Each company retains its own identity and management structure, and short lines of communication exist between group companies to facilitate interaction on contracts, in case a customer wants a *turnkey* system.

The group management also reorganises production and improves the level of technology used, particularly in computer-aided-design systems. The group spent more than £6 million in 1988 on capital projects, including new factories for two companies. CNC equipment is being installed in each of the operations, although the nature of the business limits the gains to be expected from higher levels of automation. The benefits that such technologies as CAD have brought are reflected in such recent projects as a refurbished electro-galvanising line, which one of the group companies undertook for British Steel. The project involved 10,000 man-hours of engineering development work using CAD which previously would have been cast aside once it was completed. The CAD system now enables design work to be retained on disk, so that in the event of a similar or repeat order arising it can quickly be accessed and modified. The group chairman comments on the project:

> 'Now with our export drive we can take that same project and change it a bit for another customer elsewhere in the world. That process would only involve only 2,000 hours of engineering design. That makes us more competitive in price and enables us to sell more machines. That is the key to the businesses we are in. The more machines we have in the market, the more advantages there are to our customer and the greater our depth of experience'

In terms of financial performance the group made an operating profit of just over £1 million pounds in the year to January 1986 on a turnover of £12.5 million, which was quite good for a new firm servicing heavy debts, in an industry where a 10% profit margin is considered high. In the two years since then following its acquisitions, the group has increased its turnover to £39.7 million pounds for the year ending January 1988, with a profit before tax of £1.65 million.

5.2 VHME Press Company Limited

The present company started in November 1985 with the acquisition from a large UK engineering firm of its press making subsidiary. This had once been a leading manufacturer of presses but had been hit hard by the recession and was now reduced to employing only 45 people, and was in the red facing closure. Into this company the designs to make presses and minting machines were added from a large US machine tool manufacturer, which had divested itself of its press making subsidiary, considered as incompatible with the rest of its machine tool business. In 1988 the company acquired a cold roll forming business which well fitted the pattern of industrial decline in Britain, being a traditional 'Black Country' firm founded in 1888 whose products at their peak had been installed around the world. However, over the years its management had neglected to invest in new production equipment and introduce new products. Instead it relied on selling its existing products in traditional British markets, often in the commonwealth which offered a degree of protection from foreign competitors. Its gradual decline was heightened by the economic recession and when purchased was a skeleton of its former self employing only 18 people. (A similar pattern of gradual decline was common to most of the acquired companies). This company has now been brought onto the main company site (as have the others) and the name kept to retain its identity as its products still enjoy a good reputation.

Having acquired several small firms and brought them onto a single site, the Managing Director now sees their integration and modernisation as the main task ahead. Asked what distinguished the VSN Group from other engineering "conglomerates" he replied that:

> 'Other engineering firms acquire new businesses to diversify, this is not the case with VSN, when a company like Hanson takes over a firm, it is usually not able to bring any new markets or products to the company being acquired, the VSN group does so by providing a geographically broader market'.

The *synergy* within the group can best be described by way of example. The sister company BF Engineering makes equipment for the seam welding of oil drums. Their current "set up" takes blanks of steel and feeds them through a rolling device to complete the hoop and then through the seam welding aspect of the machine. After BF Engineering had joined the group in April 1989, it became obvious that this could be expanded into a complete system by the addition of BX engineering coil processing cut to length equipment, for the production of the component parts associated with the complete drum. It is therefore now possible to offer the customer a complete drum making facility, virtually totally supplied from within the group. The customer therefore only has to go to one supplier who takes turnkey responsibility and ensures that the customer gets a full working system. Figure 5.2 shows the author's interpretation of the conceptual model held by the management of the existing company business strategy and production problems and the "optimal" model of the business which the management is trying to move towards.

The company inherited a large number of old press designs from each of the acquired companies and its product development program has mainly concentrated on the refinement of these to form a new rationalised range of general purpose power presses. The development of synchronised down-stroke press brakes has involved the application of new servo hydraulic control and CNC systems. Further developments of high speed minting equipment has enabled machines to run at 700 rpm, with a pressing force of 160 tons. In order to achieve this performance, significant problems with vibration and dynamics had to be overcome to obtain stable, consistent performance.

Central to the company's future plans has been investment in new manufacturing technology, principally CNC and CAD. When the first companies were brought together they had no CNC machines, and as the Managing Director commented:

> 'the plant and machinery were totally unmatched to what we wanted to make, simply to "break ice" we purchased a 20 year old early NC machine not only to get sales orders out, but also to make the workforce think in terms of 'numerical control'.

The 'people problem' as the Managing Director put it, was identified as the central issue to implementing new technology successfully, since the workforce was built up from several companies from a traditional manufacturing environment with little or no experience of CNC. He saw CNC as requiring a 'totally different way of thinking' due to the increased machining load, and new skills required. This situation was not helped by the company still being in a constant state of change, and assimilating workers from different companies with different working practices, into a single efficient workforce was proving to be a much more arduous task than originally thought. To overcome its skills shortage task the company had tried to recruit workers with CNC skills locally and, being situated in a traditional manufacturing area with high unemployment, had expected a good response. In practice this was disappointing and the managing director suggested that the reason for this was that a side effect of the recession had been that many skilled workers had either retired, or sought jobs in other sectors and the engineering industry in general was now facing a potential skills shortage. Those who had applied were often found to be more "semi-skilled" rather than "skilled" and were

Figure 5.2 Conceptual Model of Existing/Optimal Business and Production Pattern of VHME Press Company

	EXISTING BUSINESS/ PRODUCTION PATTERN	OPTIMAL BUSINESS/ PRODUCTION PATTERN
Business Objectives	- Company relatively new and requiring considerable expenditure to restructure - At present in a low volume/ high variety market and able to manufacture across wide size range of presses, much of output is customised to individual requirements	- High operating margins - Want to develop new production systems using products from group companies - Increased emphasis upon standardised range of presses, which offer cost benefits associated with longer production runs of component press parts
Sales/ Marketing	- Export Sales Developing - Need to develop a greater awareness of the company in the engineering industry and what it can offer. Customers still associate with the old names of the acquired companies	- Target of 70% of output exported - Modern CNC machines could be used for sub-contract work - Introduction of new innovative products including high speed presses/ minting machines offer potential to increase sales
Product Design	- Use of CAD progressing, but learning curves and manufacturing leadtime still long	- The introduction of CAM with reduced manufacturing leadtimes
Production Technology/ Organisation	- Order backlog in machine shop, large overloads on many machines	- Machines have the productive capacity needed to growth with the company turnover
	- Mixture of CNC machines and older manual machines, many machines not really suitable for what the company is trying to make	- All CNC machine shop - Several key CNC Machining Centres - Automatic machine loading/unloading possibily using robotics - Low rate of scrap & rework
	- Manual machines have long setup times	- Continuous monitoring of tool wear and breakage, with ability to take corrective action automatically so machine can continue - Automatic in-process guaging - Automatic swarf removal
	- High dependence on operator skill - One man per machine operation	- Reduced skill requirements - Multi-Machine operation by operator - Facility for minimally manned operation giving third unmanned shift
	- High Maintainance Costs	- Minimum maintenance on a planned programme
	- Workforce from traditional non-CNC background, need to acquire new skills and learn to think 'CNC'	- Well trained workforce, able to adapt to new technology
Production Control	- Basic materials requirements planning system used, which does not take account of capacity planning	- Compter Based Production Control System with analysis of previous performance and linked to stock control, production planning and other key variables

unable to operate CNC machines without an unacceptably high scrap rate. In the longer term, he sees a key aspect to achieving the company's objectives as being to get the workforce to 'understand what we are trying to do, and then doing it'.

In regard to the CAD system the company had recently introduced, this was acknowledged to have been a success in terms of the improvements it had provided in terms of design productivity. Experience gained from its use had also shown the importance of its implications for the management function. Since the company is still building up its library of drawings, it was often necessary to decide whether priority should be given to new design work, or transferring existing manually drawn parts onto the system. This required effective communication between the design engineers and production engineering functions within the firm.

While the company's eventual aim is to have an all CNC machine shop, it has been cautious in its purchases. Firstly, because of the substantial sums required, but also because the technological catch-phrases of the machine tool industry have less effect in the metal forming and press sectors, than in the larger area of metal cutting. Presses perform very basic tasks and to a great extent rely on traditional engineering for their success. In selecting a new CNC machine the Managing Director identified three key factors as being:

(1) Must be economical producing in small batches, with an ideal EBQ of one.

(2) Able to operate on a minimally manned basis, to facilitate multi-machine operation.

(3) Produce high quality components consistently.

Given that the company has currently an order backlog entailing machines being overloaded and considerable overtime worked, he saw the main problem in the machine shop as 'increasing throughput, by capturing the idle time when the machine was not running', citing the process industries as the model of industries which had reduced this to a minimum. At present out of the 16 available hours from two 8 hour shifts only about 12 would actually be spent cutting metal. In 1988 the company introduced a Yamazaki Slant Turn 30 CNC with the stated objective of reducing the costs of its 'turned' components and improving quality. The results of the first 12 months of production have shown that these objectives have been achieved with reduction in component cycle times of between 20-40% and quality improvements have resulted in fitting time being reduced by 5-10%.

To improve its throughput the company is now considering the purchase of an advanced CNC machining centre costing £600,000 which would have the facility to operate on a three shift basis with the third being (nearly) unmanned. The machine will have an enhanced tool storage capability, multiple part loading and diagnostic system to monitor the wear on the tools. The Machining centre is expected to triple the rate of component output through its greatly reduced cycle time and is perceived as a 'technological leap' for the company and also provide the necessary experience for the introduction of other advanced automation technologies. Appendices 5.1-5.8 discuss the financial and technical aspects of the justification of the machining centre.

In terms of the financial justification procedures themselves, these were described by the managing director as 'fairly informal'. The group as a whole requires machine investments to achieve a payback within three years, but is flexible on this if a good enough case can be made. The financial director does construct a basic cash flow projection of a particular investment, but DCF is not used due to a 'lack of reliable data' upon which to base such projections. The benefits of the investments so far, are perceived as having been 'so obvious' that there was considered to be no real need for an in-depth quantification. The company does not have a specific required rate of return on capital invested. The managing director summed up the overall policy as 'investments are not just financial, they are strategic, without CNC we just could not compete'. Given that the company was still relatively new, it was not considered worthwhile to attempt any systematic post-audits on the machines bought so far.

In terms of the wider effects the introduction of CNC technology is likely to have on the firm in the future, the financial director identified the way the company calculates its overhead recovery as 'needing to change'. At present, like the majority of engineering firms, the company calculates its overhead recovery based on the number of direct labour hours booked, against the jobs in the factory. There are three main categories of labour and each carries a set burden rate to cover the costs of factory overheads. At the end of each month the number of hours booked is added up and compared to the actual costs in the operating budget, to indicate whether the company has over or under absorbed its costs. As several authors have pointed out in discussing the economics of AMT, (Hunter 1985, Kaplan 1984, Johnson & Kaplan, 1987) such labour based absorption systems are acceptable when the main cost of production is labour but in a more capital intensive environment, as is the case with AMT, the results they produce can be misleading, since the operators will need to individually carry proportionately higher burden rates since there are fewer of them. The situation could arise (and has) when a company may turn down what would be profitable work, but which as a result of it's costing system, appears to be unprofitable. Several authors have suggested that companies investing in AMT need to redesign their costing systems based on the number of machine hours utilised.

In envisaging that the company would eventually need to change its absorption system to one based on machine hours, the author was able to collaborate with the company to design a basic system using spreadsheets to demonstrate the effect of the planned new CNC machining centre.

5.3 Structure of VHME Absorption Model

The Objectives of the VHME pilot spreadsheet model were as follows:

- To assess the value of using a model based approach to quantify the effect of technical change upon the financial performance of the "total business".

- To assist the company in preparing for its eventual objective of having an all-CNC machine shop by setting up a prototype absorption costing system based on machine hours, rather than the conventional one used at present based on direct labour hours.

- To use the models to assist with the justification procedure for an advanced machining centre under consideration, by providing a greater understanding of the costs involved and the effects of alternative courses of action.

- To model the effects of introducing two further CNC machines to replace existing conventional machines.

The initial development of the models began with the author and financial director drawing up a basic outline of how the absorption model based on machine hours, would operate in this company using the flow diagram modelling techniques described in chapter 4. From an initial specification the author was able to develop a prototype spreadsheet model. Further discussions and feedback over several months, resulted in a series of subsequent modifications and refinements until the model structure as shown in figure 5.3 was eventually set up. From the objectives it can be seen that a key consideration in designing the model was that, as well as being used for the research purposes of the author, it is also intended to install the spreadsheet software developed on a microcomputer in the firm for its use by the financial director and his staff. To a large extent therefore, the design of the model was determined by the practical requirements of the company.

In setting up the model it was decided to project the time horizon over one year only and use as a base the production schedule on that of the firm's financial year from 1st February 1989 to 31st January 1990. The decision to model over one year instead of several was due to the fact that possible acquisitions of more complementary businesses and ongoing rapid pace of change taking place in the company, meant that it would be difficult to model anything beyond a year with a high degree of reliability.

The structure of the model as shown in figure 5.3 consists of three linked spreadsheets. The numbered boxes within the spreadsheets each represent a display screen in the model. The data input displays are highlighted in italics and the arrows show the links and direction of flow of information within the model. The function of the first spreadsheet is to calculate the number of machining hours required on each of the ten main machine tools in the factory over the year to realise the production schedule. The second spreadsheet takes these hours and calculates the associated absorption charge and determines whether a machine is over or under loaded. The third spreadsheet contains the information required to calculate the other company overheads and brings all the inputs together in the operating budget summary. Looking in more detail at the operation of the model and the assumptions made as shown in model 5.1 in appendix 5.9.

Spreadsheet 1

Sheet 1: Production Schedule (rows 1 to 41) - In terms of output, the company aims to manufacture around 60 presses per year, although the number made is not a good indicator of productivity since the size of presses can vary considerably. Based on manufacturing leadtimes the company product range can be divided into four main groupings of three, four and five months for presses and eight months for roll forming and tooling equipment. The company is presently seeking to standardise its product range in order to achieve a greater number of common components between presses which has useful cost benefit implications.

These leadtimes represent average leadtimes which are adjusted to balance the machine capacity available and the outstanding customer orders. The company usually has an ongoing programme of building a number of small standard presses which have not yet been ordered by any particular customer, but for which the company knows there is always a demand. The benefit of this arrangement is that it ensures that the machines are kept at a high utilisation rate when there are no definite outstanding customer orders to run on a machine. In terms of the pattern of customer orders, these tend to be spread fairly evenly throughout the year.

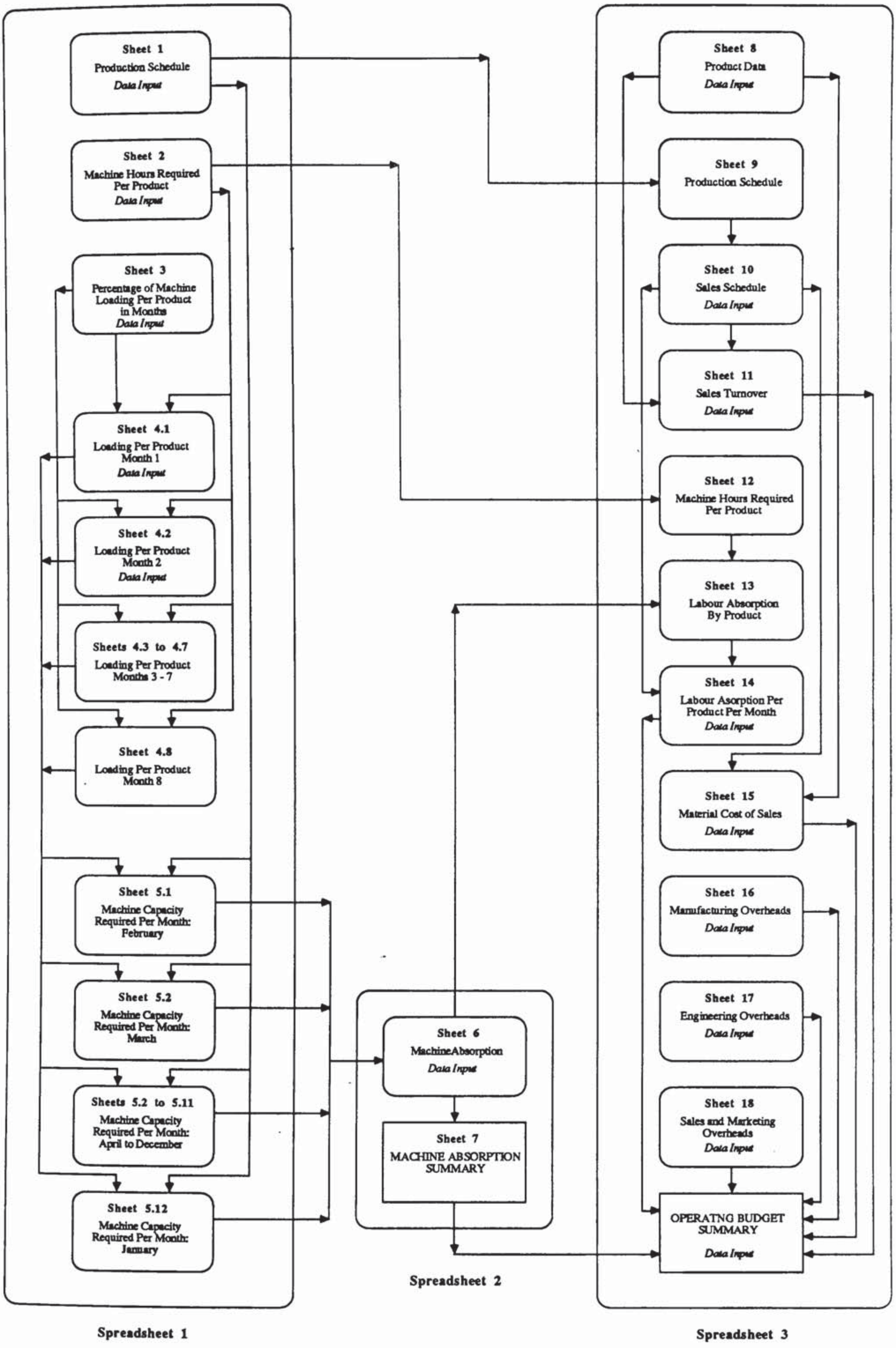

Figure 5.3 Structure of VHME Absorption Model
(Arrows show direction of information flow)

Sheet 2: Machine Hours Required Per Product (rows 42 to 83) - This screen requires the user to input the number of machining hours required on each of the ten main machine tools to manufacture each of presses and roll forming equipment in the company product range. It is here that a key assumption in the model has to be made, since due to the limitations of computer memory size and the logic available in a spreadsheet, the model is not able take production routings into account to show the sequence in which operations would be performed. In real life the production manager would be able to use alternative production routings to overcome production overloads. While this may appear as a serious limitation in the model, it needs to be remembered that the objective of the model is to provide an aggregated "picture" of the firm. Any modeller has to judge the level of detail required. If the model is too large it risks being unwieldy and difficult to use and may lose sight of what the objective of the model is; too simple and the results obtained may not be meaningful. The aim is to produce a simple enough model that can can be readily understood, but which has the right level of complexity to embody the nature of the subject under consideration. If the user wished to take detailed routings into account, then a spreadsheet would not have been selected in the first place and a high level computer language or database would need to be used. However, for the purpose of what the author is seeking to show, it is believed that a spreadsheet is appropriate and that by "fine tuning" the machine loading hours, results can be obtained that are representative of the performance of the business.

The machines selected for inclusion in the model were made on the basis that it is on these that capacity constraints in production occur and which therefore will affect manufacturing leadtimes. A number of other older machines are used in the factory as well but capacity on those is not critical and are therefore not included in the model. In addition to machining hours, a considerable number of hours are required in mechanical and electrical fitting work which is treated in the model on the same basis as a machine, since the hours available are limited.

Sheet 3: Percentage of Machine Loading Per Product in Months (rows 84 to 130) - This spreadsheet takes the total number of machine hours needed from sheet 2 and requires the user to input how the machining hours are divided as a percentage over the manufacturing lead time. For example, presses with three month leadtimes (rows 89 to 97) on average have about 20% of the machining performed in the month following the initial production order, 60% in the second month and 20% in the final month. For all the products it is assumed that all the mechanical and electrical fitting work is performed in the final two months of the manufacturing leadtime. When entering data there is a logic insert in column C to ensure that the percentage spread of loading always adds up to 100%, since if a mistake is made "Error" appears next to the product in question instead of the normal "OK" displayed.

Sheets 4.1 to 4.8: Loading Per Product (rows 131 to 459) - Spreadsheets 4.1 to 4.8 take the number of hours required from sheet 2 and the percentage of machining performed in each month from sheet 3 to show the loading of machine hours over the manufacturing lead time. For example, the GI30 press requires a total of 40 hours machining on the Cincinnati T30 machine as shown in sheet 2. Sheet 3 shows that the machining is spread over its three month lead time as 20% in the first month, 60% in month two and the remaining 20% in month three. Sheet 4.1 sums the value of the 20% of 40 hours (ie. 8 hours) in the first month, sheet 4.2 sums the value of the second month, 60% of 40 hours (ie 24 hours) and sheet 4.3 sums the third month, 20% of 40 hours (ie. 8 hours). Since the longest manufacturing leadtime is that of rollforming and tooling at eight months, successive sheets run to 4.8. In sheets 4.1 and 4.2 the facility is also available to enter values for opening stock from the previous years operation before the model. In setting up the model, it is necessary to take into account that the company will have items such as stock and sales which refer to events outside of the time horizon under consideration and which need to be allowed for in the model.

Sheets 5.1 to 5.12: Machine Capacity Required Per Month (rows 460 to 942) - These sheets combine the machining hours loading profile calculated in sheets 4.1 to 4.8 with the production schedule of sheet 1 to calculate the actual number of machining hours required for each product on the ten key machines per month. This is the most complex part of the model in terms of logic since the spreadsheet has to be able to accept the overlaps of manufacturing leadtimes from products ordered in different months.

Spreadsheet 2

Sheets 6: Machine Absorption (rows 1 to 155) - This sheet requires the user to enter for each machine and each month: the hourly charge rate, the hours available per month and the efficiency of the machine. The efficiency is given as the percentage of the total hours available on a particular machine at which it is actually involved in productive work. The non-productive hours are taken up by such tasks as setting and maintenance etc. It would be expected that a more modern CNC machine would have a higher efficiency rating than older machines which the model is thus able to allow for. Using the efficiency rate and the hours available the effective number of machining hours is shown. The charge (or burden rate) represents the proportion of the factory overhead costs which have to be covered by the use of that machine for an hour and this is based upon the experience of the production manager. Using the hours required per machine per month from sheets 5.1 to 5.12 multiplied by the associated charge rate, the machine absorption values per month can then be calculated. For example, in February (column D) in sheet 6 the Union 130 machine has 360 total hours available (row 5), and a 85% efficiency rating (row 7) thus giving an effective availability of 306 hours (row 8). The machining total of 297.5 hours required on the Union 130 machine calculated in spreadsheet one (column C, row 500) is copied across to row 8, (rounded to the nearest full hour) and is multiplied by the hourly charge rate of £35 (row 4) to give the total absorption charge of £10,411 (row 9).

By varying the number of hours available, the user is able to test for example, the effect of a two shift working pattern compared with a three shift one and the effect upon the overhead recovery through varying the charge rates. The more modern CNC machine generally have a higher charge rate than an older manual machine. Assuming that the hours required is less than the hours available, sheet 6 has a logic insert which indicates "OK" (row 10). If the hours required is greater than those available, an "Overload" is displayed instead together with its value as a percentage in row 11. If the overload is less than a user specified value (typically 15%) in row 12, then in the view of the production manager, he can cope with that level of overload within the factory through overtime working and routing through other machines. In the model if the total overload is less than 15% the excess overload hours are carried forward to the next month, as shown in row 14.

If the absorption is greater than the value in row 12 then the production manager is able to subcontract work out of the factory to other firms, usually local small ones who typically have low overheads and are able to offer very competitive rates. In the model subcontracting is treated as another absorption centre and charged at an appropriate rate. Capacity is not a problem since more firms can be subcontracted and so capacity in the model is given the notional value of 2000 hours per month at 100% efficiency. The number of hours subcontracted to outside firms is shown in row 13.

If on the other hand the company finds that its machines are underutilised, the production manger has the option to subcontract out their own machine hours by bringing in work from outside customers. Since several of the types of machines used by the company are in considerable demand this can be highly profitable. In the model if the underutilisation is above an input value on a particular machine (usually 15%) specified in row 15, then the model logic enables the spare hours available to be subcontracted to outside customers as shown in row 16. The materials cost of the subcontracted hours is assumed to be equal to the charge rate in row 4, and to allow for a profit, this is specified as a percentage (typically 20%) in row 17. The subcontract gross profit is shown in row 18 and the material cost in row 19.

Sheet 7: Machine Absorption Summary (rows 211 to 247) - This provides a summary of the machine absorption values calculated in sheet 6. The sheet also shows the value of the machine hours sold to outside firms.

Spreadsheet 3

Sheet 8: Product Data (rows 121 to 158) - The sales price per for each press is specified by the user. The value of the material in each press can either be specified by the user, or in the case of the models used in this chapter, given as a percentage of the selling price.

Sheet 9: Production Schedule (rows 159 to 198) - This is the production schedule copied across automatically from sheet 1 in spreadsheet one.

Sheet 10: Sales Schedule (rows 199 to 239) - Because it takes several months to build a press, there can be a considerable delay between a customer placing an order and the company dispatching the finished press and receiving payment. Usually a customer will be expected to make an initial down payment upon order, with a further payment upon despatch and a final payment after commissioning trials. The exact details are often tailored to meet the requirement of each customer and their credit risk rating if it is an export order. Clearly, it would be difficult to build into a spreadsheet model, the total complexity of the sales arrangements and so a simple logic rule was adopted to allow for the time lag - a production order will be sold and payment received in the month following its manufacturing leadtime. For example a GI 30 press ordered in February has a three month leadtime and so the sales schedule will show it as being sold in May. Although this is a considerable simplification, the net effect over a year should, from the financial director's experience, balance itself out.

Sheet 11: Sales Turnover (rows 240 to 307) - This links the sales schedule in sheet 10 with the selling of each press given in the product data of sheet 8 to give the sales turnover value. The sheet also requires the user to input the outstanding sales from the previous year to be entered as opening stock.

Sheet 12: Machine Hours Required Per Product (rows 308 to 350) - This is copied across from sheet 2 on spreadsheet one. The reader should note that because of the large size of the model, the first spreadsheet from where the values are read from has to be closed down in order to provide enough memory space for the third spreadsheet to be printed out. This has the effect of breaking all the dependent links between spreadsheets and so in the thesis printout of sheet 9 all links will display "REF!". However, because all calculations involving links have already been performed before the first spreadsheet is closed down and the calculation facility is manually switched off, this means means that all interdependent values displayed within spreadsheet three are unaffected.

Sheet 13: Labour Absorption By Product (Labour Cost of Sales) (rows 351 to 394) - The machine hours required given in sheet 12 is multiplied by the charge rate per machine copied across from sheet 6 in spreadsheet two (shown in row 357 on sheet 13) to give the labour absorption for each product. For example, the labour absorption for the GI30 press on the Union 130 machine is the charge rate shown in row 357, column C) multiplied by the machine hours required from row 315, column C in sheet 12. The total labour absorption is summed in column Q of sheet 13.

Sheet 14: Labour Absorption Per Product Per Month (rows 395 to 466) - This takes the total hours in calculated in column Q of sheet 13 and multiplies them with the sales schedule in sheet 10 to give the labour absorption charges associated with each product over the twelve months of the model. For example, the value of labour absorption of £13,354 shown for a GI30 press in June of sheet 14 (row 398, column G), is obtained by the multiplication of the sale of the single unit of GI30 press in sheet 10 in June (row 203, column G) by the value of labour absorption associated with this type of press, obtained from row 359, column Q of sheet 13. The sheet also requires the user to input the outstanding labour absorption cost per product of the opening stock carried forward from the previous year. For example, the opening labour absorption cost of the GP55 press (row 409, column D) is £11,559 which refers to a press in the previous year's production schedule in December 1988.

Sheet 15: Material Cost of Sales (rows 467 to 538) - The material cost per press obtained from sheet 8 is multiplied by the sales schedule of sheet 10 to give the material cost of sales. For example, the material cost of £9,900 for the GI30 press in June (row 470, column G) is obtained from the multiplication of material cost of a GI30 press obtained from sheet 8 (row 126, column F) with the single unit of GI30 press in the June sales schedule of sheet 10 (row 203, column G). As with sheet 14, the user has again to input the outstanding material cost of the opening stock carried forward from the previous year.

Sheet 16: Manufacturing Overheads (rows 539 to 576) - This requires the user to input the administrative and service overhead costs of the business. The cost categories used within this sheet can be changed if required by the user.

Sheet 17: Engineering Overheads (rows 577 to 599) - This requires the the user to input the costs of the design office which includes such items as CAD/CAM maintenance and the depreciation of the equipment used in the department.

Sheet 18: Sales and Marketing Overheads (rows 600 to 624) - This requires the user to list all the costs relating to sales and marketing including advertising, promotion and travelling expenses.

Operating Budget Summary (rows 1 to 120) - This sheet brings together the values calculated in the rest of the model to show their effect upon the operating budget. The sheet has two parts, a summary of the operating budget which just shows the essential details (rows 1 to 25) and below that, a more detailed breakdown of the operating budget. The values in the sales budget (rows 27 to 41) for presses, CM presses, press brakes and roll forming are copied from the sheet 11 - Sales Turnover (rows 304 to 307). The value for subcontract hours sold to outside customers (row 33) is copied across from spreadsheet two, row 238. In the direct labour category of the operating budget (rows 44 to 58), the values for presses, CM presses, press brakes and roll forming is copied across from sheet 14, Labour absorption per product per month (rows 461 to 464). In the materials cost category (rows 61 to 74), the values for presses, CM presses, press brakes and roll forming are copied across from sheet 13, Material Cost of Sales, (rows 533 to 536). The value for the cost of sub-contract materials (row 66) is copied across from spreadsheet two (row 239). Several items such as scrap, warranty and the value of sub-contract work performed for other companies are input into the operating summary sheet and can therefore be varied.

The value for manufacturing absorption is shown in the operating budget in row 95 and is copied across from spreadsheet two (sheet 7, row 231). The totals of the manufacturing, engineering and sales and marketing overheads (sheets 16 to 18) are linked to the operating budget in rows 85, 99 and 108 respectively.

5.4 Company Model Experiments

The objective of the experiments performed with the model was to analyse the effects upon the manufacturing absorption recovery and the operating budget as the company adopts more CNC machines in three successive stages, as an example of how the models are intended to be used as a "total model" of the company when implemented. The stages are as follows:

Base Model 1.0 - This is the current situation in the company, with 10 main production machines of which only three are CNC, namely the Cincinnati T30, Mazak Slant turn and Mazak QT15.

Model 2.0 - This shows the effect of acquiring the CNC Travelling Column machining centre discussed in the text to replace the existing conventional Union 130 and Union 125 Boring machines.

Model 3.0 - This stage of automation involves replacing two manual machines with one CNC machine.

Model 4.0 - This stage involves replacing a manual machine and a CNC machine with a more modern CNC vertical machining centre.

As the company introduces more CNC technology, the following effects were expected to be shown in the models:

- New CNC machines would be able to replace more than one existing manual machine

- The overload situation on key machines would be reduced

- More spare machining hours would become available for profitable subcontract work

- The company's scrap and warranty charges would decrease due to the precision and high quality parts produced by CNC machines

- The company intend to move towards a three shift operational system on the CNC machines in order to increase the machining hours available.

Model 5.1 - The initial starting model as shown in model 1.0 is based on the company's operating budget and production schedule from the beginning of February 1989 to the end of January 1990. From model 1.0 it can be seen that the net sales can vary considerably from month to month. In the type of heavy engineering operations in which the firm is involved this is typical since, for example, the selling price of a large press can be in excess of £150,000 and for roll forming equipment over £1M in value. This means that a few large orders can distort the sales turnover considerably over a short period. Since the presses are manufactured over a lead time of several months, the manufacturing costs are generally more evenly spread and not subject to such large distortions as the sales. The result of this is that the firm can often find itself moving from a loss making to a profitable position very quickly as a result of receiving payment for a few large orders. This pattern can clearly can place considerable strain upon the company's cash flow at certain points over a year. Building the logic to model the cashflow was considered at an early stage in the design of the models, but in view of the considerable number of changes taking place in the company, and the large number of variables already included, it was decided that this would over complicate matters and that this could be built into the model when it is later implemented in the company.

Sheet 1 of Model 5.1 (rows 1 to 41) shows the production schedule over twelve months based on the previous year's orders. This was adjusted slightly to make the schedule used in the models more representative of what the Financial Director considered was the pattern of production the company is seeking to move towards. Most of the production orders tend to be spread fairly evenly throughout the years and the majority of orders received tend to be for the smaller presses requiring 3 and 4 month manufacturing leadtimes. The company would expect on average to pick up no more than one or two orders for such large items as roll forming equipment. Sheet 6 shows the current absorption and machine loading situation. This indicates that the productive capacity available in the factory is currently insufficient to cope with the machining load required and necessitates subcontracting work to outside suppliers. In particular, the Union 125, Binns & Berry, Poreba and Mazak Slant turn machines are all shown by the model to have average overloads in excess of 50%. In practice, this situation is not quite as bad since the production manager is able to reroute production on different machines to some extent. (The logic to represent this would would be too complicated to build into a spreadsheet model and insufficient memory is available on the computer). However, in order to validate the model the production manager was asked to compare the "picture" of overload to that occurring in the factory. In general, he thought that the "fit" between the model and the real life situation was quite good, the most overloaded machines were correctly identified and degree of overload was within the levels he would expect. At present the firm does subcontract out a large number of its overload hours, and the service and electrical fitting personnel also work a considerable number of overtime hours. He was unable to provide exact figures for comparison since the production department does not record information in terms of the percentage overload. The operating budget shows that the model predicts that the company will "over recover" its costs by around 12% based on a machine based absorption system (rows 93 and 95). On average the FD aims to recover around £150K per month in terms of absorption and so an average value of £152K per month as shown by the model was acceptable. In terms of subcontracting out machine hours on underutilised machines, since the factory is presently heavily overloaded, nearly all the capacity is already taken up and the model reflects this predicting a year end total of just over £100K. A full printout of model 5.1 is shown in appendix 5.9 and the financial results summarised in table 5.1.

Model 5.2 - In this model the Union 130 and Union 125 Boring Machines in model 5.1 are replaced by the travelling column CNC machining centre. Sheet 2, column D shows the estimated CNC machining hours based on an analysis performed by the production manager. The productivity benefits can be clearly seen in comparing for example, the hours required to produce the K360 press (sheet 2, row 72). At present

Table 5.1 - Summary of VHME Absorption Modelling Results

Model	Cell Reference	Model 5.1	Model 5.2	Model 5.2.1	Model 5.2.2	Model 5.2.3	Model 5.2.4	Model 5.3	Model 5.4
Description	All values come from column O in sheet 6	Base Model with Union 130 and Union 125 Boring Machines	Union 130 and Union 125 machines replaced with New CNC mach/centre	As 2.1 but, includes 10% Reduction in Scrap & warrantly Costs due to new CNC	As 2.1 but, the hours available on the B&B, Poreba and Hydrotel M/cs from 190 to 360	As 2.2, but hrs avail on the M/Centre, T30, Poreba, Mazak ST & Mazak QT, 360 to 420	As 2.3 but, 1 extra unit of GI30, GP40, AH80, AH120, Press Brakes 50 &110 made	As 2.1 but, WB M/c Replaced by WB CNC and B&B M/c Deleted	As 3.0 but, New Vertical Maching Centre Replaces Mazak QT & Pobreba
Net Sales	Row 41	10,063,655	10,213,509	10,213,509	10,253,552	10,341,085	10,456,048	10,343,548	10,289,775
% Change from Base			1.5%	0.0%	0.4%	0.9%	1.1%	-1.1%	2.2%
Subcontract Sales	Row 33	108,557	258,411	258,411	298,454	385,987	372,950	388,450	334,677
% Change from Base			138.0%	138.0%	174.9%	255.6%	243.6%	257.8%	208.3%
Subcontract Profit	Row 33 minus Row 66	18,093	43,069	43,069	49,742	64,331	62,158	64,742	55,779
% Change from Base			138.0%	138.0%	174.9%	255.6%	243.5%	257.8%	208.3%
Direct Labour Costs	Row 58	2,375,453	2,282,038	2,276,738	2,276,738	2,276,738	2,330,421	2,280,861	2,324,801
% Change from Base			-3.9%	-4.2%	-4.2%	-4.2%	-1.9%	-4.0%	-2.1%
Material Costs	Row 74	6,204,158	6,329,037	6,323,537	6,356,906	6,429,850	6,489,386	6,431,902	6,387,091
% Change from Base			2.0%	1.9%	2.5%	3.6%	4.6%	3.7%	2.9%
Cost of Sales	Row 76	8,579,611	8,611,075	8,600,275	8,633,644	8,706,588	8,819,807	8,712,763	8,711,892
% Change from Base			0.4%	0.2%	0.6%	1.5%	2.8%	1.6%	1.5%
Gross Profit	Row 78	1,484,044	1,602,435	1,613,235	1,619,908	1,634,497	1,636,241	1,630,785	1,577,882
% Change from Base			8.0%	8.7%	9.2%	10.1%	10.3%	9.9%	6.3%
Manufacturing Costs	Row 93	1,632,964	1,632,964	1,632,964	1,632,964	1,632,964	1,632,964	1,632,964	1,632,964
Absorption	Row 95	1,830,549	1,771,651	1,771,651	1,772,128	1,827,131	1,875,216	1,784,417	1,882,399
% Over/(Under) Absorption		12.1%	8.5%	8.5%	8.5%	11.9%	14.8%	9.3%	15.3%
% Change Absorp/Base			-3.2%	-3.2%	-3.2%	-0.2%	2.4%	-2.5%	2.8%
Net Profit Before Tax	Row 119	542,658	584,151	594,951	602,101	671,693	721,522	595,267	610,346
% Change from Base			7.6%	9.6%	11.0%	23.8%	33.0%	9.7%	12.5%

as shown in model 5.1 (sheet 2, columns D and E, row 72) this requires 170 and 98 hours on the Union 130 and 125 machines respectively. The new CNC machining centre will combine the operations and require only 75 hours, approximately a 3.4 to 1 improvement. Similar improvements in machining hours are given for the other presses in the product range. There is also the benefit of the press not having to be transported from machine to machine with a corresponding reduced set up time. Since the machine will replace two others it will therefore have to bear a higher proportion of the overhead costs of the factory and so the charge rate for the machine has been increased from £35 per hour on the Borers to £70 per hour (sheet 6, row 4).

The effect of the new machining centre on the company compared to model 5.1 is a reduction in the absorption compared to model 5.1 at a charge rate of £70, although the company is still over absorbing its costs by just over 8.5%. In terms of subcontract hours sales (sheet 6, row 13), the new machine provides considerable benefits by taking over the load of the two borers. Part of the plan in introducing the machining centre is to retain the Union 130 machine and use it only for outside subcontract work and as a backup machine in the event of breakdown of the CNC. The management is well aware of their increasingly vulnerability to production disruption in the event of a breakdown as they concentrate their production capability in fewer, more advanced machines. Where possible, taking into account the cost and space implications on the shop floor, the production manager intends to retain some backup capability. In Model 5.2, sheet 6 the Union 130 is shown in the space occupied in the model by the Union 125 machine (rows 21 to 36) and its hours available (row 24) are defaulted to subcontract work (sheet 6, row 33). The result of the increased subcontract capability is to increase the subcontract hours sales from £108K in model 5.1 to £258K in model 5.2 (sheet 7, row 238). The effect upon the net profit (before tax) of these changes, is to increase the company's profit by £42K which represents a 7.6% increase (operating budget, row 119). An insight gained from this model is that the machining centre may not be available for as many subcontract hours as were forecast for the initial financial justification by the company as shown in appendix 5.1. Appendix 5.10 shows a full printout of model 5.2.

Model 5.2.1 - This is the same as model 5.2 except that it includes a 10% reduction in scrap and warranty costs as shown in the direct labour (appendix 5.11, operating budget, rows 54 & 55) and material cost of sales (operating budget, rows 70 & 71). This was felt to be representative of the order in reduction in costs that would be expected due to the improved quality and consistancy of the CNC machining centre. This increases the net profit (operating budget, row 119) by just over £10K compared with model 5.2.

Model 5.2.2 - This model is as 5.2.1 except that it takes into account the plan by the production manager to work a double shift pattern on manual machines, namely the Binns & Berry, Poreba and Hydrotel which have a large overload currently subcontracted to outside firms. The effect in terms of hours is to increase them from an average of 190 to 360 hours per month (appendix 5.12, sheet 6, rows 73, 90 & 141). However, the benefits of this are not realised to any great extent in the absorption since the company treats subcontracted hours as if they were a machine in its own factory, thereby assisting its own overhead recovery. While work put outside the factory would be expected to incur a penalty in terms of cost, the problem is further complicated by the fact that since the overload work put outside is usually for simple parts, (the production manager retains the complex parts for his own CNC machines), the situation often arises where a small local firm can actually make parts for less than it costs VHME to manufacture, since they usually have relatively small overheads. In the model the production manager gave an average charge rate of £18 hour per hour for subcontract work based on current machining rates.

Model 5.2.3 - This model is as 5.2.2, except that the on the Machining centre, the Cincinnati T30, Poreba, Mazak Slant Turn and Mazak Quick Turn machines, the double shift pattern being worked giving 360 hours, is modified to include an extra half shift, thereby increasing the hours available to 420 (appendix 5.13, sheet 6, rows 39, 90, 107 & 124). The effect of this is to again reduce the overload in the factory and to increase the hours available for subcontract work. In terms of absorption this shows a considerable improvement in the operating budget increasing the absorption by £55K and increasing the net profit before tax compared to model 5.2.2 by £69K.

Model 5.2.4 - As Model 5.2.3, except that six more presses are added to the production schedule to increase the work load. This has the effect of increasing the absorption recovery by £48K and increasing the net profit by £50K as shown in appendix 5.14, sheet 6. The subcontract sales are reduced by £13K since machine capacity is now taken up in the manufacturing of their own products.

In discussing with the production manager the problems of the company with its current machines and the "ideal" productive facilities he wished to implement, the next two automation stages are as follows:

Model 5.3. - This model is as 5.2, except that the Webster Bennett manual machine is replaced by a CNC version. Assuming a 3 to 1 improvement factor, the existing hours were divided by 3 for the new CNC. In addition, the Binns & Berry machine is removed and its hours divided by three and apportioned 90% to the Webster Bennett CNC and 10% to the Poreba. It would also be expected that this would have a beneficial effect on more reduction in scrap and warranty costs, although these have not been shown in this model.

Model 5.4 - This model is as 5.3 and shows the effect of introducing a vertical CNC machining centre to replace the Mazak Quick Turn machine. To model this the Mazak QT was deleted from the model and replaced with the new CNC machine. The Poreba was also deleted and it full load transferred to the new CNC machine. The existing Mazak QT load was transferred 10% to the the new CNC and 90% to the Mazak ST. The hours on the Mazak ST were then reduced by 30% and transferred to the new CNC to represent the method of machine loading the production manager would carry out. This model is projecting some 3/4 years into the future since the technical problems of vertical CNC machines have still not been adequately overcome to the production managers satisfaction.

5.5 Summary

In discussing the models it needs to be noted that they are not intended to predict the *exact* values if the company were to follow the options outlined, since with any model a large number of assumptions and generalisations have to be made. Their value lies in showing what could be expected to happen within reasonable limits and comparing the results with the experience and judgement of the managers within the business, to highlight their agreements and differences with the results shown and to gain an insight provided by the modelling procedure which would not otherwise be revealed. In this firm, one of the main insights gained from the modelling process was that it made the management question their existing procedures and think through the conceptual problems of adopting a machine based absorption system, as opposed to their existing labour based one. Although the literature on advanced manufacturing technology readily identifies the problems of conventional costing systems and suggests possible solutions, it is only when one actually tries to develop such a system oneself, that it is possible to appreciate that it is not as conceptually easy to realise in practice as it may appear in the literature.

The financial director kindly provided a review of the models developed and how they will be used in the company to assist in the evaluation of new CNC machines, writing as follows:

> 'The present financial models used by VHME are relatively simplistic spreadsheets using Lotus 1-2-3. They do not allows such a complicated model to be formulated and therefore at present I use several spreadsheets with manual data transfers between each. Your model overcomes this by incorporating all of the variables in sub-spreadsheets within one main spreadsheet. This saves a significant amount of time especially when a model is being used under varying assumptions.

The second main feature of the model as I see it, stems from the inclusion of both capacity planning and absorption together. Our present package does not use capacity planning in any scientific way, however, we do forward plan our manufacturing hours against our production schedule. Sheet 6 "Machine Absorption" details our major machine cost centres and summarises the forward position of each by month. The basic model shows the available or overload position by machine based on the sales/production schedule applied within our capacity constraints very clearly and assumes a carry forward of any shortfall in current manufacturing hours. Whilst this occurs in reality, once the overload reaches an unacceptable level, shop floor routings would alleviate this position. Subsequent adaptations to the basic model show a further possibility relating to sub-contract work. With a shortfall in the manufacturing capacity, the alternative to rerouting work around our machines is to sub-contract the work to external machine operators. The model allows for a 15% overload to occur before transferring the excess hours into a sub-contract pool. This assumption takes account of the possibility of both reroutings and and increased overtime to cope with this relatively minor overload.

The interface between absorption and cost of sales is also an important benefit over our existing financial model. Direct labour is charged to products based on a rate for that type of operation, the total of which assumes a full recovery of manufacturing and engineering overheads. In other words, assuming we predict 100,000 hours of work will be available in the year, those hours are multiplied by a rate or a series of rates allocated to a specific manufacturing operation is assumed to fully recover the total costs of its manufacture, but also the secondary charge of recovering the non-direct costs of administration, finance etc. Your model takes the hours required per product allocated to the manufacturing operation which will produce that product, at the rate allocated to each manufacturing operation and charges this cost to direct labour and cost of the sales. Our present model merely predicts a margin per product and allocates the relevant cost of sale between direct materials and direct labour on a relatively ad-hoc basis. This direct labour is not interfaced with our absorption model which merely uses estimated total hours available without allocating these to the forecast production schedule.

The amount of sensitivity analysis which this model allows is one of the major attractions for its use in forward planning. The model can be fed with data from sales, including both quantities and unit prices, absorption ie. burden rates, labour and overhead costs etc. material cost of sales, production lead times and machine hours per product. These variables add up to an extremely powerful financial planning model, which can be expanded over as many time periods as required. This model enables a variety of machine tool investments to be considered, with the potential benefit from purchase being seen on the bottom line of the profit and loss account. Prior to this, capital expenditure has largely been just using a crude payback calculation'.

From the author's point of view, several of the most revealing insights provided by the models arose not from the results they provided, but through the actual task of developing them and the discussions carried out with management to obtain the necessary data inputs. What was often revealed was the different "conceptual models" of the business held by individuals, even those who worked closely with one another on a daily basis. For example, the financial director with whom the author worked most closely, often had to call upon the production manager to supply key pieces of information for the models relating to the hours worked on machines and the different charging rates. When questioned on how he would ideally like to develop the production facilities over the next five years, the production manager was able to provide a concise account of the different machines he wished to purchase and how they would overcome existing shopfloor problems such as capacity overloads and increase the scope for taking in profitable subcontract work. The problem with his ideas as the financial director saw them, was that while the production manager could provide a solid technical argument for new investment, he lacked appreciation of the economic dimension of the such proposals. Likewise the FD not having an extensive engineering background was less aware of the possibilities for technical improvement readily identified by the production manager. While the differences in perspective between the "technical" and "finance" functions within manufacturing have been often commented upon in the literature relating to new technology, the research demonstrated how a task which brings them together such as in this case through a modelling process can act as an effective communication tool.

The main technical problem with the model in its present form is that it requires a considerable amount of memory, which limits its availability to certain potential users. Attempts have been made to minimise the random access memory requirements of the model, and it is expected that when used on a frequent basis in the company, further scope for efficiencies will be identified. The lack of inbuilt routing assumptions is also a limiting factor for the model. However, it is accepted by the company that it is not feasible to incorporate this feature in a spreadsheet, and it has been largely overcome by the inclusion of the sub-contract assumption.

While it cannot be claimed that the model described in this chapter has "solved" the problem, it has served as a useful prototype for the company in thinking about one of the effects of increasing automation, that of the need to reevaluate existing cost systems. The author and the FD are preparing to install the model in the company and several future refinements to the have already been identified as shown in figure 5.4. These include, labour capacity planning, lease parameters for future machine tool additions, machine depreciation data and a cash flow model.

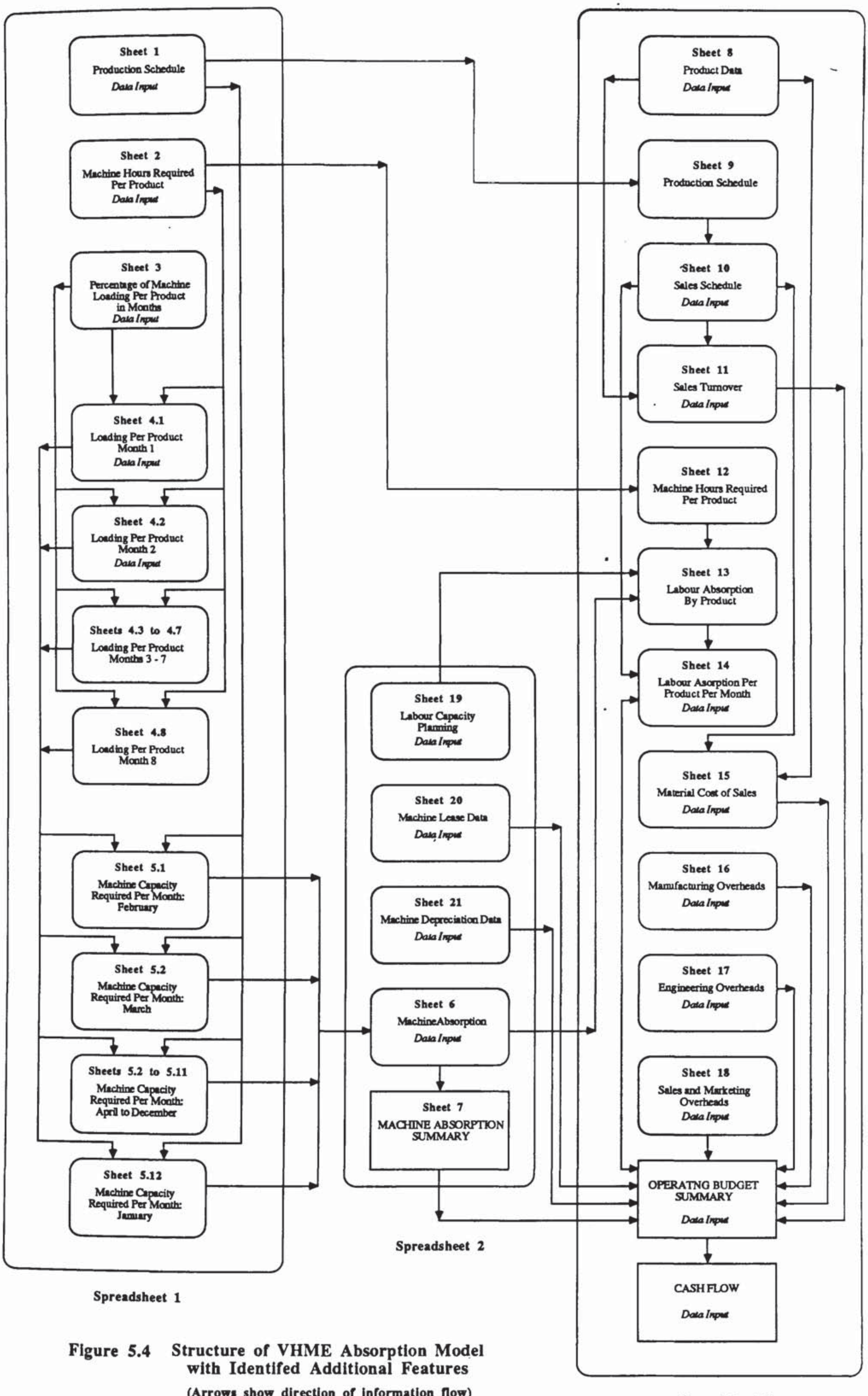

Figure 5.4 Structure of VHME Absorption Model with Identifed Additional Features

(Arrows show direction of information flow)

Chapter Five References

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Chapter Six
Midland Ballscrew Company Limited Case Study

'We're not that bloody clever'.....Technical Director

Preamble

In recent years Flexible Manufacturing Systems (FMS) have become one of the most widely discussed topics in advanced manufacturing technology. This chapter discusses a case study of a medium sized company which conducted a detailed feasibility study of an FMS to manufacture ballscrew shafts. The company had a large share of the UK market, but was facing growing competition from foreign suppliers, especially Japanese. Installing an FMS was seen as a means of significantly reducing costs and retaining its competitiveness. However, the major technological leap that this would have represented for the company with uncertainty about the risks involved, led the management to decide not to pursue the FMS route. Using the feasibility study and company financial data, together with discussion with management, the author has tried to analyse the implications of the FMS had it been introduced.

6.0 Introduction

Ballscrews are efficient converters of rotary-to-linear or linear-to-rotary motion. Their function is similar to that of the acme screw and nut, but with the following advantages:

- High conversion efficiency: Ballscrews permit linear actuation of heavy loads by means of a small power source
- Low starting friction: This is another factor that keeps input power requirements low
- Accurate Positioning: With proper preloading, ballscrews permit accurate positioning of machine components, with little wear and also zero backlash

Although the basic principles involved in ballscrew operation have been understood for some 50 years, the impetus for their large-scale commercial production was a result of the aerospace technology requirements of the Korean war. It order to produce high precision parts for jet aircraft, the US airforce had sponsored research into numerically controlled machine tools at the Massachusetts Institute of Technology, which was to result in several US machine tool manufacturers starting NC production. In order to move the transverse axes of machine tools, the acme screw had previously been used. However, the higher transverse speeds at which NC machines were intended to operate required a more efficient mechanical system, for which the pre-loaded ballscrew is ideal, and so the demand for ballscrews was created. While small ballscrews (under 0.1m) had been used in certain applications on a small scale during the second world war, two main technological problems needed to be overcome for their commercial production for NC use. Firstly, only short-bed thread grinders were then available, which limited the length to which ballscrews could be made. Secondly, the heat treatments available for hardening were limited to either carburising or flame hardening, both of which lacked the precision required in ballscrew manufacture. During the 1950's these problems were overcome through the advent of long-bed thread grinders, making it possible to produce ballscrews of the length required for the NC machine tools of the 1950's, and innovation in induction hardening techniques (Hope, 1961). While the machine tool industry is still the major market for the pre-loaded ballscrew, the potential of their application in a wide range of mechanical devices, most notably in the aerospace and nuclear industries has led to other rapidly growing markets. In many respects ballscrew-manufacture is still a developing technology.

6.1 Business and Product Strategies

The Midlands Ballscrew Company Limited is one of the largest manufacturers of recirculating ballscrews for the machine tool industry and has been involved in their manufacture for nearly 30 years. The company started as part of a British subsidiary of a large US machine tool company producing gear cutting equipment, which identified the growing market for ballscrews in the mid 1960's as a means of developing its sales potential. The ballscrew side of the business experienced steady growth and in 1980 moved into a purpose-built 40,000 sq.ft factory. In 1983 the ballscrew business was the subject of a management buyout. The company has since become the central part of an industrial holding group with interests in two other ballscrew making firms.

The strategy of the company is based on the need to be able to compete with other suppliers of ballscrews, particularly those from Japan, on the basis of cost and quality. Many of its foreign competitors enjoy home-based markets which require high volumes of ballscrews thereby allowing costs to be kept low as a consequence of the economics associated with large scale production. The resulting high investments in automation also lead to consistency of product quality. The Midlands Ballscrew company on the other hand operates in a home market which demands high variety but low volumes, with the result that it is difficult to automate for large production runs. Although employing modern production techniques, the company therefore depends heavily on the skills of its labour force to cope with the demand for variety in its products.

The Ballscrew market can be divided into three basic categories according to size: small (under 0.5 metres), medium (0.5 - 2 metres) and large (over 2 metres). A market survey in 1988 estimated that the type of ballscrews demanded within the UK may be categorised as shown in table 6.1

	Small	Medium	Large	Total
Demand for categories	0-0.5m	0.5-2m	2m+	
1-3 in UK market	40%	50%	10%	100%
Company's production profile	25%	65%	10%	100%
UK main competitor I	10%	85%	5%	100%
UK main competitor II	30%	70%	-	100%
Foreign	20%	70%	10%	100%

Table 6.1 Ballscrew Market Categories (source: company document)

The table shows that 90% of the ballscrews required within the UK are under two metres in length and the remaining 10% two metres or over. This compares the production profile at the company where 90% of output felt within categories 1 and 2. The majority of 0.5 to 2 metre ballscrews are mainly produced for the machine tool industry. This market has seen considerable growth as the use of CNC technology has expanded, since CNC machines use four or five ballscrews per machine. Large ballscrews, typically 4/5 metres in length, but on occasion up to 10m in length have been produced mainly for the nuclear industry, where they are used to control the movement of reactor fuel rods. This market enjoyed considerable growth in the 1970's. The company, in addition to supplying the UK nuclear industry, has contracts with the Swedish and Indian nuclear authorities. However, with growing environmental concerns, especially in Sweden, demand has stagnated in recent years. The market which is currently the largest growth area is that for aerospace applications, where ballscrews are used in the guidance systems of aircraft and missiles to control wing and fin flaps.

While ballscrews of all sizes operate on the same basic principles, the various processes and markets they serve make quite different demands upon the manufacturer. Large ballscrews require long production lead times and the cost of the thread grinders used to produce ballscrews up to five metres in length is very substantial (£500,000 per machine at current prices). Medium sized ballscrews used in machine tools need to be made to very high specifications. This requires considerable specialised heat and chemical treatment, some of which is sub-contracted out of the factory and necessitates the company losing direct control over the manufacturing process. Production leadtimes for ballscrews of this category are of the order of 12 to 16 weeks.

By contrast, aerospace ballscrews are usually very small, often between 0.1 to 0.2 of a metre in length and require a different series of production processes. Aerospace ballscrews are not required to operate to the same precision of movement, but they must meet the very highest standards of reliability, since in several of their applications, if a ballscrew were to fail in operation this could result in the loss of the aircraft. A growing concern for manufacturers in this market is the product liability legislation in the US which passes liability in the event of operational failure of a component from the manufacturer of aircraft, to the supplier of the component. Despite their smaller size the production lead times of aerospace ballscrews tend to be long as a result of lengthy design and development phases. To augment its own range of ballscrews, the company holds the European distribution franchise of a US manufacturer of ballscrews which come in standard lengths. The company is also involved in the repair of ballscrews, both of its own and other makes, and in recent years has become involved in a number of technology transfer agreements, advising firms in India and Eastern Europe on ballscrew manufacturing techniques.

In terms of its customers, the 80:20 rule applies, where the company obtains about 80% of its business from 20% of its customers. One concern expressed by management was their overdependence on a few key customers in the machine tool ballscrew market which takes the majority of its output, although to some extent this is counter-balanced by the fact that its total of 200 customers are spread across a whole range of engineering applications. The pricing of ballscrews varies considerably and depends on the quantity ordered and the complexity of their design. Ballscrew design and development involves significant learning curves and in order to gain a long term contract, the company is sometimes willing to incur short term losses as it progresses along the learning curve.

The high variety/low volume nature of the company's business is reflected in the production technology used by the company, which has a wide variety of machines ranging from 30 year old manual machine tools used for small batch work, adjacent to modern CNC ones. The first CNC machine was successfully introduced in 1979 and the experience gained from its use encouraged the company to introduce further machines and to retrofit CNC controls on a number of its manual lathes, which has proven to be a very cost effective form of automation. The justification of new machines is usually one of necessity, to replace older machines which have become unreliable and cannot manufacture to the tolerances required and also to take advantage of the improved productivity benefits of more modern machines. The selection of new machines is based on the empirical experience of the production and technical managers, who have extensive knowledge of the machine tool industry. Company policy in selecting new machines, tries to favour machine tool manufacturers who are customers for their ballscrews, provided it is economical. Calculations of payback and DCF are carried out to support their judgement in submitting a request for funds.

The organisational structure of the company has the advantage of short lines of communication, since following the management buyout, a whole layer of management was removed. Separating the ballscrew business also provided its management with the autonomy they required to develop the firm more successfully, by concentrating their expertise in this single area. The company employs about 100 personnel with about 75 engaged in direct productive operations, and relations between the workforce and management are generally good. The introduction of new technologies has generally been welcomed by the workforce and seen as a sign that the company intends to ensure its future through investment.

6.2 Change to Manufacturing Strategy

In the early 1980's in order to take advantage of the growing volume business in medium length ballscrews and to compete with Japanese ballscrew suppliers who were beginning to make inroads into the UK market, it was considered by management that the company had to alter its manufacturing strategy. This would involve moving from a strategy dependent upon standalone machine and skilled labour to one which was more capital intensive using machines organised in such a way that they can cope with variety in demand while ensuring consistency of quality. Figure 6.1 shows the author's interpretation of the conceptual model of the existing/optimal business and production pattern held at that time by management.

One way of achieving these objectives was considered to be what is usually referred to as a Flexible Manufacturing System (FMS) and to assess if this was feasible for the company, a study was commissioned from a management consultancy firm to design and cost such a system. It was intended that the system would realise the above strategy of the company by significantly cutting its production costs through reductions in setting and machining costs, work-in-progress and labour requirements. The flexibility of production could be used to meet variable market requirements effectively so as to extend its customer base. The system would produce ballscrews in the medium length category, which formed the majority of the company's production output. In terms of technological innovation, the system would represent a significant leap for the company in progressing from the use of manual and standalone CNC machines to the use of modern machine tools linked in a comprehensive flexible system of manufacture.

The idea for the FMS arose from its entrepreneurial company chairman who was one of the main instigators of the management buyout in 1983 and has acted in a "project champion" role in the company (and in others in whom he has interests) on a number of

Figure 6.1 Conceptual Model of Existing/Optimal Business and Production Pattern of Midland Ballscrew Company at time of FMS study

	EXISTING BUSINESS/ PRODUCTION PATTERN	OPTIMAL BUSINESS/ PRODUCTION PATTERN
Business Objectives	- Maintain Growth and profitability - Still reorganising after management buyout - At present in a low volume/ high variety market and ability to manufacture across complete size range. Much of output is made to individual customer requirements - Need to compete with growing presence of Japanese manufacturers in UK market	- Maintain Growth and profitability - Stable management structure - Move into higher volume/ lower variety market for medium length ballscrews - Increased emphasis upon standardised range of ballscrews - Internationally competitive company - Development of Export market
Sales/ Marketing	- Large number of sales derived from a few key customers - Machine tool market is largest single market - Aerospace market seen as growth area - Large ballscrew market declining	- Company sales spread accross a wider base of customers - Development of new ballscrew applications with export potential
Product Design	- Manual design procedures used with long manufacturing leadtimes	- The introduction of CAD to give reduced manufacturing leadtimes and improved design
Production Technology/ oranisation	- Do not have production facilities for long production runs - Mixture of CNC machines and older manual machines. - First CNC machine introduced successfully in 1979 - Grinding machines which are central to production of ballscrews getting worn and becoming more difficult to keep in tolerance - Manual machines have long setup times - Have retrofitted CNC controls onto existing manual lathes - Ballscrew manufacture still requires a high dependence on operator skill - High inspection costs to ensure quality - One man per machine operation - High Maintenance Costs	- Equipment better able to handle longer production runs - FMS able to cope with variety in demand while ensuring consistency of quality - CNC based technology used throughout - manufacturing processess - Introduction of CNC Grinding technology. - Low rate of scrap & rework - Continuous monitoring of tool wear and breakage, with ability to take corrective action automatically so machine can continue - Automatic in-process guaging - Automatic swarf removal - Reduced skill requirements - Multi-Machine operation by operator - Facility for minimally manned operation - Minimum maintenance on a planned programme
Production Control	- Rudimentary Production Control on manual basis	- Computer Based Production Control System with analysis of previous performance and linked to stock control, production planning and other key variables

occasions. One of the factors that has enabled him to play such a role is that when the company was bought out he decided not to base himself at the company and become involved in the day to day running of the firm. Instead he has confined himself to a "strategic thinking" role, an arrangement which had worked well, since it has enabled a key member of the management to take a longer term perspective, and through contact with the other firms with whom he has interests to keep abreast of technological trends.

The eventual study showed that the project was technically feasible and would cost £1.765 million and take 2 years to develop and build. The direct benefit of the system to the company would be to increase its output of medium length ballscrews by a factor of around three and with reduced direct labour. The production leadtime per ballscrew would be significantly reduced, with a corresponding reduction in the considerable cost of work-in-progress. The indirect benefits to the company and to UK industry in general would be the installation of a high technology computer controlled FMS for ballscrew shafts for which the technology involved would have applications in many sectors of manufacturing other than ballscrews, and at the time would have been at the forefront of technical installations of this kind.

The company also envisaged that there would be a spin-off from the successful development and installation of the system in the application of computer technology and techniques on cylindrical parts in general and the handling of production control systems for small batch, high variety applications. Although, the successful installation of the system would provide considerable long term benefits, the company believed that developing the system would incur a high level of risk. For this reason although the company could raise the funds for such a project if it could be shown to viable, it was unwilling to take such a risk. It therefore sought Government assistance through the DTI for a grant of 50% to cover total project costs which were then available for advanced projects of this kind. This would leave the company to supply £0.88 million from its own resources.

6.3 Proposed Flexible Manufacturing System

The system was composed of six advanced, high technology machine tools with integrated workhandling, tool changing (where appropriate) and computer control facilities, all under the control of a system management computer. It would be capable of dealing at random with varying size batches of different components, with minimum manning, automatic tool monitoring, automatic tool changing and in-process inspection. Scheduling and manufacturing precedence would be determined by the system management computer. In addition to the acquisition of high-technology machines, the success of the system would depend upon technical development in a number of areas, including the extension of the application of computers to machine tools, practical application of modern technology in the areas of workhandling, tool changing and new cutting techniques. The system was designed to machine hardened steel bar to produce ballscrew shafts under minimally manned conditions within the following range:

Ballscrew Length - 0.5 to 2m
Ballscrew Diameter - 25 to 50mm
Ballscrew Pitch - 5 to 20mm
Batch Size - 1+
Material - EN19 hardened to 58 RC

The system would be capable of accepting the above bar from stores and of producing ballscrew shafts complete up to the finish track grinding operations. It was not considered technically feasible to extend the system beyond track grinding, because of the large degree of manual skill involved in setting work steadies and in achieving the final product finishes on CNC thread grinders.

The FMS would therefore consist of the following constituent parts:

(i) 1 CNC cut off-machine with work loader and 1 conveyor

(ii) 1 CNC facing and centering machine with tool attachments; overhead work loader and 1 conveyor

(iii) 2 CNC lathes and associated work loaders; 2 controlled work steadies and gauging with 2 conveyors

(iv) 2 CNC cylindrical grinding machines with associated work loaders; 2 controlled work steadies and gauging; 2 conveyors

(v) Coolant supply, swarf removal system; guards; safety devices; monitors

(vi) Shaft in-process inspection

Figure 6.2 shows an artist's impression of the FMS. The system management computer (SMC) would receive production schedules in advance. The detailed instructions on how to make each ballscrew would be held in the planning data file, together with the requirements on the use of tools and tooling; this information could be amended and/or updated manually as necessary. An operator would confirm batch details on the terminal provided at entry to the FMS. The SMC would communicate with each CNC controller on each machine (thereby designating how each machine tool and its work loader would operate) and would control the swarf removal system. The SMC would initiate all instructions relevant to the change-over from one batch to another, such as the changing of tools and machine adjustments.

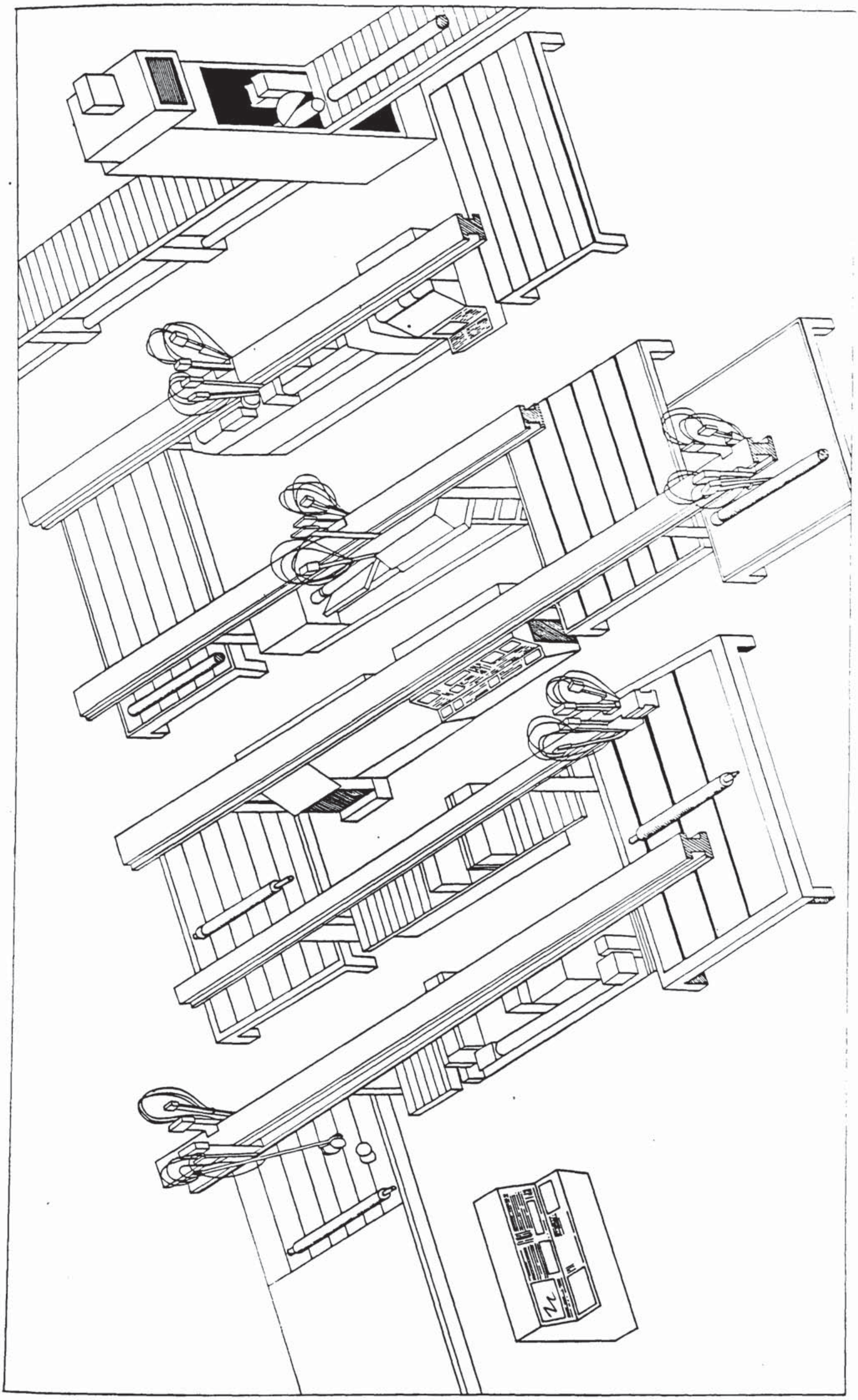

Figure 6.2

An operator would confirm batch details on the terminal provided on final inspection. This terminal would also be used to initiate machine adjustments to prevent the continuation of any ballscrew discrepancies found in final inspection. Ballscrew shafts would be loaded to the cut-off machine which, under CNC, would collect and pass each shaft in turn to the machine where it would be cut-off to size. The shaft would then be placed on the conveyor to the facing and centering machine where it would be faced, centred, and possibly drilled and milled. The shaft would then be placed via the conveyor and the work loader into the lathe where it would have for example, two grooves and one journal end (consisting of perhaps three diameters and one screw) turned. The shaft would then proceed again via a conveyor and work loading arm to the second CNC lathe where the other journal end would be turned and the ball track cut. Each shaft would then be checked (possibly by a gauge transported by the travelling steady) for straightness and for parallelism prior to being taken by conveyor and loader, to the first grinding machine. If it were insufficiently straight, the shaft would be passed out of the FMS by a conveyor for rectification. The shaft, if sufficiently straight, would be ground at one end (possibly consisting of three diameters or so) and along the outside periphery of the ballscrew track. The other end of the shaft would be ground on the final grinding machine and passed to inspection.

Each CNC unit would store a sufficient number of computer programs to maintain production, would control its machine tool, work loading unit, individual coolant supply and swarf removal facilities, and would link directly with the SMC. The SMC would be responsible for controlling conveyors, the coolant system and swarf removal for the total manufacturing system in addition to all aspects of production through the system. The SMC and each CNC unit would interface with monitors and gauges throughout the system, to provide a means of constraint control. The system was expected to sometimes require manual intervention to overcome stoppages of the conveyors, work loaders, cut-off machine or the facing and centring machine. It was considered that the risk of stoppage of the conveyors or loaders would be small and that of the cut-off machine and the facing and centring machine would be less than that of the lathes and grinding machines. Each of the lathes and grinding machines were therefore planned to be capable of carrying out the work of its partner, so that, if one of the machines stopped, the manufacturing system would continue to produce (though at a lower rate than normal). The overhead loading arm to each lathe and grinding machine also included a feature to turn a shaft through 180 degrees to facilitate the carrying out of the work of its partner should the need arise. The FMS was designed to produce about 16 ballscrew shafts per shift.

6.4 Cost of Flexible Manufacturing System

The costs associated with the FMS fell into three main categories:

- Labour Cost
- Capital Cost
- Development Cost

The labour cost was primarily the cost of the company labour involved in the design, development, manufacturing and commissioning of the FMS, whilst the capital cost was the total purchase cost of each machine and the pieces of equipment included in the system. The development cost was associated with the provision of software and the integration of each of the machines and supporting equipment into the total system. Tables 6.2 to 6.4 summarise the costs of these categories.

Item	Cost (£k)
Labour	260
Machines, Toolhandling Units, Toolhandling Units, Conveyors, Stores, Attachments, Installation	660
Computer Hardware for System Management Computer	55
Monitors, Gauging, Final Inspection, Guarding, Cooling supply, Swarf removal	155
Outside assistance and development	635
TOTAL	**1,765**

Table 6.2 Summary of FMS Costs

Year	Cost (£k)
First Year	1,200
Second Year	565
TOTAL	**1,765**

Table 6.3 Distribution of Costs with Time

Item (k)		Company man-years	Capital (k)	Outside Assistance & Development
(1)	CNC Cutting-off machine with work loader	0.5	45	15
(2)	CNC Face & centering machine,	0.5	45	25
	Tooling attachments	0.5	10	15
	Work loading units	0.5	20	10
(3)	2 CNC lathes and associated work loading units	0.5	200	50
	Steadies, gauging, work drive, tailstock location	0.5	10	35
(4)	2 CNC Grinding machines and associated work loading units	0.5	250	100
	Steadies, gauging, work drive tailstock location	0.5	10	25
(5)	System Management computer, VDU, 4 terminals, printer, interfacing units with CNC systems	0.5	55	15
	Executive Software Additional CNC Software	1	-	130
(6)	Work Conveyors	1	70	45
(7)	Coolant supply and Swarf removal	0.5	25	25
	Guarding, safety, environmental		20	15
	Monitoring and diagnostics	0.5	30	25
	Final inspection equipment		80	10
(8)	Installation and Commissioning	1	-	20
(9)	Supplementary Development and supervision	1	-	20
(10)	Supporting Development	-	-	55
TOTAL		**10**	**870**	**635**

On the basis that one company man-year costs 26K:

Labour - £260K
Capital - £870K
Development - £635K

TOTAL - 1765K

Table 6.4 Detailed Breakdown of FMS Costs

6.5 Company Models

The objective of the spreadsheet models used in this chapter is to analyse the viability of the FMS under a series of different economic scenarios. The models are based upon company financial information, the original FMS study, interviews with management and literature on FMS. The models provide the opportunity to compare how the company has since performed with the original FMS plans and to include other factors which the company with the benefit of hindsight, now considers would be relevant to such a project.

The author was particularly interested in modelling the proposed FMS, since at the time it was considered the system would have represented a major technological step for the company and flexible manufacturing was attracting considerable discussion.

Table 6.5 shows how profit and loss account and the balance sheet between 1984 and 1989, with projected figures for 1990. In terms of sales turnover until 1987, (row 8) the company had enjoyed considerable sales growth averaging around 20% per annum, with a gross profit margin of over 50% (row 30) and an operating margin of over 15% (row 73) which is extremely profitable for a manufacturing company. In order to develop a series of financial models of the company it was necessary to break down the profit and loss account into more detail, breaking the sales down into its individual product categories and company production and overhead costs which is shown in Table 6.6 It should be noted that it was not always possible to obtain exact information for this breakdown, but the author, by using the documents available and discussion with company management, has constructed what is agreed by the mangers to be a representative model of the company. Figure 6.3 shows the share of the individual product categories in 1984 when the FMS would have been built. The largest product Category at 55% is for medium length ballscrews which are primarily for the machine tool industry, followed by large ballscrews at 16% for the nuclear industry and aerospace applications at 12%.

While the economic recession of the early 1980's affected all sectors of industry, the general machine tool industry was deeply affected with many firms closing and other companies making losses. The worst affected were firms making conventional manual machine tools, which did not employ ballscrew technology on a large scale. An unanticipated effect of the recession was to cause many non-ballscrew users to convert to applications which require ballscrews (ie. go up-market with their product in order to survive as a business). On the same basis the majority of new machine tools being manufactured were NC and CNC which usually require 4 to 5 ballscrews per machine. As a result the company was able to maintain its growth and considered the FMS as a way to substantially increase its competitiveness and market share.

SUMMARY OF MIDLAND BALLSCREW COMPANY OPERATING BUDGETS (1984-1990)

TABLE 6.5

	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
	1984	1985	1986	1987	1988	1989	1990
SALES TURNOVER	**1,459,646**	**1,952,582**	**2,433,308**	**2,321,072**	**2,512,984**	**2,794,132**	**3,400,000**
Diff from Previous year		25.2%	19.8%	-4.8%	7.6%	10.1%	17.8%
COST OF SALES	1984	1985	1986	1987	1988	1989	1990
Materials	205,852	448,111	575,106	519,700	658,786	767,189	933,543
Difference from Previous year		54.1%	22.1%	-10.7%	21.1%	14.1%	17.8%
As a Percentage of Cost of Sales	29%	46%	52%	44%	47%	48%	47%
As a Percentage of Total Costs	17%	28%	32%	27%	28%	29%	29%
Tooling	41,060	57,668	66,778	70,090	92,609	64,448	78,423
Difference from Previous year		28.8%	13.6%	4.7%	24.3%	-43.7%	17.8%
Productive Wages	433,598	510,375	529,796	589,579	707,527	815,692	992,563
Difference from Previous year		15.0%	3.7%	10.1%	16.7%	13.3%	17.8%
As a Percentage of Cost of Sales	61%	53%	48%	50%	51%	51%	50%
As a Percentage of Total Costs	35%	32%	30%	30%	30%	31%	31%
Opening Stock & Work in Progress	378,330	378,330	439,700	519,700	553,800	661,875	779,500
Closing Stock & Work in Progress	378,330	439,700	519,700	553,800	661,875	779,500	880,000
Stock & WIP Movements	0	-61,370	-80,000	-34,100	-108,075	-117,625	-100,500
Difference from Previous year		14.0%	15.4%	6.2%	16.3%	15.1%	11.4%
Closing Stock as a percentage of Sales	25.9%	22.5%	21.4%	23.9%	26.3%	27.9%	25.9%
Freight	28,064	15,744	17,072	28,261	46,484	63,789	77,621
TOTAL	**708,574**	**970,528**	**1,108,752**	**1,173,530**	**1,397,331**	**1,593,493**	**1,981,650**
Difference from Previous year		27.0%	12.5%	5.5%	16.0%	12.3%	19.6%
Other Items to add to profit				44,692			
GROSS PROFIT	**751,072**	**982,054**	**1,324,556**	**1,147,542**	**1,115,653**	**1,200,639**	**1,418,350**
Gross Profit as a %	51.5%	50.3%	54.4%	49.4%	44.4%	43.0%	41.7%
Diff from Previous year		-2.3%	7.6%	-10.1%	-11.4%	-3.3%	-3.0%

	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
COMPANY OVERHEADS	1984	1985	1986	1987	1988	1989	1990
-Salaries, Directors	31,107	44,842	39,421	46,594	70,000	66,000	
-Salaries, Staff	108,506	104,366	106,689	126,417	136,807	157,864	
-National Insurance	47,990	44,853	48,715	53,469	72,081	85,174	
-Pensions	18,052	27,941	25,459	27,892	28,352	30,998	
-Rates	21,044	33,906	35,548	44,555	47,594	51,656	
-Light Heat & Power	33,239	34,724	38,189	38,743	39,630	42,493	
-Insurances	20,116	22,265	30,398	46,818	48,339	37,626	
-Postage & Telephone Charges	7,770	10,683	11,423	12,775	14,134	13,178	
-Printing, Stationary & Advertising	23,945	26,148	26,427	38,045	31,519	34,304	
-Motor & Travelling Expenses	18,815	23,320	16,444	28,443	20,359	22,060	
-Overseas Sales Promotions			37,185	0	83,026	67,048	
-Repairs & Maintainance	24,906	29,346	32,227	37,297	41,436	42,449	
-Depreciation	51,641	78,803	93,552	102,112	119,776	129,457	
-Cleaning & Miscellaneous Expenses	18,981	0	0				
-Accountancy Charges	0	5,000	5,000	8,465	16,195	15,000	
-Auditors Charges	6,967	2,100	17,000	3,855	10,000	13,000	
-Consultants Charges			5,053	8,459	5,840	8,486	
-Management Charges		8,000		30,000		31,996	
-Computer Expenses	6,000	6,359	3,779			11,692	
-Commissions	23,018	12,751	8,758	35,662	29,524	56,442	
-Legal Costs	0	0	1,798	7,852	10,955	5,300	
-Leasing Costs	9,423	6,215	9,291	9,531	11,565	15,357	
-Finance Charges	52,262	57,411	41,294	30,871	36,399	30,000	
-Redundancy Payments	6,814	0	0	0	0		
-Hire Purchase Charges			1,649	1,799	1,800	1,800	
-Other Tax Costs		10,517					
-Doubtful Debts		10,427			21,098		
-Sundries		24,879	37,236	25,723	33,785	39,172	
-Exchanges Losses							
TOTAL OVERHEADS	**530,596**	**624,856**	**672,535**	**765,377**	**930,214**	**1,008,552**	**1,227,242**
Diff from Previous year		15.1%	7.1%	12.1%	17.7%	7.8%	17.8%
TOTAL COMPANY COSTS (Direct Production & Overheads)	1,239,170	1,595,384	1,781,287	1,938,907	2,327,545	2,602,045	3,208,892
Diff from Previous year (%)		22.3%	10.4%	8.1%	16.7%	10.5%	18.9%
NET TRADING PROFIT	**220,476**	**357,198**	**652,021**	**426,857**	**185,439**	**192,087**	**191,108**
Diff from Previous year		38.3%	45.2%	-52.7%	-130.2%	3.5%	-0.5%
Operating Margin (before tax)	15.1%	18.3%	26.8%	18.4%	7.4%	6.9%	5.6%
						Recent Year End Estimate	Based on Strategic Plan Forecast

Analysis of Product Sales and Company Costs as a % of Sales Turnover

Sales Turnover	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Materials	14.1%	22.9%	23.6%	22.4%	26.2%	27.5%	27.5%
Tooling	2.8%	3.0%	2.7%	3.0%	3.7%	2.3%	2.3%
Productive Wages	29.7%	26.1%	21.8%	25.4%	28.2%	29.2%	29.2%
Freight	1.9%	0.8%	0.7%	1.2%	1.8%	2.3%	2.3%
Total Cost of Sales	48.5%	49.7%	45.6%	50.6%	55.6%	57.0%	58.3%
Gross Profit Margin	51.5%	50.3%	54.4%	49.4%	44.4%	43.0%	41.7%
Administration Overheads	36.4%	32.0%	27.6%	33.0%	37.0%	36.1%	36.1%
Net Profit Margin	15.1%	18.3%	26.8%	18.4%	7.4%	6.9%	5.6%

Table 6.5

	A	B	C	D	E	F	G	H	I
94		*MIDLAND BALLSCREW COMPANY BALANCE SHEETS*							
95									
96		*TABLE 6.5*	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
97			1984	1985	1986	1987	1988	1989	1990
98		**FIXED ASSETS**							
99		Tangible Assets	1,138,038	1,221,042	1,207,409	1,251,551	1,306,864	1,262,076	
100		Investments	100,373	93,504	93,510	4,276,920	4,724,198	1,181,800	
101		Loans to Group Companies						3,450,783	
102		TOTAL	1,238,411	1,314,546	1,300,919	5,528,471	6,031,062	5,894,659	0
103									
104		**CURRENT ASSETS**							
105		Stock and Work in Progress	315,330	340,000	420,000	553,800	661,875	793,500	
106		Debtors and Prepayments	368,984	484,140	724,558	828,434	1,007,564	925,939	
107		Cash at Bank and In Hand	247,131	215,559	202,053	720,515	601	483,607	
108		Loans to Associated Companies	221,394	179,107	345,209	250,526			
109		TOTAL	1,152,839	1,218,806	1,691,820	2,353,275	1,670,040	2,203,046	0
110									
111		**Less: CREDITORS - Due within one year**							
112		Bank Overdraft				278,977	283,932	133,299	
113		Coporation Tax				342,303	18,535	423,971	
114		Hire Purchase Accounts				12,650	6,401	1,714	
115		Bank Loan				291,250			
116		Loans from Associated Companies				0			
117		Other Creditors and Accurals				413,822	422,541	748,813	
118		TOTAL	143,774	298,104	272,020	1,339,002	731,409	1,307,797	0
119									
120		NET CURRENT ASSETS	1,009,065	920,702	1,419,800	1,014,273	938,631	895,249	0
121		Deferred Taxation		184,500	184,500	192,912	214,189	163,291	
122		Bank Loan			307,950			1,968,131	
123									
124		NET TOTAL ASSETS	2,247,476	2,050,748	2,228,269	6,349,832	6,755,504	4,658,486	0
125									
126									
127		**CAPITAL AND RESERVES**							
128		Share Capital - Issued	33,334	33,334	33,334	2,133,334	2,133,334	2,133,334	
129		Capital Reserves	1,208,666	1,025,056	1,025,056	946,527	819,816	811,016	
130		Revenue Reserves	220,476	492,358	1,169,879	1,301,840	1,834,223	1,714,136	
131		Long Term Loans	785,000	500,000		1,968,131	1,968,131		
132		TOTAL	2,247,476	2,050,748	2,228,269	6,349,832	6,755,504	4,658,486	0
133									
134									
135									

DETAILED SUMMARY OF MIDLAND BALLSCREW COMPANY OPERATING BUDGETS (1984-1990)

TABLE 6.6

SALES BY CATEGORY	1984	1985	1986	1987	1988	1989	1990
-Large Ballscrews (over 2 metres in length)	233,543	263,599	243,331	197,291	188,474	181,619	204,000
-Difference from previous year (%)		12.9%	-7.7%	-18.9%	-4.5%	-3.6%	12.3%
- Value of Change (£)		30,055	-20,268	-46,040	-8,817	-6,855	22,381
-Total Medium Length Ballscrews (0.5-2m in length)	802,805	1,083,683	1,399,152	1,323,011	1,419,836	1,592,655	1,972,000
-Difference from previous year (%)		35.0%	29.1%	-5.4%	7.3%	12.2%	23.8%
- Value of Change (£)		280,878	315,469	-76,141	96,825	172,819	379,345
-Aerospace Ballscrews	175,158	253,836	340,663	371,372	389,513	405,149	476,000
-Difference from previous year (%)		44.9%	34.2%	9.0%	4.9%	4.0%	17.5%
- Value of Change (£)		78,678	86,827	30,708	18,141	15,637	70,851
-Small Ballscrews (under 0.5m)	58,386	87,866	109,499	92,843	138,214	153,677	170,000
-Difference from previous year (%)		50.5%	24.6%	-15.2%	48.9%	11.2%	10.6%
- Value of Change (£)		29,480	21,633	-16,656	45,371	15,463	16,323
-Factored Standard Ballscrews	72,982	107,392	145,998	150,870	175,909	209,560	272,000
-Difference from previous year (%)		47.1%	35.9%	3.3%	16.6%	19.1%	29.8%
- Value of Change (£)		34,410	38,606	4,871	25,039	33,651	62,440
-Repair Work	87,579	117,155	145,998	139,264	150,779	195,589	238,000
-Difference from previous year (%)		33.8%	24.6%	-4.6%	8.3%	29.7%	21.7%
- Value of Change (£)		29,576	28,844	-6,734	11,515	44,810	42,411
-Other	29,193	39,052	48,666	46,421	50,260	55,883	68,000
-Difference from previous year (%)		33.8%	24.6%	-4.6%	8.3%	11.2%	21.7%
Total Sales (Model)	1,459,646	1,952,582	2,433,308	2,321,072	2,512,984	2,794,132	3,400,000
Percentage Change		33.8%	24.6%	-4.6%	8.3%	11.2%	21.7%
	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
COST OF SALES	1984	1985	1986	1987	1988	1989	1990
Materials							
-Steel Bar EN 19/34	82,341	179,244	230,042	207,880	263,514	306,876	373,417
-Steel Balls and Tubes	10,293	22,406	28,755	25,985	32,939	38,359	46,677
-Other Material	10,293	22,406	28,755	25,985	32,939	38,359	46,677
-Bought in components	61,756	134,433	172,532	155,910	197,636	230,157	280,063
-Outwork	16,468	35,849	46,008	41,576	52,703	61,375	74,683
-Heat & Chemical Treatments	24,702	53,773	69,013	62,364	79,054	92,063	112,025
MATERIALS TOTAL	205,852	448,111	575,106	519,700	658,786	767,189	933,543
Difference from previous year (%)		117.7%	28.3%	-9.6%	26.8%	16.5%	21.7%
As a percentage of Cost of Sales	29.1%	46.2%	51.9%	44.3%	47.1%	48.1%	47.1%
As a percentage of Total Overheads	16.6%	28.1%	32.3%	26.8%	28.3%	29.5%	47.1%
TOOLING TOTAL	41,060	57,668	66,778	70,090	92,609	64,448	78,423
Difference from previous year (%)		40.4%	15.8%	5.0%	32.1%	-30.4%	21.7%
Productive Wages	433,598	510,375	529,796	589,579	707,527	815,692	992,563
As a percentage of Cost of Sales	61.2%	52.6%	47.8%	50.2%	50.6%	51.2%	50.1%
As a percentage of Total Overheads	35.0%	32.0%	29.7%	30.4%	30.4%	31.3%	50.1%
Value of Change (£)		76,777	19,421	59,783	117,948	108,165	176,871
Freight	28,064	15,744	17,072	28,261	46,484	63,789	77,621
Stock & WIP Movements					0		0
Opening Stock & Work in Progress	378,330	378,330	439,700	519,700	553,800	661,875	779,500
Closing Stock & Work in Progress	378,330	439,700	519,700	553,800	661,875	779,500	880,000
Stock & WIP Movements	0	-61,370	-80,000	-34,100	-108,075	-117,625	-100,500
Difference from Previous year		14.0%	15.4%	6.2%	16.3%	15.1%	11.4%
Closing Stock as a percentage of Sales	25.9%	22.5%	21.4%	23.9%	26.3%	27.9%	25.9%
TOTAL COST OF SALES	708,574	970,528	1,108,752	1,173,530	1,397,331	1,593,493	1,981,650
Diff from Previous year		27.0%	12.5%	5.5%	16.0%	12.3%	19.6%
Other factors to add to profit				44,692			
GROSS PROFIT	751,072	982,054	1,324,556	1,192,234	1,115,653	1,200,639	1,418,350
Gross Profit as a % of Sales	51.5%	50.3%	54.4%	51.4%	44.4%	43.0%	41.7%
Diff from Previous year		30.8%	34.9%	-10.0%	-6.4%	7.6%	18.1%
COMPANY OVERHEADS							
	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
Indirect Production Costs	1984	1985	1986	1987	1988	1989	1990
-Supervision	16,276	15,655	13,336	15,802	17,101	19,733	0
-Inspection	14,106	13,568	13,336	15,802	17,101	19,733	0
-Pensions & NI	10,127	9,741	8,891	10,535	11,401	13,155	0
-Light, Heat & Power	33,239	34,724	38,189	38,743	39,630	42,493	0
-Other Costs			0	0	0	0	0
Total Indirect Production Costs	73,748	73,687	73,752	80,882	85,232	95,114	0
As a percentage of total overheads	14%	12%	11%	11%	9%	9%	#DIV/0!
Difference From Previous Year (%)			0.1%	9.7%	5.4%	11.6%	-100.0%
Sales & Marketing	1984	1985	1986	1987	1988	1989	1990
-Salaries	26,041	25,048	26,672	31,604	34,202	39,466	0
-Pensions & NI	8,680	8,349	8,891	10,535	11,401	13,155	0
-Advertising & Printing	17,959	19,611	19,820	28,534	23,639	25,728	0
-Exhibitions	0	0	0	0	0	0	0
-Overseas sales promotions	0	0	37,185	0	83,026	67,048	0
-Travel	9,408	11,660	8,222	14,222	10,180	11,030	0
-Commissions	23,018	12,751	8,758	35,662	29,524	56,442	0
-Other Costs	19,504	23,058	25,471	23,691	31,497	41,551	0
Total Sales & Marketing Costs	104,611	100,477	135,019	144,247	223,468	254,420	0
As a percentage of total overheads	20%	16%	20%	19%	24%	25%	#DIV/0!
Difference From Previous Year (%)			34.4%	6.8%	54.9%	13.9%	-100.0%
Design	1984	1985	1986	1987	1988	1989	1990
-Salaries	23,871	22,961	26,672	31,604	34,202	39,466	0
-Pensions & NI	7,957	7,654	8,891	10,535	11,401	13,155	0
-CAD Expenses			0	0	0	0	0
Total Design Costs	31,828	30,614	35,563	42,139	45,602	52,621	0
As a percentage of total overheads	6%	5%	5%	6%	5%	5%	#DIV/0!
Difference From Previous Year (%)			16.2%	18.5%	8.2%	15.4%	-100.0%

	A	B	C	D	E	F	G	H	I
238		**Administration**	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
239		ADMINISTRATION SALARIES	1984	1985	1986	1987	1988	1989	1990
240		-Salaries, Directors	31,107	44,842	39,421	46,594	70,000	66,000	0
241		-Salaries, Staff	28,212	27,135	26,672	31,604	34,202	39,466	0
242		-National Insurance & Pensions	19,773	23,992	22,031	26,066	34,734	35,155	0
243		TOTAL	79,091	95,970	88,124	104,264	138,936	140,621	0
244									
245									
246		ADMINISTRATION OFFICE OVERHEADS	1984	1985	1986	1987	1988	1989	1990
247		-Rates	21,044	33,906	35,548	44,555	47,594	51,656	0
248		-Insurances	20,116	22,265	30,398	46,818	48,339	37,626	0
249		-Postage & Telephone Charges	7,770	10,683	11,423	12,775	14,134	13,178	0
250		-Printing, Stationary & Advertising	5,986	6,537	6,607	9,511	7,880	8,576	0
251		-Motor & Travelling Expenses	9,408	11,660	8,222	14,222	10,180	11,030	0
252		-Repairs & Maintainance	24,906	29,346	32,227	37,297	41,436	42,449	0
253		-Depreciation	51,641	78,803	93,552	102,112	119,776	129,457	0
254		-Cleaning & Miscellaneous Expenses	18,981	0	0	0	0	0	0
255		TOTAL	159,852	193,200	217,977	267,290	289,338	293,972	0
256		As a percentage of total overheads	30%	31%	32%	35%	31%	29%	#DIV/0!
257		Difference From Previous Year (%)			12.8%	22.6%	8.2%	1.6%	-100.0%
258									
259		ADMINISTRATION PROFESSIONAL CHARGES	1984	1985	1986	1987	1988	1989	1990
260		-Accountancy Charges	0	5,000	5,000	8,465	16,195	15,000	0
261		-Auditors Charges	6,967	2,100	17,000	3,855	10,000	13,000	0
262		-Consultants Charges	0	0	5,053	8,459	5,840	8,486	0
263		-Management Charges	0	8,000	0	30,000	0	31,996	0
264		-Computer Expenses	6,000	6,359	3,779	0	0	11,692	0
265		-Legal Costs	0	0	1,798	7,852	10,955	5,300	0
266		TOTAL	12,967	21,459	32,630	58,631	42,990	85,474	0
267									
268		ADMINISTRATION FINANCE CHARGES	1984	1985	1986	1987	1988	1989	1990
269		-Leasing Costs	9,423	6,215	9,291	9,531	11,565	15,357	0
270		-Finance Charges	52,262	57,411	41,294	30,871	36,399	30,000	0
271		-Redundancy Payments	6,814	0	0	0	0	0	0
272		-Hire Purchase Charges	0	0	1649	1799	1800	1800	0
273		-Other Tax Costs	0	10,517	0	0	0	0	0
274		-Doubtful Debts	0	10,427	0	0	21,098	0	0
275		-Sundries	0	24,879	37,236	25,723	33,785	39,172	0
276		TOTAL	68,499	109,449	89,470	67,924	104,647	86,329	0
277									
278		TOTAL ADMINISTRATION COSTS	320,409	420,078	428,201	498,109	575,911	606,396	0
279		As a percentage of total overheads	41%	40%	29%	32%	33%	37%	0%
280		Difference From Previous Year (%)		31.1%	1.9%	16.3%	15.6%	5.3%	-100.0%
281									
282		TOTAL OVERHEADS	530,596	624,856	672,535	765;377	930,214	1,008,552	0
283		Diff from Previous year		15.1%	7.1%	12.1%	17.7%	7.8%	#DIV/0!
284			220,476	357,198	652,021	426,857	185,439	192,087	191,108
285		NET TRADING PROFIT	220,476	357,198	652,021	426,857	185,439	192,087	1,418,350
286		Diff from Previous year		62.0%	82.5%	-34.5%	-56.6%	3.6%	638.4%
287		Actual Net Trading Profit	1,459,646	1,952,582	2,433,308	2,321,072	2,512,984	2,794,132	3,400,000
288		Profit as a Percentage of Sales	15%	18%	27%	18%	7%	7%	42%
289									
290									
291									
292		***ANALYSIS OF COSTS AS A PERCENTAGE OF SALES TURNOVER***							
293									
294			Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
295		As a Percentage of Sales Turnover	1984	1985	1986	1987	1988	1989	1990
296		Large Ballscrews	16.0%	13.5%	10.0%	8.5%	7.5%	6.5%	6.0%
297		Medium Ballscrews	55.0%	55.5%	57.5%	57.0%	56.5%	57.0%	58.0%
298		Aerospace Ballscrews	12.0%	13.0%	14.0%	16.0%	15.5%	14.5%	14.0%
299		Small Ballscrews	4.0%	4.5%	4.5%	4.0%	5.5%	5.5%	5.0%
300		Factored Ballscrews	5.0%	5.5%	6.0%	6.5%	7.0%	7.5%	8.0%
301		Repair Work	6.0%	6.0%	6.0%	6.0%	6.0%	7.0%	7.0%
302		Other	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
303									
304		Materials	14.1%	22.9%	23.6%	22.4%	26.2%	27.5%	27.5%
305		Tooling	2.8%	3.0%	2.7%	3.0%	3.7%	2.3%	2.3%
306		Productive Wages	29.7%	26.1%	21.8%	25.4%	28.2%	29.2%	29.2%
307		Freight	1.9%	0.8%	0.7%	1.2%	1.8%	2.3%	2.3%
308		Total Cost of Sales	48.5%	49.7%	45.6%	50.6%	55.6%	57.0%	58.3%
309		Gross Profit Margin	51.5%	50.3%	54.4%	51.4%	44.4%	43.0%	41.7%
310									
311		Indirect Production Costs	5.1%	3.8%	3.0%	3.5%	3.4%	3.4%	0.0%
312		Sales & Marketing	7.2%	5.1%	5.5%	6.2%	8.9%	9.1%	0.0%
313		Design	2.2%	1.6%	1.5%	1.8%	1.8%	1.9%	0.0%
314		Administration Salaries	5.4%	4.9%	3.6%	4.5%	5.5%	5.0%	0.0%
315		Administration Office Costs	11.0%	9.9%	9.0%	11.5%	11.5%	10.5%	0.0%
316		Administration Professional Charges	0.9%	1.1%	1.3%	2.5%	1.7%	3.1%	0.0%
317		Administration Finance Charges	4.7%	5.6%	3.7%	2.9%	4.2%	3.1%	0.0%
318		Total Administration Costs	22.0%	21.5%	17.6%	21.5%	22.9%	21.7%	0.0%
319		Total Overheads	36.4%	32.0%	27.6%	33.0%	37.0%	36.1%	0.0%
320		Total Company Costs	84.9%	81.7%	73.2%	83.5%	92.6%	93.1%	58.3%
321		Net Profit Margin	15.1%	18.3%	26.8%	18.4%	7.4%	6.9%	41.7%
322									
323									
324									

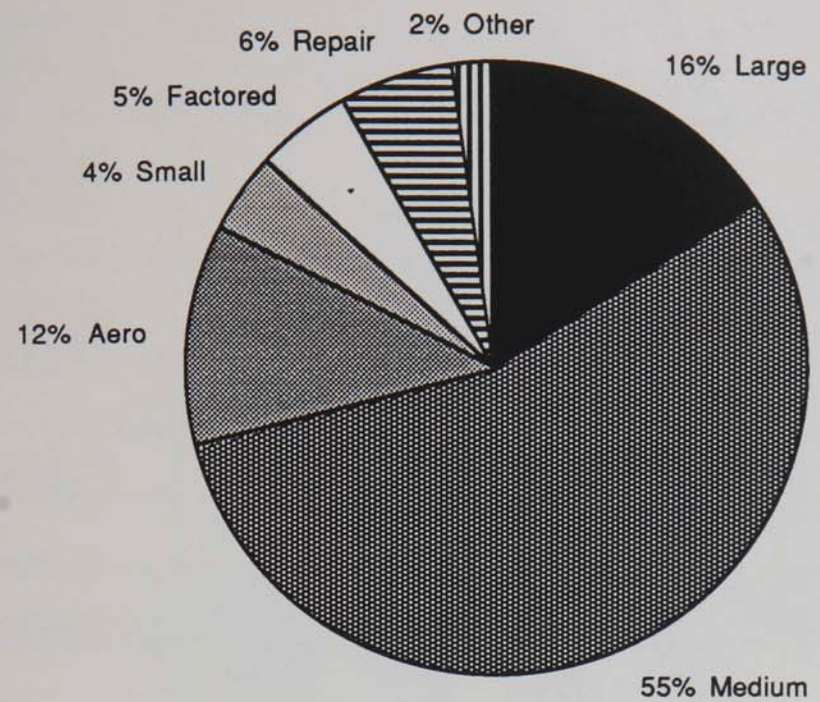

Figure 6.3 - Analysis of Ballscrew sales by size category in 1984

From 1987 onwards the company has had to endure more severe market conditions and consequently has had to accept reduced gross and operating margins. To illustrate the problems the company has faced, Table 6.7 shows the expected company performance for 1984 to 1990 as forecast by the managing director at the end of 1987. (Note: the final 1987 figures were subsequently adjusted to those shown in Table 6.5). This shows that the company had projected a return to high gross and operating margins with a turnover of £3.5M for 1989 and £4M in 1990. At present the company is hoping for a turnover of £3.4M in 1990 and does not foresee the return of the margins obtained in the first half of the 1980's. Figure 6.4 shows the breakdown of product category sales for 1989 with medium length ballscrews remaining the main market for the company. Repair work is expected to become an expanding market, as the widespread use of CNC machines over several years in industry will result in their ballscrews requiring overhauling.

SUMMARY OF MIDLAND BALLSCREW COMPANY PROFIT & LOSS ACCOUNTS

TABLE 6.7

	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
	1984	1985	1986	1987	1988	1989	1990
SALES TURNOVER	**1,459,646**	**1,952,582**	**2,433,308**	**2,321,072**	**2,890,000**	**3,500,000**	**4,000,000**
Diff from Previous year		25.2%	19.8%	-4.8%	19.7%	17.4%	12.5%

COST OF SALES	1984	1985	1986	1987	1988	1989	1990
Materials	205,852	448,111	575,106	489,922	610,000	716,314	805,854
Difference from Previous year		54.1%	22.1%	-17.4%	19.7%	14.8%	11.1%
As a Percentage of Cost of Sales	29%	46%	52%	42%	45%	45%	45%
As a Percentage of Total Costs	17%	28%	32%	26%	28%	28%	28%
Tooling	41,060	57,668	66,778	70,090	76,000	89,246	100,401
Difference from Previous year		28.8%	13.6%	4.7%	7.8%	14.8%	11.1%
Productive Wages	433,598	510,375	529,796	589,579	640,000	751,543	845,486
Difference from Previous year		15.0%	3.7%	10.1%	7.9%	14.8%	11.1%
As a Percentage of Cost of Sales	61%	53%	48%	50%	47%	47%	47%
As a Percentage of Total Costs	35%	32%	30%	31%	30%	30%	30%
Stock & WIP Movements		-61,370	-80,000		0		0
Freight	28,240	15,744	17,072	28,201	40,000	46,971	52,843
Stock Adjustments	-176						0
TOTAL	**708,574**	**970,528**	**1,108,752**	**1,177,792**	**1,366,000**	**1,604,074**	**1,804,584**
Difference from Previous year		27.0%	12.5%	5.9%	13.8%	14.8%	11.1%
Other Items to add to profit				44,692			
GROSS PROFIT	**751,072**	**982,054**	**1,324,556**	**1,143,280**	**1,524,000**	**1,895,926**	**2,195,416**
Gross Profit as a %	51.5%	50.3%	54.4%	49.3%	52.7%	54.2%	54.9%
Diff from Previous year		-2.3%	7.6%	-10.5%	6.6%	2.7%	1.3%

	Year 1	Year 2	Tear 3	Year 4	Year 5	Year 6	Year 7
COMPANY OVERHEADS	1984	1985	1986	1987	1988	1989	1990
-Salaries, Directors	31,107	44,842	39,421	46,594			
-Salaries, Staff	108,506	104,366	106,689	126,417			
-National Insurance	47,990	44,853	48,715	53,469			
-Pensions	18,052	27,941	25,459	27,892			
-Rates	21,044	33,906	35,548	44,555			
-Light Heat & Power	33,239	34,724	38,189	38,743			
-Insurances	20,116	22,265	30,398	46,818			
-Postage & Telephone Charges	7,770	10,683	11,423	12,775			
-Printing, Stationary & Advertising	23,945	26,148	26,427	38,045			
-Motor & Travelling Expenses	18,815	23,320	16,444	28,443			
-Overseas Sales Promotions			37,185	0			
-Repairs & Maintainance	24,906	29,346	32,227	37,297			
-Depreciation	51,641	78,803	93,552	102,112			
-Cleaning & Miscellaneous Expenses	18,981	0	0				
-Accountancy Charges	0	5,000	5,000	8,465			
-Auditors Charges	6,967	2,100	17,000	3,899			
-Consultants Charges			5,053	8,459			
-Management Charges		8,000					
-Computer Expenses	6,000	6,359	3,779				
-Commissions	23,018	12,751	8,758	35,662			
-Legal Costs	0	0	1,798	7,852			
-Leasing Costs	9,423	6,215	9,291	9,531			
-Finance Charges	52,262	57,411	41,294	30,826			
-Redundancy Payments	6,814	0	0	0			
-Hire Purchase Charges			1,649	1,799			
-Other Tax Costs		10,517					
-Doubtful Debts		10,427					
-Sundries		24,879	37,236	25,723			
TOTAL OVERHEADS	530,596	624,856	672,535	735,376	790,000	927,686	1,043,646
Diff from Previous year		15.1%	7.1%	8.5%	6.9%	14.8%	11.1%

NET TRADING PROFIT	220,476	357,198	652,021	452,596	734,000	968,240	1,151,770
Diff from Previous year		38.3%	45.2%	-44.1%	38.3%	24.2%	15.9%
Operating Margin (before tax)	15.1%	18.3%	26.8%	19.5%	25.4%	27.7%	28.8%
					Based on Strategic Plan Figures	Based on Strategic Plan Figures	Based on Strategic Plan Figures

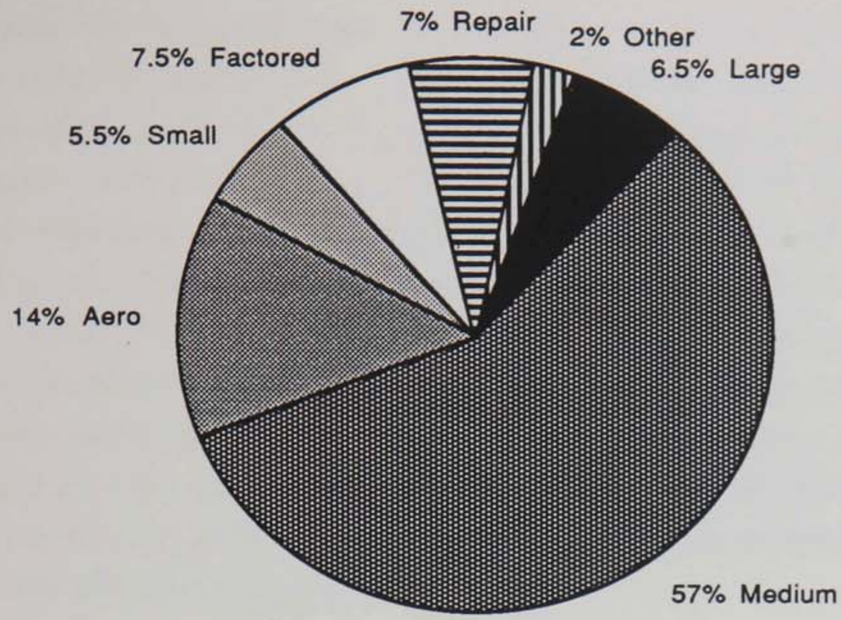

Figure 6.4 - Analysis of Ballscrew sales by size category in 1989

In terms of direct production costs the two major items are materials and productive wages. The basic raw material used in the manufacture of ballscrews is hardened steel, which is required in a number of different widths and lengths. This is purchased from a supplier in Sheffield and can be obtained at relatively short notice, in effect, an unofficial *just-in-time* system operates. Included in material costs also are the bought-in components and the specialised heat and chemical treatments for which the ballscrews are sent outside the factory. Material costs average around 45% of the cost of sales. Productive wages make up around 50% of the cost of sales since the manufacture of ballscrews requires a high degree of skill. In terms of work-in-progress and stock, despite efforts over the years to reduce the levels held by the company, as a general rule the WIP and stock averages around 25% of the value of the sales turnover, giving four stock turnovers per annum. The company does not employ any computer based production control system, although they are presently considering one, using the principles of the *optimised production technology* philosophy, which is based on identifying production bottlenecks and scheduling the workload to overcome them. The overhead costs are broken down in table 6.6 into several categories; indirect production costs (rows 207 to 215) which include supervision and inspection; sales and marketing, (rows 217 to 228) and design and administration costs rows (230 to 280).

The spreadsheet models break down the company sales and production costs and company overheads in the same categories as Table 6.6. In designing the model, the author is attempting to provide one which would be acceptable in accountancy terms, but is not primarily for accounting purposes. To analyse the effect of varying key financial inputs as shown in model 6.1 in appendix 6.1, the model provides the user with a *percentage change value* to alter the expected financial change from the previous year. The financial value of this change is also displayed to give the user an idea of the magnitude of the financial effects of any change that is made. For example, the extra sales provided by the FMS would require a corresponding increase in the purchase of materials, for which an appropriate increase in the percentage change in material costs would be entered (rows 360 to 382). Likewise a *wider* effect of the FMS may be the need for increased expenditure on sales & marketing in the company in order to sell the extra output provided by the FMS. Again a percentage change figure can be entered (rows 445 to 469). By analysing each of the different cost categories in turn, a model of how the FMS affected the company can be built up.

In modelling the company it was not possible to relate the number of ballscrew units sold at a particular price, since the majority of the output is designed to individual customer requirements and prices vary considerably depending upon the amount of design time involved and the number ordered. Thus the model provides only the sales turnover of each category except for medium length ballscrews (row 332). Since the FMS would be directed towards the production of more standard sizes, there would be expected to be less variation between medium length ballscrew prices and from an analysis of the company's output, a representative price per unit was suggested by the management as £500 (row 335).

At the end of the operating budget a simple company cash flow model is provided (rows 578 to 601). In this model it assumed that two months credit is taken from the company trade creditors and the same two month period is taken by the company debtors. All salaries, wages and other company overheads are paid for in the month in which they are incurred. The cashflow also takes the company taxation into account, tax being paid one year in arrears and the logic built into the spreadsheet (row 587) conforms to current tax rates (no tax paid in loss situation, 25% below £100,000 profit and 35% on profits over £100,000) and losses being carried forward to offset against profits. VAT is not built in to the model since, while this will effect cash flow, it should not have an effect upon the long term investment plans of the company which is the purpose of these models. Although capital allowances would undoubtedly have assisted the project, progressive changes in the way they are calculated for tax purposes mean that they are not as critical as they once were in determining the viability of investments and have not been included in the models.

The following variables were identified as relevant to the viability of the FMS project:

(1) Model 6.1 - Base model assuming that FMS is introduced as planned

(2) Model 6.2 - Lower revenue as a result of reduced unit sales price

(4) Model 6.3 - Lower revenue as a result of reduced output

(5) Model 6.4 - The effect of technical problems on financial viability

(6) Model 6.5 - Extra equipment costs to balance the increased FMS output

(7) Model 6.6 - Higher productive labour costs than planned

(8) Model 6.7 - Higher overheads than planned

(9) Model 6.8 - Viability of project without Government grant

The modelling results are summarised in table 6.9. Model 6.1 is shown in appendix 6.1, and models 6.7 and 6.7.1 are shown in appendices 6.2 and 6.3 and a printout of the spreadsheet logic in appendix 6.4.

Model 6.1 - This assumes that the FMS is introduced according to plan taking two years to develop and build, becoming operational at the start of 1986, within budget and that the anticipated increased sales and cost savings would be achieved. This model as shown in appendix 6.1 represents what might be termed the "ideal" and is used as a base model against which the effects of changing key variables can be compared. Table 6.8 shows the expected percentage sales increases from 1986 onwards when the FMS would be assumed to become operational. These forecasts were based on the rapid expansion the company had experienced in the early 1980's.

Type of Ballscrew	1986	1987	1988	1989	1990
Large Ballscrews	5%	5%	5%	5%	5%
Medium Ballscrews	130%	10%	10%	2%	2%
Aerospace Ballscrews	15%	15%	15%	15%	15%
Small Ballscrews	10%	10%	10%	10%	10%
Factored Range	10%	10%	10%	10%	10%
Repair Work	15%	15%	15%	15%	15%

Table 6.8 - Expected Sales Growth with FMS (%)

Table 6.9 Summary of Midland Ballscrew Company Model Results

MODEL DESCRIPTION	VARIABLE	FMS Development		FMS Operational				
		1984	1985	1986	1987	1988	1989	1990
MODEL 6.0	Net Sales	1,459,646	1,952,582	2,433,308	2,321,072	2,512,984	2,794,132	3,400,000
	Gross Profit	751,072	982,054	1,324,556	1,147,542	1,115,653	1,200,639	1,418,350
	Gross Profit (%)	51.5%	50.3%	54.4%	49.4%	44.4%	43.0%	41.7%
Actual company results	Net Trading Profit	220,476	357,198	652,021	426,857	185,439	192,087	191,108
	Net Trading Profit (%)	15.1%	18.3%	26.8%	18.4%	7.4%	6.9%	5.6%
MODEL 6.1	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
	Gross Profit	751,072	982,054	2,027,124	2,236,314	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
Base Model assuming	Net Trading Profit	-31,524	-66,023	655,389	773,880	852,194	1,000,375	1,001,822
FMS introduced as	Net Trading Profit (%)	-2.2%	-3.4%	18.9%	20.3%	20.3%	23.1%	22.4%
planned and achieves	Proft (%) to Actual	-699.4%	-541.0%	99.5%	55.2%	21.8%	19.2%	19.1%
expected cost benefits	Opening Balance	34,000	-304,136	-517,594	-73,099	432,017	940,163	1,589,702
	Closing Balance	-304,136	-517,594	-73,099	432,017	940,163	1,589,702	1,939,153
Model 6.2	Net Sales	1,459,646	1,952,582	2,963,111	3,269,161	3,588,660	3,723,450	3,875,633
	Gross Profit	751,072	982,054	1,552,328	1,713,682	1,879,365	1,912,068	1,950,385
	Gross Profit (%)	51.5%	50.3%	52.4%	52.4%	52.4%	51.4%	50.3%
Unit price of £500	Net Trading Profit	-31,524	-66,023	203,093	275,998	308,231	451,342	447,064
reduced in years 3 to 7	Net Trading Profit (%)	-2.2%	-3.4%	6.9%	8.4%	8.6%	12.1%	11.5%
by 20%	Proft (%) to Actual	-699.4%	-541.0%	321.0%	154.7%	60.2%	42.6%	42.7%
	Profit (%) to Base	100.0%	100.0%	322.7%	280.4%	276.5%	221.6%	224.1%
	Opening Balance	34,000	-304,136	-517,594	-446,262	-272,753	-126,256	165,482
	Closing Balance	-304,136	-517,594	-446,262	-272,753	-126,256	165,482	153,290
MODEL 6.2.1	Net Sales	1,459,646	1,952,582	3,213,111	3,544,161	3,888,660	4,023,450	4,175,633
	Gross Profit	751,072	982,054	1,788,745	1,973,930	2,163,706	2,199,092	2,240,437
	Gross Profit (%)	51.5%	50.3%	55.7%	55.7%	55.6%	54.7%	53.7%
Unit price of £500	Net Trading Profit	-31524	-66023	428,261	523,871	579,072	724,865	723,615
reduced in years 3 to 7	Net Trading Profit (%)	-2.2%	-3.4%	13.3%	14.8%	14.9%	18.0%	17.3%
by 10%	Proft (%) to Actual	-699.4%	-541.0%	152.2%	81.5%	32.0%	26.5%	26.4%
	Profit (%) to Base	100.0%	100.0%	153.0%	147.7%	147.2%	138.0%	138.4%
	Opening Balance	34,000	-304,136	-517,594	-260,498	78,105	404,673	874,692
	Closing Balance	-304,136	-517,594	-260,498	78,105	404,673	874,692	1,042,814
MODEL 6.2.2	Net Sales	1,459,646	1,952,582	3,713,111	4,094,161	4,488,660	4,623,450	4,775,633
	Gross Profit	751,072	982,054	2,267,068	2,500,401	2,738,766	2,778,675	2,825,131
	Gross Profit (%)	51.5%	50.3%	61.1%	61.1%	61.0%	60.1%	59.2%
Unit price of £500	Net Trading Profit	-31,524	-66,023	884,083	1,025,592	1,127,132	1,277,449	1,281,309
increased in years 3 to 7	Net Trading Profit (%)	-2.2%	-3.4%	23.8%	25.1%	25.1%	27.6%	26.8%
by 10%	Proft (%) to Actual	-699.4%	-541.0%	73.8%	41.6%	16.5%	15.0%	14.9%
	Profit (%) to Base	100.0%	100.0%	74.1%	75.5%	75.6%	78.3%	78.2%
	Opening Balance	34,000	-304,136	-517,594	115,604	788,365	1,479,292	2,309,320
	Closing Balance	-304,136	-517,594	115,604	788,365	1,479,292	2,309,320	2,840,880
MODEL 6.3	Net Sales	1,459,646	1,952,582	2,963,111	3,269,161	3,588,660	3,723,450	3,875,633
	Gross Profit	751,072	982,054	1,691,879	1,867,650	2,048,394	2,087,911	2,133,926
	Gross Profit (%)	51.5%	50.3%	57.1%	57.1%	57.1%	56.1%	55.1%
Number of medium	Net Trading Profit	-31,524	-66,023	342,645	429,966	477,260	627,184	630,605
length ballscrews sold	Net Trading Profit (%)	-2.2%	-3.4%	11.6%	13.2%	13.3%	16.8%	16.3%
reduced by 20%	Proft (%) to Actual	-699.4%	-541.0%	190.3%	99.3%	38.9%	30.6%	30.3%
	Profit (%) to Base	100.0%	100.0%	191.3%	180.0%	178.6%	159.5%	158.9%
	Opening Balance	34,000	-304,136	-517,594	-329,969	-53,737	205,390	612,675
	Closing Balance	-304,136	-517,594	-329,969	-53,737	205,390	612,675	721,196
MODEL 6.3.1	Net Sales	1,459,646	1,952,582	3,213,111	3,544,161	3,888,660	4,023,450	4,175,633
	Gross Profit	751,072	982,054	1,861,136	2,053,781	2,251,325	2,289,978	2,335,016
	Gross Profit (%)	51.5%	50.3%	57.9%	57.9%	57.9%	56.9%	55.9%
Number of medium	Net Trading Profit	-31524	-66023	500,651	603,721	666,691	815,752	818,195
length ballscrews sold	Net Trading Profit (%)	-2.2%	-3.4%	15.6%	17.0%	17.1%	20.3%	19.6%
reduced by 10%	Proft (%) to Actual	-699.4%	-541.0%	130.2%	70.7%	27.8%	23.5%	23.4%
	Profit (%) to Base	100.0%	100.0%	130.9%	128.2%	127.8%	122.6%	122.4%
	Opening Balance	34,000	-304,136	-517,594	-200,172	191,700	576,644	1,106,339
	Closing Balance	-304,136	-517,594	-200,172	191,700	576,644	1,106,339	1,336,615
MODEL 6.3.2	Net Sales	1,459,646	1,952,582	3,713,111	4,094,161	4,488,660	4,623,450	4,775,633
	Gross Profit	751,072	982,054	2,190,054	2,415,980	2,646,203	2,683,109	2,726,168
	Gross Profit (%)	51.5%	50.3%	59.0%	59.0%	59.0%	58.0%	57.1%
Number of medium sold	Net Trading Profit	-31,524	-66,023	807,520	941,171	1,034,569	1,181,882	1,182,347
length ballscrews	Net Trading Profit (%)	-2.2%	-3.4%	21.7%	23.0%	23.0%	25.6%	24.8%
10% higher than	Proft (%) to Actual	-699.4%	-541.0%	80.7%	45.4%	17.9%	16.3%	16.2%
planned	Profit (%) to Base	100.0%	100.0%	81.2%	82.2%	82.4%	84.6%	84.7%
	Opening Balance	34,000	-304,136	-517,594	51,802	668,248	1,297,517	2,064,876
	Closing Balance	-304,136	-517,594	51,802	668,248	1,297,517	2,064,876	2,531,488

Table 6.9 Model Results Summary

MODEL DESCRIPTION	VARIABLE	FMS Development		FMS Operational				
		1984	1985	1986	1987	1988	1989	1990
	Net Sales	1,459,646	1,952,582	2,213,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.4	Gross Profit	751,072	982,054	1,153,431	2,180,355	2,389,213	2,426,599	2,470,204
	Gross Profit (%)	51.5%	50.3%	52.1%	57.1%	57.0%	56.1%	55.2%
Technical delays in FMS	Net Trading Profit	-81,924	-140,143	-236,174	643,801	716,959	915,153	939,883
becoming operational	Net Trading Profit (%)	-5.6%	-7.2%	-10.7%	16.9%	17.1%	21.2%	21.0%
reduce year 1 output by	Proft (%) to Actual	-269.1%	-254.9%	-276.1%	66.3%	25.9%	21.0%	20.3%
50% and finance costs	Profit (%) to Base	38.5%	47.1%	-277.5%	120.2%	118.9%	109.3%	106.6%
are 20% higher than	Opening Balance	34,000	-354,536	-642,114	-943,566	-509,575	70,108	681,822
planned	Closing Balance	-354,536	-642,114	-943,566	-509,575	70,108	681,822	999,234
	Net Sales	1,459,646	1,952,582	2,213,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.4.1	Gross Profit	751,072	982,054	1,153,431	2,180,355	2,389,213	2,426,599	2,470,204
	Gross Profit (%)	51.5%	50.3%	52.1%	57.1%	57.0%	56.1%	55.2%
Technical delays in FMS	Net Trading Profit	-56,724	-103,083	-199,114	680,861	754,019	927,013	939,883
becoming operational	Net Trading Profit (%)	-3.9%	-5.3%	-9.0%	17.8%	18.0%	21.4%	21.0%
reduce year 1 output by	Proft (%) to Actual	-388.7%	-346.5%	-327.5%	62.7%	24.6%	20.7%	20.3%
50% and finance costs	Profit (%) to Base	55.6%	64.0%	-329.2%	113.7%	113.0%	107.9%	106.6%
are 10% higher than	Opening Balance	34,000	-329,336	-579,854	-844,246	-373,195	195,815	806,418
planned	Closing Balance	-329,336	-579,854	-844,246	-373,195	195,815	806,418	1,119,679
	Net Sales	1,459,646	1,952,582	2,213,111	3,131,661	4,188,660	4,323,450	4,475,633
MODEL 6.4.2	Gross Profit	751,072	982,054	1,153,431	1,745,164	2,434,455	2,473,412	2,518,792
	Gross Profit (%)	51.5%	50.3%	52.1%	55.7%	58.1%	57.2%	56.3%
Technical delays in FMS	Net Trading Profit	-56,724	-103,083	-199,114	276,607	799,261	973,825	988,471
becoming operational	Net Trading Profit (%)	-3.9%	-5.3%	-9.0%	8.8%	19.1%	22.5%	22.1%
reduce year 1 output by	Proft (%) to Actual	-388.7%	-346.5%	-327.5%	154.3%	23.2%	19.7%	19.3%
50% and year 2 output by	Profit (%) to Base	55.6%	64.0%	-329.2%	279.8%	106.6%	102.7%	101.4%
25% and finance costs	Opening Balance	34,000	-329,336	-579,854	-844,246	-704,917	-58,058	612,071
are 10% higher than plan	Closing Balance	-329,336	-579,854	-844,246	-704,917	-58,058	612,071	957,240
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.5	Gross Profit	751,072	982,054	2,027,124	2,236,124	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
Extra equipment to	Net Trading Profit	-31,524	-66,023	401,289	519,780	598,094	746,275	747,722
balance production costing	Net Trading Profit (%)	-2.2%	-3.4%	11.6%	13.6%	14.3%	17.3%	16.7%
£605K requires addition	Proft (%) to Actual	-699.4%	-541.0%	162.5%	82.1%	31.0%	25.7%	25.6%
finanace costs begining in	Profit (%) to Base	100.0%	100.0%	163.3%	148.9%	142.5%	134.0%	134.0%
year 3	Opening Balance	34,000	-304,136	-517,594	-317,199	12,752	355,733	840,107
	Closing Balance	-304,136	-517,594	-317,199	12,752	355,733	840,107	1,024,393
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.5.1	Gross Profit	751,072	982,054	2,027,124	2,236,124	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
As model 5.1 but only	Net Trading Profit	-31524	-66023	528,339	646,830	725,144	873,325	874,772
50% of equipment is	Net Trading Profit (%)	-2.2%	-3.4%	15.3%	16.9%	17.3%	20.2%	19.5%
purchased with	Proft (%) to Actual	-699.4%	-541.0%	123.4%	66.0%	25.6%	22.0%	21.8%
corresponding reduction	Profit (%) to Base	100.0%	100.0%	124.0%	119.6%	117.5%	114.5%	114.5%
in associated financing	Opening Balance	34,000	-304,136	-517,594	-200,149	222,384	647,948	1,214,905
costs	Closing Balance	-304,136	-517,594	-200,149	222,384	647,948	1,214,905	1,481,773
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.6	Gross Profit	751,072	982,054	1,925,049	2,124,032	2,326,817	2,352,240	2,382,695
	Gross Profit (%)	51.5%	50.3%	55.6%	55.6%	55.6%	54.4%	53.2%
Productive Labour Costs	Net Trading Profit	-31,524	-66,023	553,314	661,598	728,683	864,513	852,374
held constant at 1985	Net Trading Profit (%)	-2.2%	-3.4%	16.0%	17.3%	17.4%	20.0%	19.0%
values rather than the	Proft (%) to Actual	-699.4%	-541.0%	117.8%	64.5%	25.4%	22.2%	22.4%
planned 20% reduction	Profit (%) to Base	100.0%	100.0%	118.4%	117.0%	116.9%	115.7%	117.5%
	Opening Balance	34,000	-304,136	-517,594	-175,174	253,386	677,320	1,234,226
	Closing Balance	-304,136	-517,594	-175,174	253,386	677,320	1,234,226	1,481,780
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.6.1	Gross Profit	751,072	982,054	1,976,087	2,180,173	2,388,573	2,420,170	2,457,419
	Gross Profit (%)	51.5%	50.3%	57.1%	57.1%	57.0%	56.0%	54.9%
Productive Labour Costs	Net Trading Profit	-31,524	-66,023	604,352	717,739	790,439	932,444	927,098
reduced by only 10%	Net Trading Profit (%)	-2.2%	-3.4%	17.5%	18.8%	18.9%	21.6%	20.7%
rather than the planned	Proft (%) to Actual	-699.4%	-541.0%	107.9%	59.5%	23.5%	20.6%	20.6%
20% reduction	Profit (%) to Base	100.0%	100.0%	108.4%	107.8%	107.8%	107.3%	108.1%
	Opening Balance	34,000	-304,136	-517,594	-124,136	342,701	808,742	1,411,964
	Closing Balance	-304,136	-517,594	-124,136	342,701	808,742	1,411,964	1,710,467

Table 6.9 Model Results Summary

MODEL DESCRIPTION	VARIABLE	FMS Development		FMS Operational				
		1984	1985	1986	1987	1988	1989	1990
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.7	Gross Profit	751,072	982,054	2,027,124	2,236,124	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
Sales., marketing and	Net Trading Profit	-76,291	-124,022	567,556	679,839	750,751	896,478	895,437
commissions expenses	Net Trading Profit (%)	-5.2%	-6.4%	16.4%	17.8%	17.9%	20.7%	20.0%
are higher than anticpated	Proft (%) to Actual	-289.0%	-288.0%	114.9%	62.8%	24.7%	21.4%	21.3%
due to the high entry	Profit (%) to Base	41.3%	53.2%	115.5%	113.8%	113.5%	111.6%	111.9%
costs of going into	Opening Balance	34,000	-348,903	-620,359	-263,699	214,084	653,701	1,234,847
overseas markets	Closing Balance	-348,903	-620,359	-263,699	214,084	653,701	1,234,847	1,514,275
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.7.1	Gross Profit	751,072	982,054	2,027,124	2,236,124	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
As Model 6.7 but overhead	Net Trading Profit	-113,463	-160,048	528,020	636,314	703,238	843,991	837,172
costs in production control,	Net Trading Profit (%)	-7.8%	-8.2%	15.2%	16.7%	16.8%	19.5%	18.7%
design and administration	Proft (%) to Actual	-194.3%	-223.2%	123.5%	67.1%	26.4%	22.8%	22.8%
are higher than planned	Profit (%) to Base	27.8%	41.3%	124.1%	121.6%	121.2%	118.5%	119.7%
	Opening Balance	34,000	-371,075	-678,558	-361,432	112,579	519,814	1,065,104
	Closing Balance	-371,075	-678,558	-361,432	112,579	519,814	1,065,104	1,304,639
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.7.2	Gross Profit	751,072	982,054	2,027,124	2,236,124	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
As Model 6.7 but overhead	Net Trading Profit	-138,663	-197,108	490,960	599,549	666,178	843,991	837,172
costs in production control,	Net Trading Profit (%)	-9.5%	-10.1%	14.2%	15.7%	15.9%	19.5%	18.7%
design and administration	Proft (%) to Actual	-159.0%	-181.2%	132.8%	71.2%	27.8%	22.8%	22.8%
are higher than planned and	Profit (%) to Base	22.7%	33.5%	133.5%	129.1%	127.9%	118.5%	119.7%
finance costs 10% higher	Opening Balance	34,000	-396,275	-740,818	-460,752	10,961	394,107	940,508
	Closing Balance	-396,275	-740,818	-460,752	10,961	394,107	940,508	1,184,194
	Net Sales	1,459,646	1,952,582	3,213,111	3,544,161	3,888,660	4,023,450	4,175,633
MODEL 6.7.3	Gross Profit	751,072	982,054	1,788,745	1,973,930	2,163,706	2,199,092	2,240,437
	Gross Profit (%)	51.5%	50.3%	55.7%	55.7%	55.6%	54.7%	53.7%
As Model 6.7 but overhead	Net Trading Profit	-138,663	-197,108	268,831	355,040	399,056	562,622	564,965
costs in production control,	Net Trading Profit (%)	-9.5%	-10.1%	8.4%	10.0%	10.3%	14.0%	13.5%
design and administration	Proft (%) to Actual	-159.0%	-181.2%	242.5%	120.2%	46.5%	34.1%	33.8%
are higher than planned and	Profit (%) to Base	22.7%	33.5%	243.8%	218.0%	213.6%	177.8%	177.3%
finance costs 10% higher	Opening Balance	34,000	-396,275	-740,818	-643,151	-357,630	-128,559	242,223
and Sales Price 10% lower	Closing Balance	-396,275	-740,818	-643,151	-357,630	-128,559	242,223	308,480
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,660	4,323,450	4,475,633
MODEL 6.8	Gross Profit	751,072	982,054	2,027,124	2,236,314	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
No Government grant for	Net Trading Profit	-283,524	-436,623	284,789	403,280	481,594	881,775	1,001,822
FMS, hence fianance costs	Net Trading Profit (%)	-19.4%	-22.4%	8.2%	10.6%	11.5%	20.4%	22.4%
doubled	Proft (%) to Actual	-77.8%	-81.8%	228.9%	105.8%	38.5%	21.8%	19.1%
	Profit (%) to Base	11.1%	15.1%	230.1%	191.9%	177.0%	113.5%	100.0%
	Opening Balance	34,000	-556,136	-1,140,194	-1,066,299	-736,538	-328,124	343,742
	Closing Balance	-556,136	-1,140,194	-1,066,299	-736,538	-328,124	343,742	734,703
	Net Sales	1,459,646	1,952,582	3,463,111	3,819,161	4,188,161	4,323,450	4,475,633
MODEL 6.8.1	Gross Profit	751,072	982,054	2,027,124	2,236,314	2,450,328	2,488,101	2,532,143
	Gross Profit (%)	51.5%	50.3%	58.5%	58.6%	58.5%	57.5%	56.6%
Government grant only 25%	Net Trading Profit	-157,524	-251,323	470,089	588,580	666,894	941,075	1,001,822
rather than the planned 50%	Net Trading Profit (%)	-10.8%	-12.9%	13.6%	15.4%	15.9%	21.8%	22.4%
	Proft (%) to Actual	-140.0%	-142.1%	138.7%	72.5%	27.8%	20.4%	19.1%
	Profit (%) to Base	20.0%	26.3%	139.4%	131.5%	127.8%	106.3%	100.0%
	Opening Balance	34,000	-430,136	-828,894	-569,699	-69,949	317,753	972,846
	Closing Balance	-430,136	-828,894	-569,699	-69,949	317,753	972,846	1,343,052
	Net Sales	1,459,646	1,952,582	3,534,009	3,747,906	4,093,057	4,201,335	4,427,832
MODEL 6.9	Gross Profit	751,072	982,054	2,090,397	2,202,619	2,401,743	2,423,018	2,513,148
	Gross Profit (%)	51.5%	50.3%	59.2%	58.8%	58.7%	57.7%	56.8%
As base model but % sales	Net Trading Profit	-31,524	-66,023	715,472	743,391	807,912	940,786	984,978
turnover changes the same	Net Trading Profit (%)	-2.2%	-3.4%	20.2%	19.8%	19.7%	22.4%	22.2%
as actual company results	Proft (%) to Actual	-699.4%	-541.0%	91.1%	57.4%	23.0%	20.4%	19.4%
	Profit (%) to Base	100.0%	100.0%	91.6%	104.1%	105.5%	106.3%	101.7%
	Opening Balance	34,000	-304,136	-517,594	-23,562	446,197	923,214	1,531,413
	Closing Balance	-304,136	-517,594	-23,562	446,197	923,214	1,531,413	1,877,194

Prior to the introduction of the planned FMS, the company was manufacturing around 2,000 medium length ballscrews per annum. The FMS would provide the production capability to increase this significantly to around 6,000 per annum with the capability for further increases, although in the models it is assumed that 6,000 will be the maximum output. Attaining full production would be carried out in a series of steps since there was expected to be a significant learning curve involved operating the FMS to its full capabilities. Analysing the costs of Production:

Materials - The model logic divides the overall material costs (rows 360 to 382) into two categories; medium length ballscrews and non-medium sized ballscrews by the same percentage as their respective sales turnovers. The material cost of the non-medium sized output is assumed to change from the previous year by the same percentage change in non-medium sales turnover (row 355) Medium length output is assumed to change in line with the percentage change in units of output (row 337).

Productive Wages - The FMS would have been able to operate on a minimally manned basis so achieving labour savings. To quantify these, based on the original estimates, it is assumed that a 20% reduction in labour costs, worth £100,000 is realised when the FMS becomes operational (row 394). It needs to be noted that £40,000 is allocated in the company overheads (row 526) to cover the cost of redundancies.

Stock & WIP - On average the company maintains stock & WIP worth 25% of its sales turnover (row 410). The company expected in the FMS proposal to achieve stock & WIP savings, although no detail was provided as to how this was to be achieved, since the company did not, (and still does not) operate a computer based materials control system and the FMS proposal did not include any plans for one. However, in this model it is assumed that the opening stock & WIP values when the FMS becomes operational will be maintained, so that as a percentage of sales turnover their value will decline in relative terms as the turnover increases.

In terms of the effect upon the company overheads, the FMS proposal did not envisage any substantial increase. In model 6.1 a percentage change figure of 15% per annum has been allowed for in most categories, with a higher rise in sales and marketing costs in the two years prior to introducing the FMS becoming operational to cover increased expenditure required in these categories in preparation for the FMS becoming operational. In financing new machines, the company usually arranges a leasing arrangement with a finance company rather than take out a bank loan. This usually involves the company making quarterly payments over a term of five years at the end of which, the company owns the asset. The leasing payments include a factor for depreciation and so at the end of the five years the machine is already written down to zero. From discussion with the company financial director, the model includes in the FMS finance charge category (row 553) what is considered to be a representative cost element, based on the assumption that it costs the company £35 for each £1000 borrowed per month. It should be noted that in practice, finance companies are usually only willing to make leasing arrangements on operational assets. Since the FMS would take two years to develop this would have posed a problem, and the company would probably have had to take out a bank loan. However, for the purposes of this model it is assumed that all the capital, labour and development costs are included in a single annual payment. The costs used of the FMS as shown in Tables 6.4 to 6.6 are £1,765,000 spread over two years with 68% of the costs in the first year equal to £1,200,000 and 32% of the costs in the second year. Table 6.10 shows a detailed breakdown of the finance costs used in the model taking into account the 50% Government grant available to the company to assist with capital and development costs.

Item (£)	Year 1: 68% of cost	Year 2: 32% of cost
Labour	176.8	83.2
Machines, Toolhandling Units, Toolhandling Units, Conveyors, Stores, Attachments, Installation	448.8	211.2
Computer Hardware for System Management Computer	37.4	17.6
Monitors, Gauging, Final Inspection, Guarding, Cooling supply, Swarf removal	105.4	49.6
Outside assistance and development	431.8	203.2
Total	1200.2	564.8
With 50% Governement Grant	600.1	282.4

Table 6.10 FMS Costs with Government Grant

Assuming that finance costs are £35 per Month per £1000 borrowed and the repayments spread over 5 years (although since the initial development costs are spread over two years the total payments will be over 6 years). The FMS finance payments will be £252K in the first year, followed by four payments of £370.6K and a final payment of £118.6K In all the models it is assumed that the during the two year development period, the sales turnover (row 353, columns C & D) and most of the company costs will be the same as occurred in the real results. This is perhaps generous, since there would probably have been considerable disruption to the business during the development period, but is difficult to estimate. No allowance is made in the models for the cost of new buildings since the present factory was designed with the FMS in mind and room for the system already exists. Figure 6.5 compares the actual company net sales to the base model 6.1 projected values showing the large jump in year 3 when the FMS becomes operational. Figure 6.6 shows the gross profit as a percentage. Since the FMS was expected to operate on a minimally manned basis, it was expected the firm would save around £100,000 in productive labour costs (equal approximately to a 20% reduction in the model). Figure 6.7 compares the net profits and figure 6.8 shows this as a percentage. This shows that the company was extremely profitable for a manufacturing company achieving an outstanding 27% in 1986, where margins of less than 10% are typical in manufacturing industry. The effect of the FMS is to sustain these margins around the 20% level (row 570 in model 6.1). Figure 6.9 shows the cash flow of model 6.1. Insufficient information was available to plot a similar graph for the actual company results. While as shown in figure 6.7, in terms of trading, the firm makes a small loss in the two years while the FMS is being developed before becoming very profitable, in terms of the effect upon cash flows the effect is more marked. Here the firm has to cope with a negative cash flow for the two development years due to the finance costs (row 596).

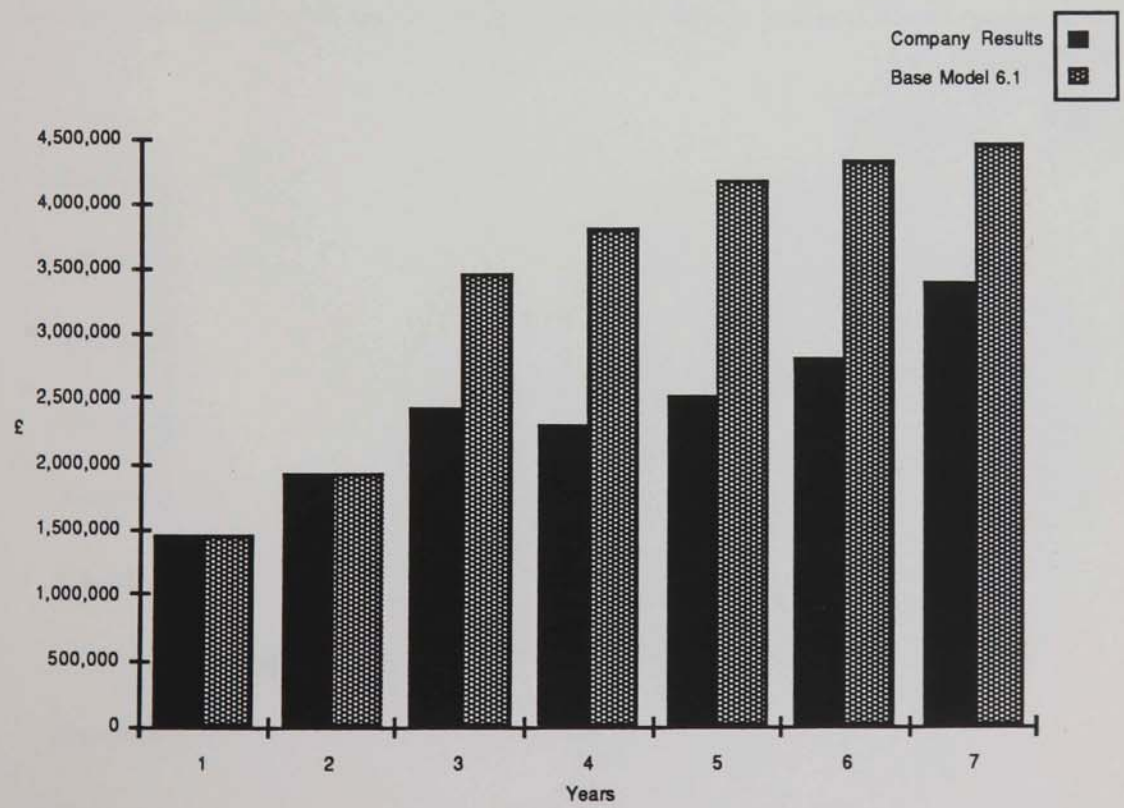

Figure 6.5 - Actual net sales versus base model 6.1 projected net sales

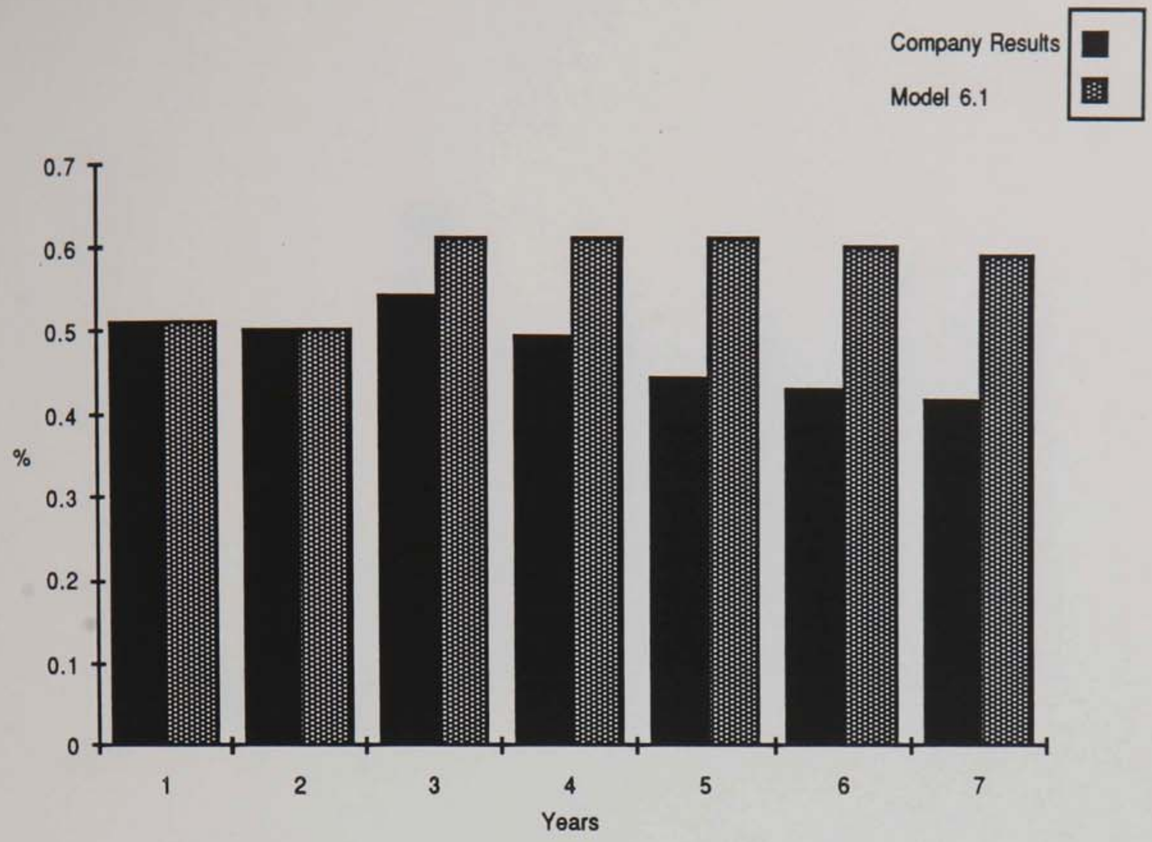

Figure 6.6 - Actual versus base model 6.1 projected gross profit expressed as a percentage

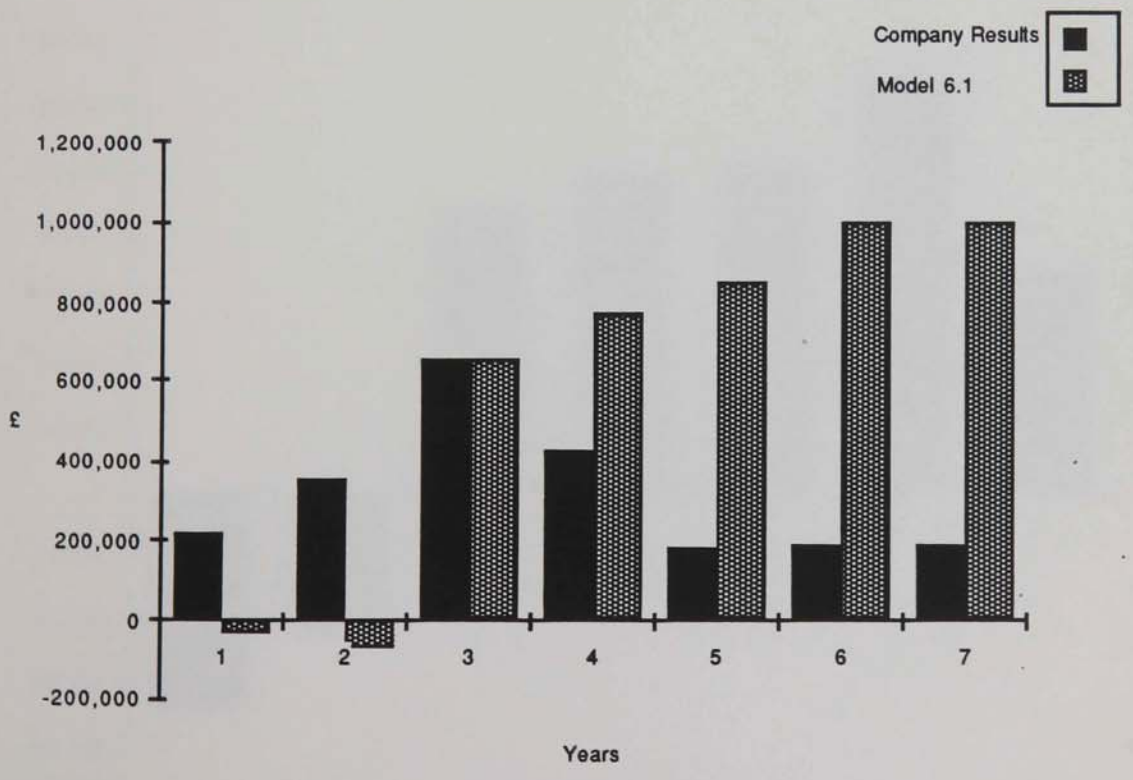

Figure 6.7 - Actual versus base model 6.1 projected net profit

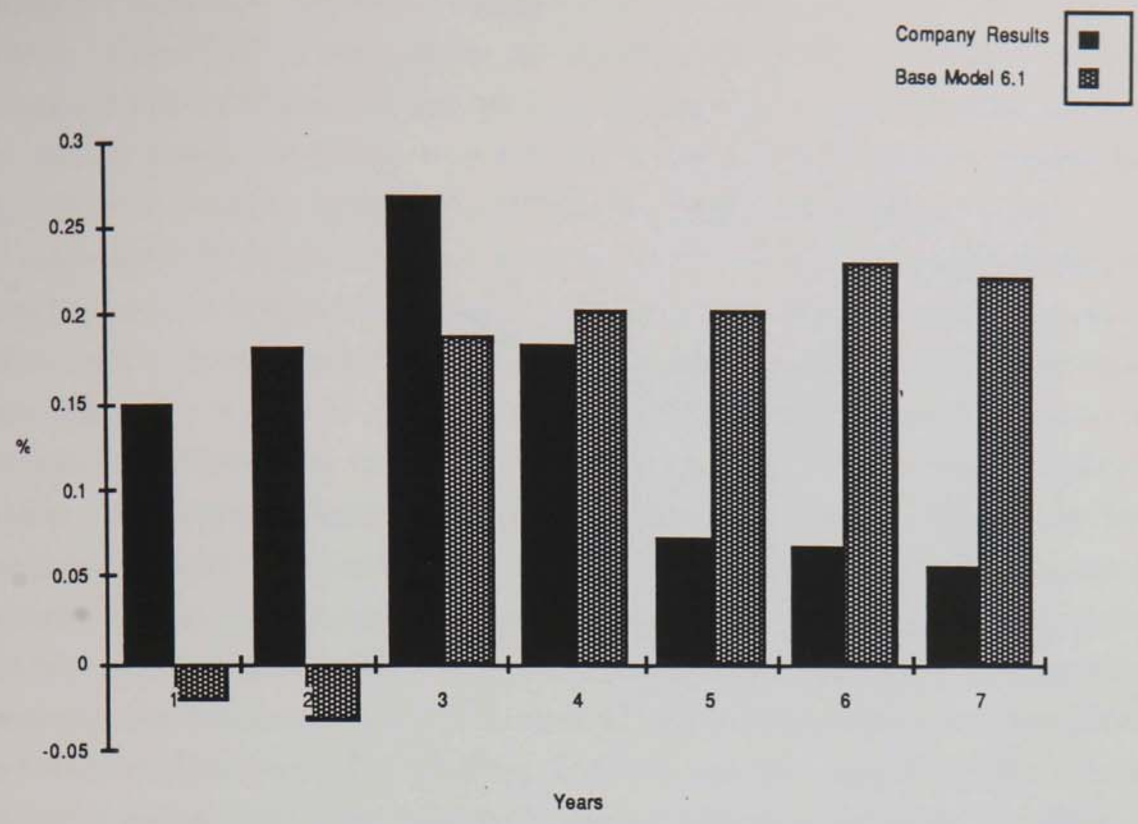

Figure 6.8 - Actual versus model 6.1 projected net profit as a % of sales

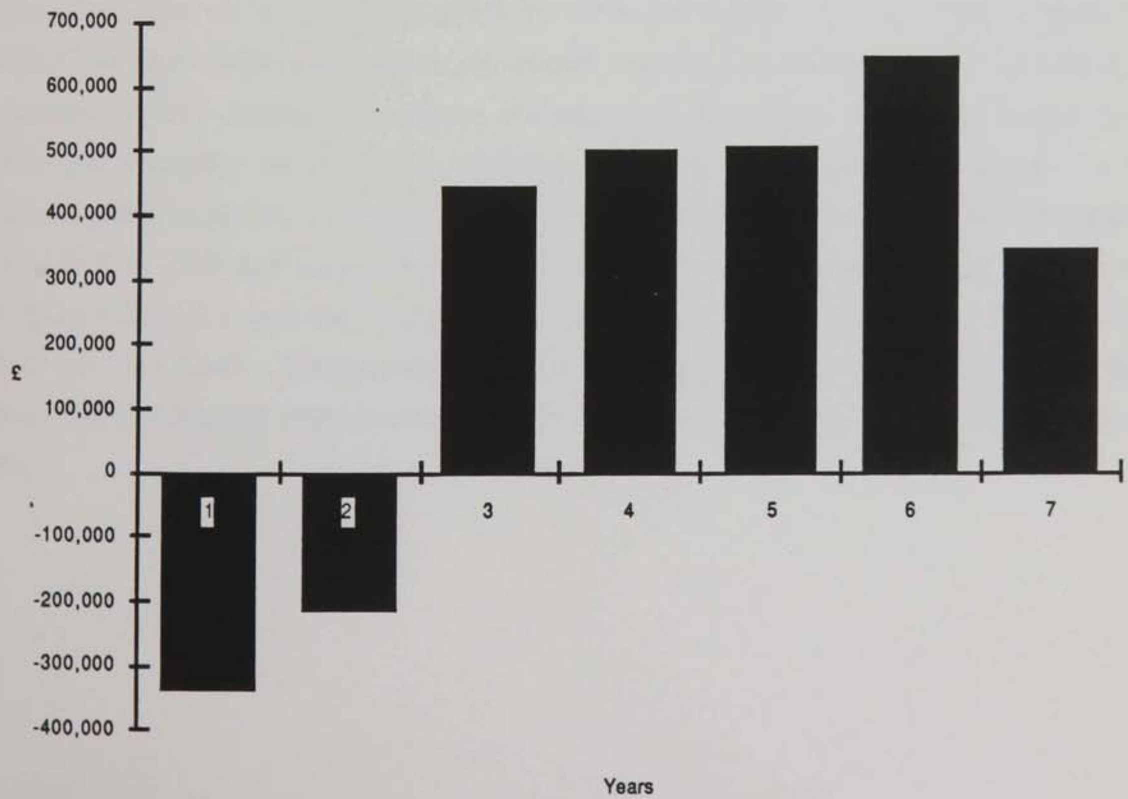

Figure 6.9 - Projection of base model 6.1 cash flow

Models 6.2 and 6.3 - The sales manager saw two main factors as relevant to the viability of the FMS. Firstly, given the already large share of the UK market the company already held, the FMS plan assumed that the market would continue to enjoy a high rate of growth, sufficient to accept the increased output without substantially reducing profit margins. In practice, although the market has continued to grow, it has not maintained the growth rate of the early 1980's. If the FMS had substantially expanded output as planned, the company could have itself in a price cutting situation, as both home and foreign competitors reduced their prices in order to retain their market share. Secondly, in order to avoid the above it was intended to increase exports, and although the company has enjoyed previous export success in the nuclear, and more recently the aerospace markets, the experience of the sales manager is that it has been considerably harder than anticipated. To establish a presence abroad often requires the appointment of an overseas agent and attendance at several of the major engineering trade fairs held abroad each year. With increasing competition in world markets, especially in competing with Japanese competitors backed by large industrial combines, the company has found the costs involved in exporting have risen over the years more than had been anticipated and in many export markets the selling price would be lower. In selling the output produced by the FMS the company would undoubtedly have had to take on overseas agents to whom commission would be paid, typically 10% of the sales value.

In order to model the effect of a reduced average unit sale price of £500, model 6.2 shows the effect of reducing the price by 20% and model 6.2.1 by 10%. Figure 6.10 shows the effect of these models on net profits compared to the base model and the actual company results. Figure 6.11 shows the effect on cash flow. The point to note is that while the company receives less revenue, its costs do not go down since it is still producing the same level of output. In contrast, model 6.3 shows the effect of reducing the output by 20% and model 6.3.1 by 10%. Figure 6.12 compares these models with the base model 6.1 and the company results in terms of net profits and figure 6.13 in terms of cash flow. Compared to model 6.2 and 6.2.1, since the output has been reduced the materials costs is correspondingly lower and the effect upon cash flow is less.

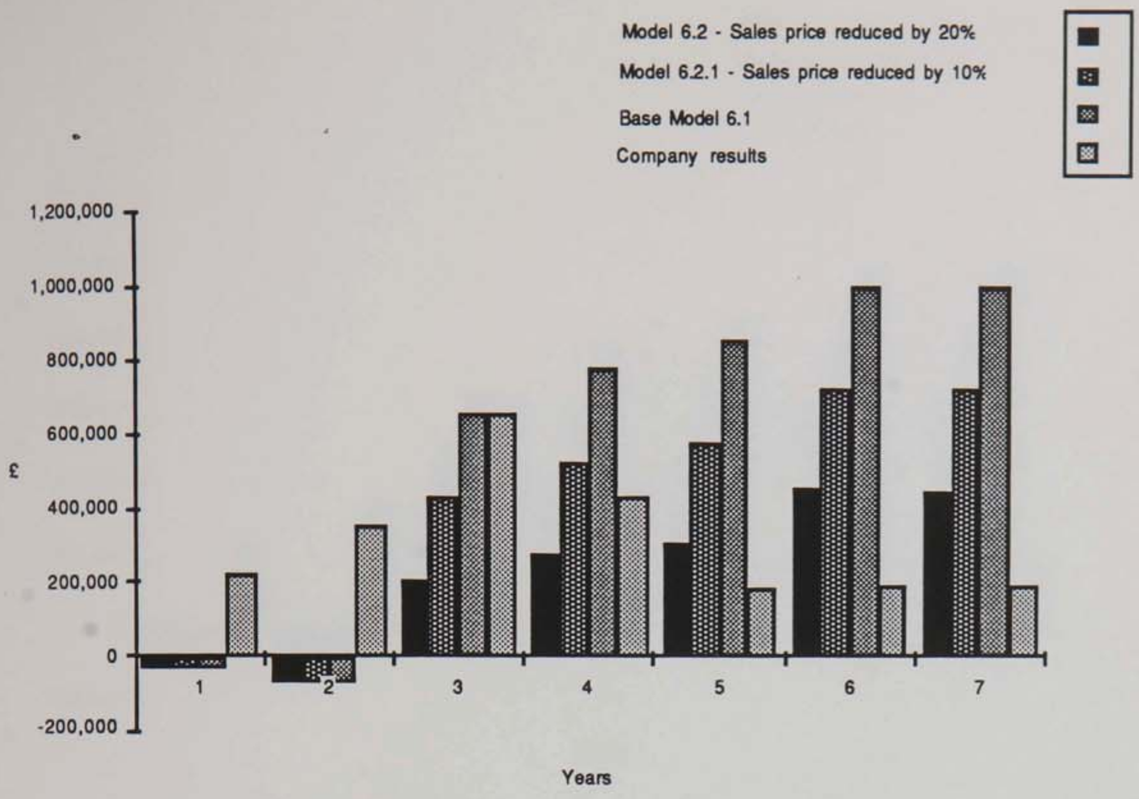

Figure 6.10 - The effect of reduced unit ballscrew sales price on net profits

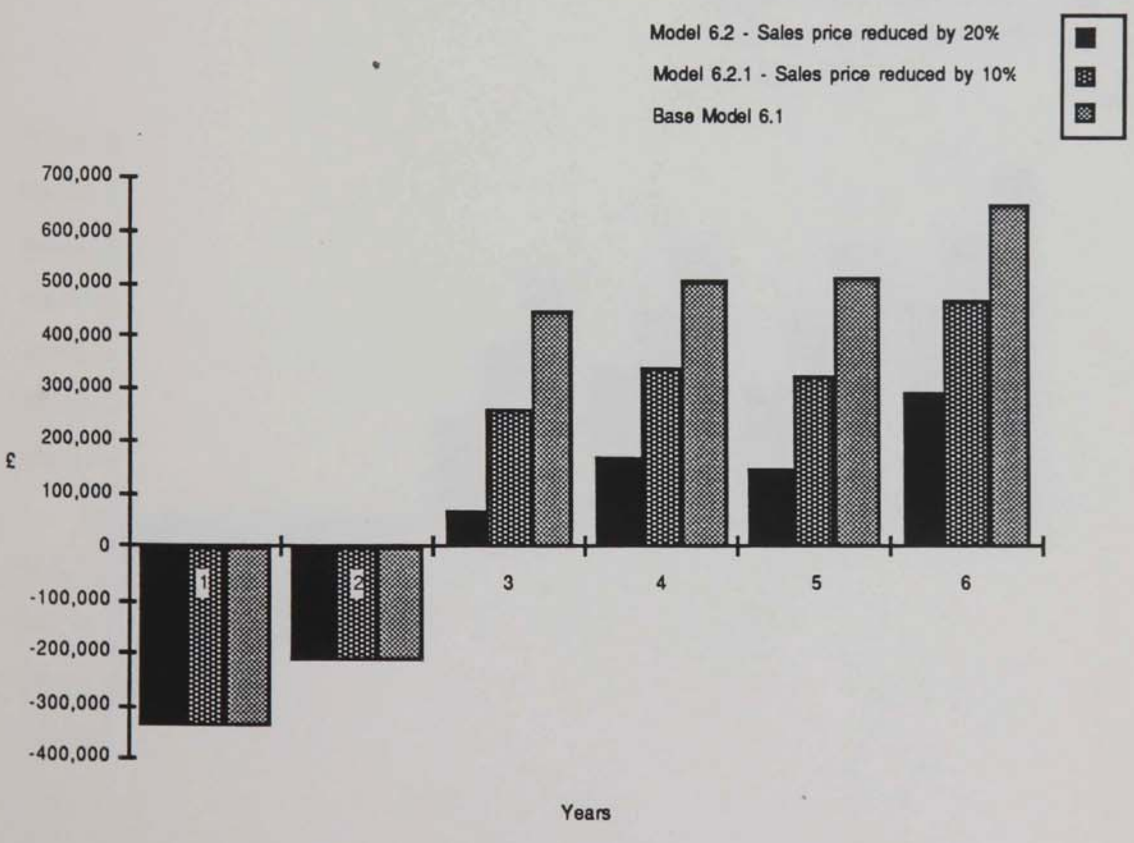

Figure 6.11 - The effect of reduced unit ballscrew sales price on cash flow

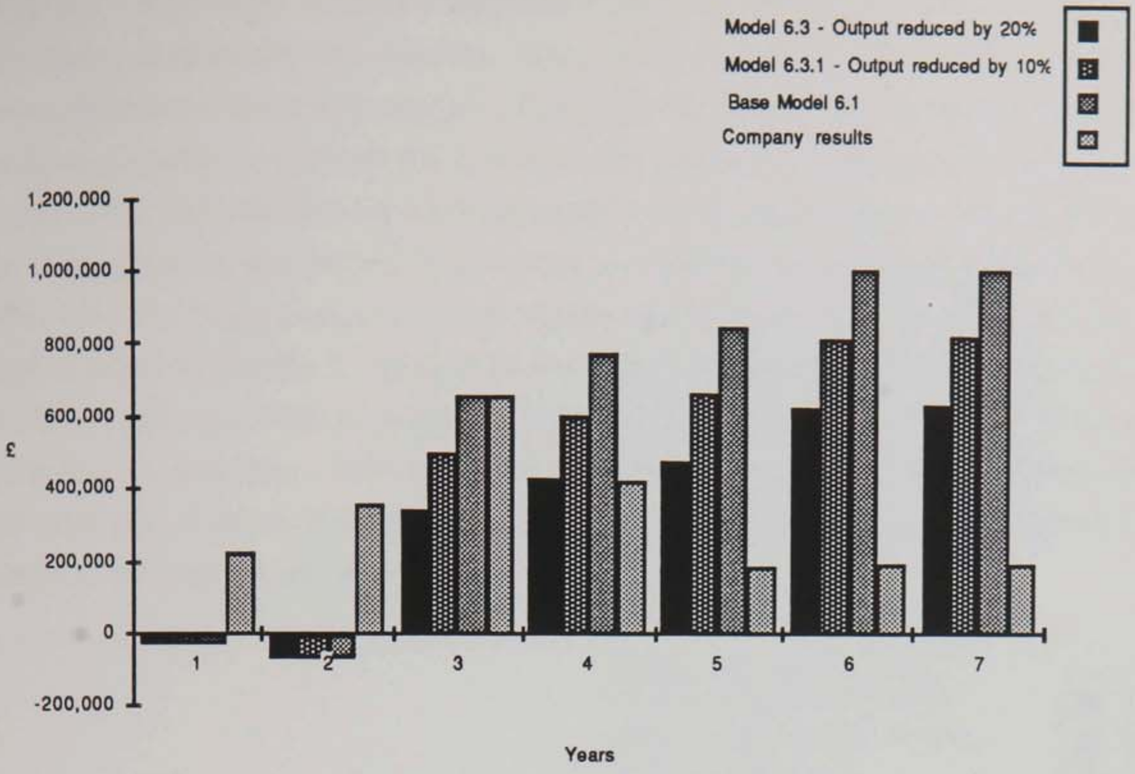

Figure 6.12 - The effect of reduced FMS output on net profits

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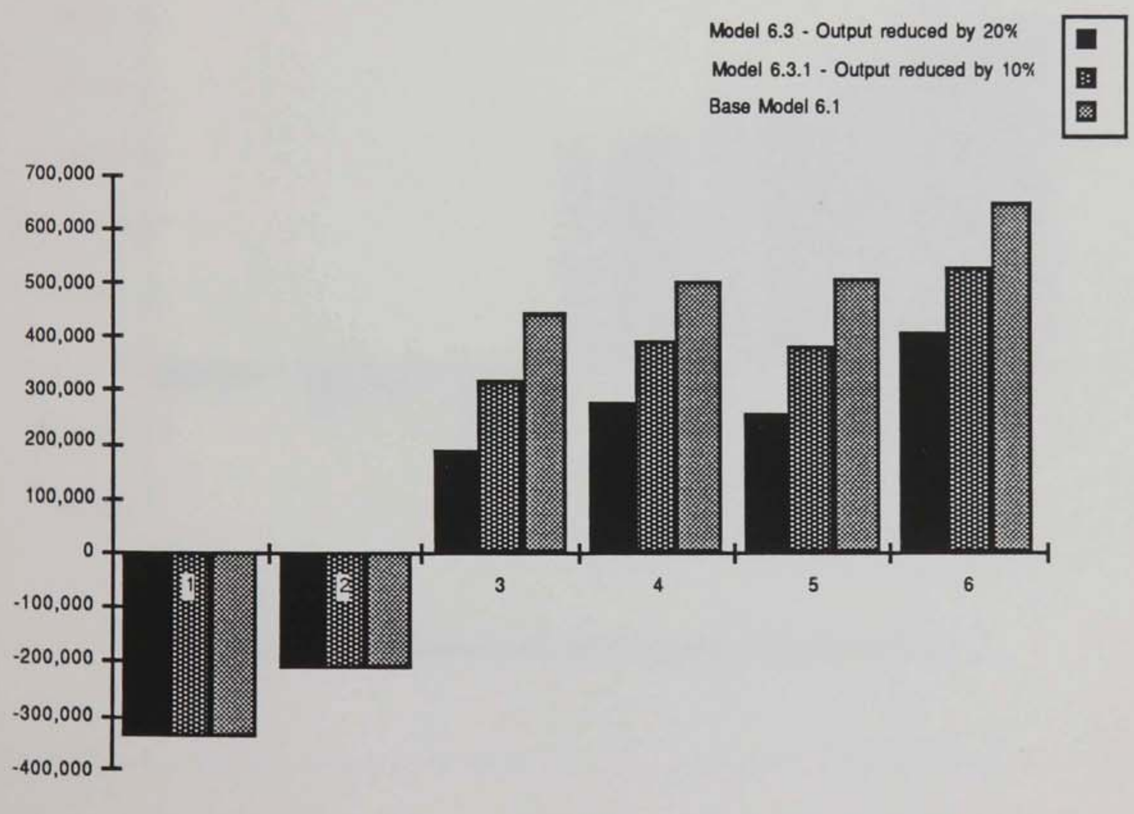

Figure 6.13 - The effect of reduced FMS output on cash flow

Model 6.4 - With many advanced engineering projects, technical problems often result in delayed operation and cost overruns. Since there were no similar FMS's in operation making ballscrews (there still aren't) it would have involved breaking much new ground and the cost implications in the event of technical problems needed to be considered. In model 6.4 it is assumed that the FMS only produces half the planned output in the first year of its operation and that the finance costs are 20% higher than in the base model. In model 6.4.1 the finance costs are 10% higher than planned and only 50% of planned output is achieved in year 3. Model 6.4.2 is as 6.4.1 except that in year 4 the output of the FMS is still only 75% of planned. Figure 6.14 shows the effect on net profits and figure 6.15 on cash flow. With model 6.4.2 the effect is to cause a negative cash flow flow until year 4 which illustrates the serious cost implications for major engineering projects in the event of unforeseen technical difficulties.

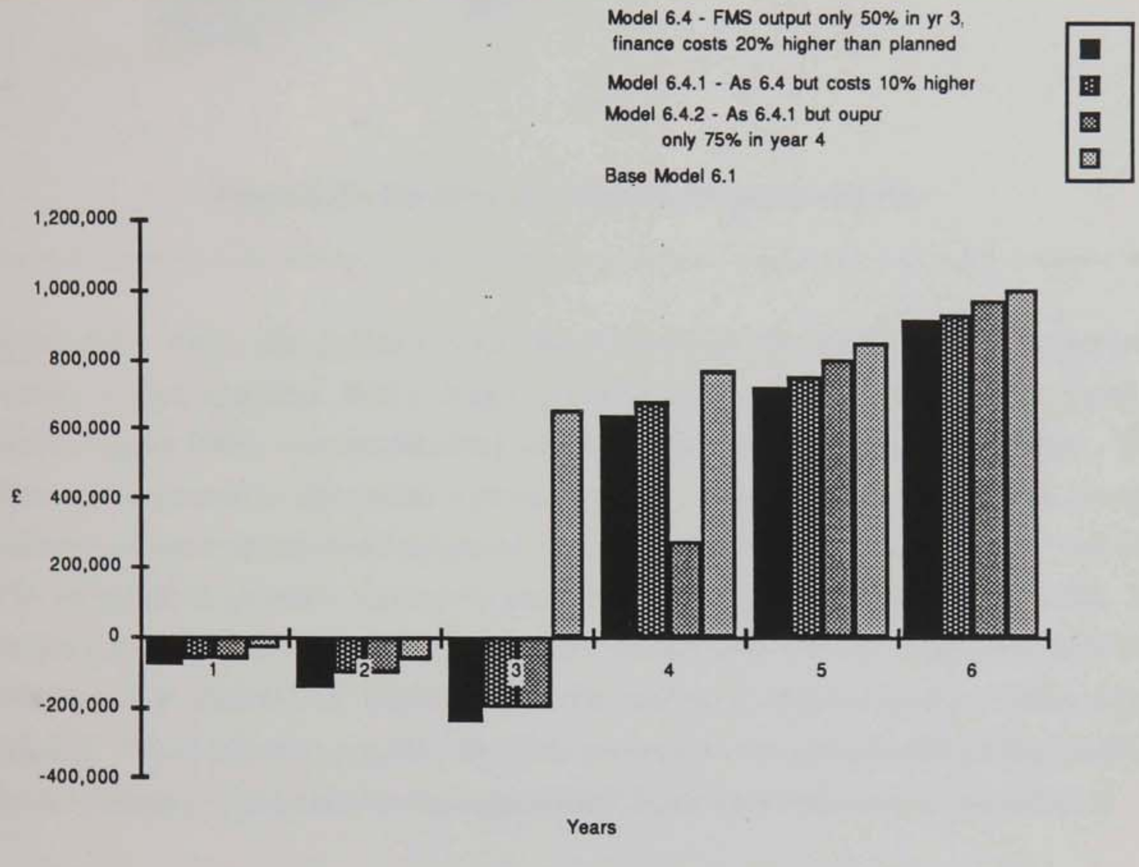

Figure 6.14 - The effect of technical problems on net profits

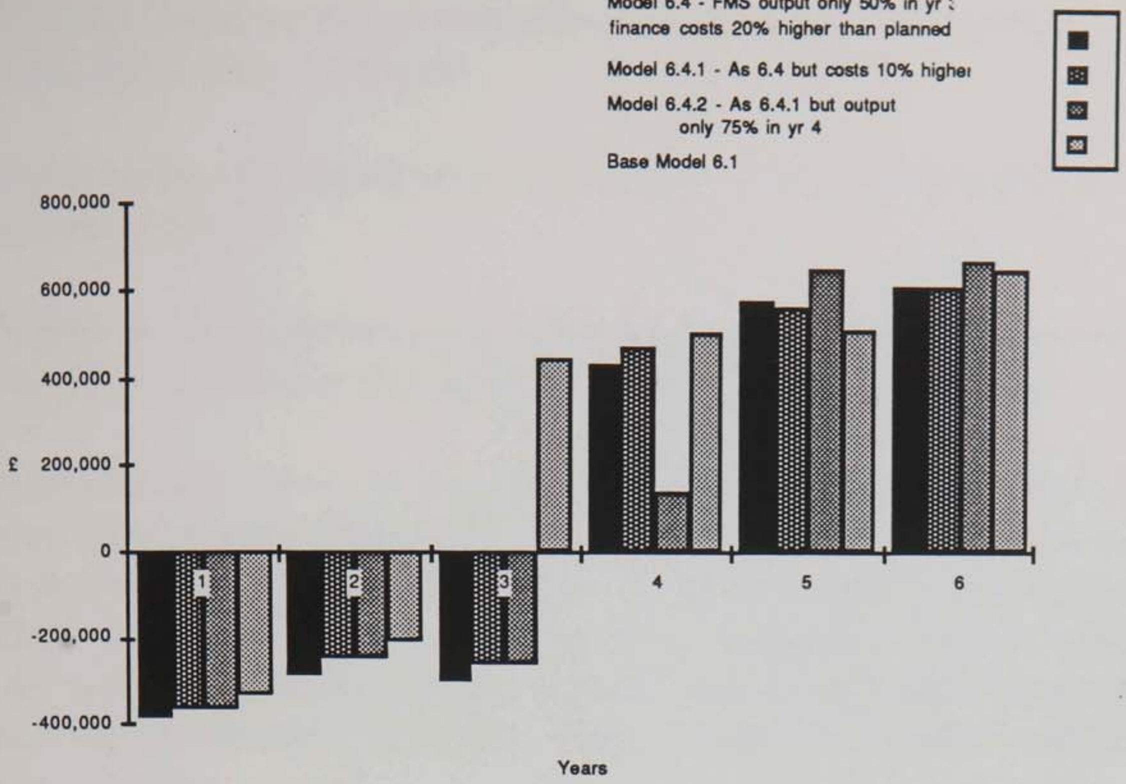

Figure 6.15 - The effect of technical problems on cash flow

Model 6.5 - From the author's own observations of the ballscrew manufacturing process, it was apparent that a major problem the company would have faced in introducing the FMS, was coordinating its output rate with the rest of the factory. This belief was confirmed in discussion with management who suggested that it was the main weakness of the original FMS proposal. The fact was that it did not explain how they were expected to produce ballscrew nuts at the same rate as ballscrew shafts. The company in trying to improve its production techniques over the years, has found the production and assembly of ballscrew nuts the hardest to improve and it remains labour intensive. When asked to quantify the extra production equipment needed the technical director estimated that £1M of extra expenditure would have been needed as follows:

<u>Estimated Extra Production Equipment Required for Ballscrew Nut Manufacture</u>

(1) Milling facilities would need to be improved, two machines costing £50,000 each

(2) Plane Grinding machines, £50,000 x2 (since the FMS study grinding technology has improved with the availability of grinding centres)

(3) Thread Grinders, Matrix 69 machine £150,000 x2

(4) To back up the ballscrew nut thread grinders, an additional 2m machine for the refinement of shafts at £200,000

(5) Improvements to the final assembly area and upgrade test rigs and the clean area, estimated at £50,000

(6) Production Control scheduling management system (a basic feasibility study was carried out in 1980 upon which no subsequent action was taken cost, £5,000)

From these figures it can be seen that a considerable associated investment would have been needed to operate the FMS successfully. Model 6.5.1 uses the same finance costs as for the FMS at £35 per £1,000 borrowed per month, requiring extra finance costs of £252K per annum for five years. This assumes that the equipment is implemented after the two year FMS development in year 3. Model 6.5.1 shows the effect if the extra finance costs are only 50% of model 6.5. Figure 6.16 shows the net profit and figure 6.17 the cashflow.

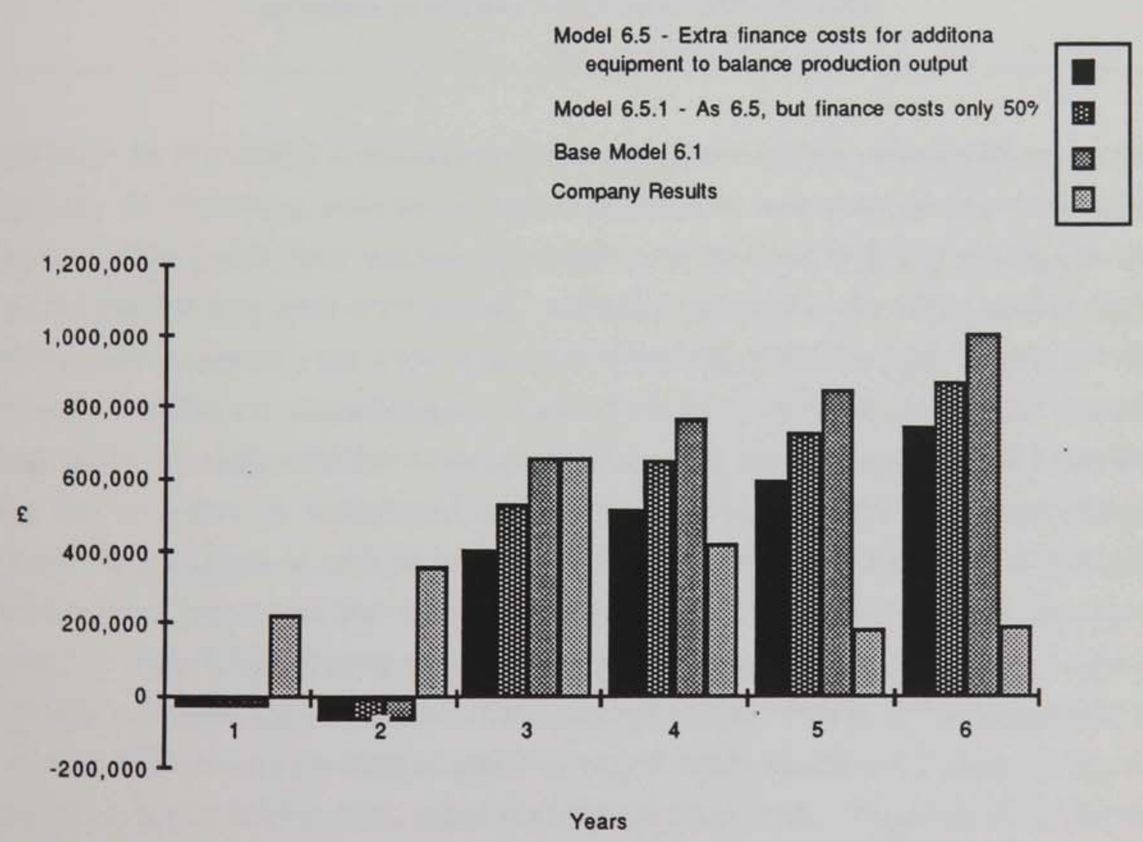

Figure 6.16 - The effect of extra finance costs for additional equipment to balance production output of FMS on net profit

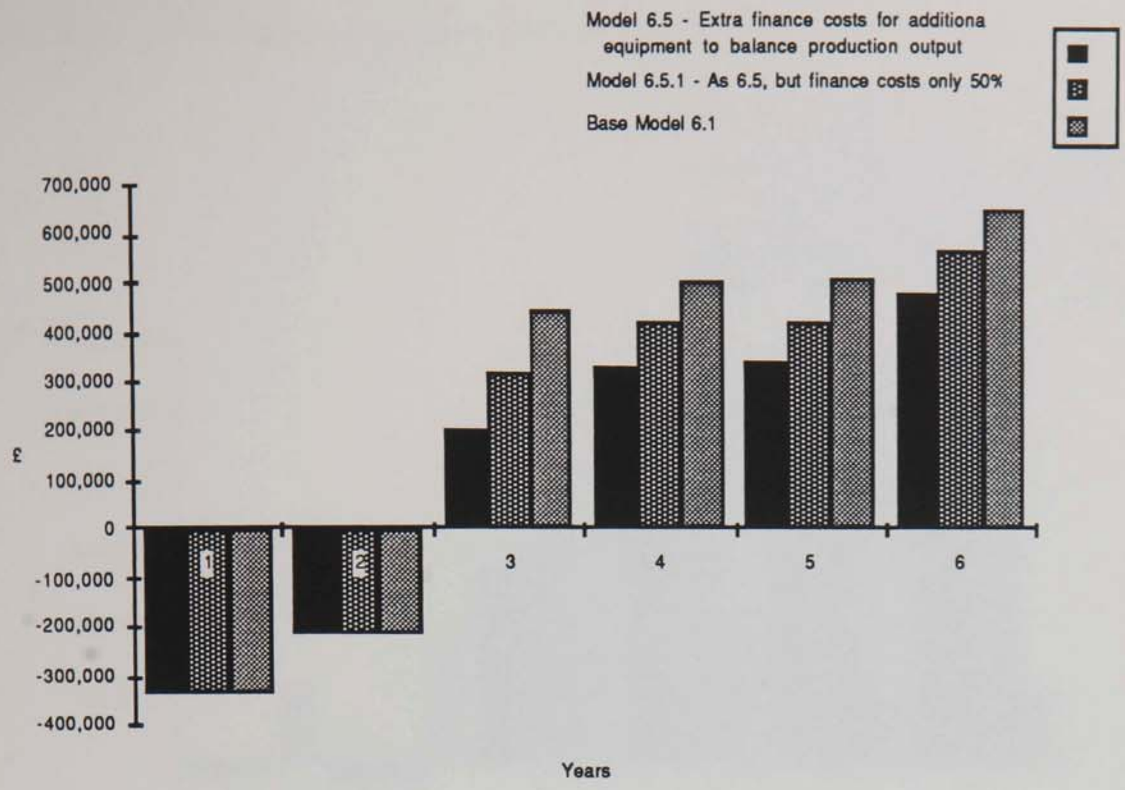

Figure 6.17 - The effect of extra finance costs for additional equipment to balance production output of FMS on cash flow

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Model 6.6 - In this model it assumed that the manpower will be redeployed rather than displaced. In discussion with the technical director, he was most insistent that while companies often justify their machine investments on the basis of labour savings, he was skeptical whether they were often actually realised in practice to the extent used in many justifications. Certainly, his experience had been that with the high degree of skill involved in ballscrew manufacture, it was difficult to remove the labour element substantially. He suggested that when operational, since the FMS operated on a two shift basis, labour would be redeployed on this basis. Since the FMS proposal did not automate final inspection, only in-process inspection, then extra manpower would need to be deployed into inspection tasks. In addition, in order to keep up with the rate of production of the FMS in terms of ballscrew nuts, manpower would have to be used on machines to achieve this, and also in final assembly tasks. Model 6.6 assumes that the productive labour costs are held constant in year 3 while model 6.6.1 assumes that the reduction in labour is only 10% rather than the planned 20%. Figure 6.18 shows that the effect upon net profits is not substantial in this case.

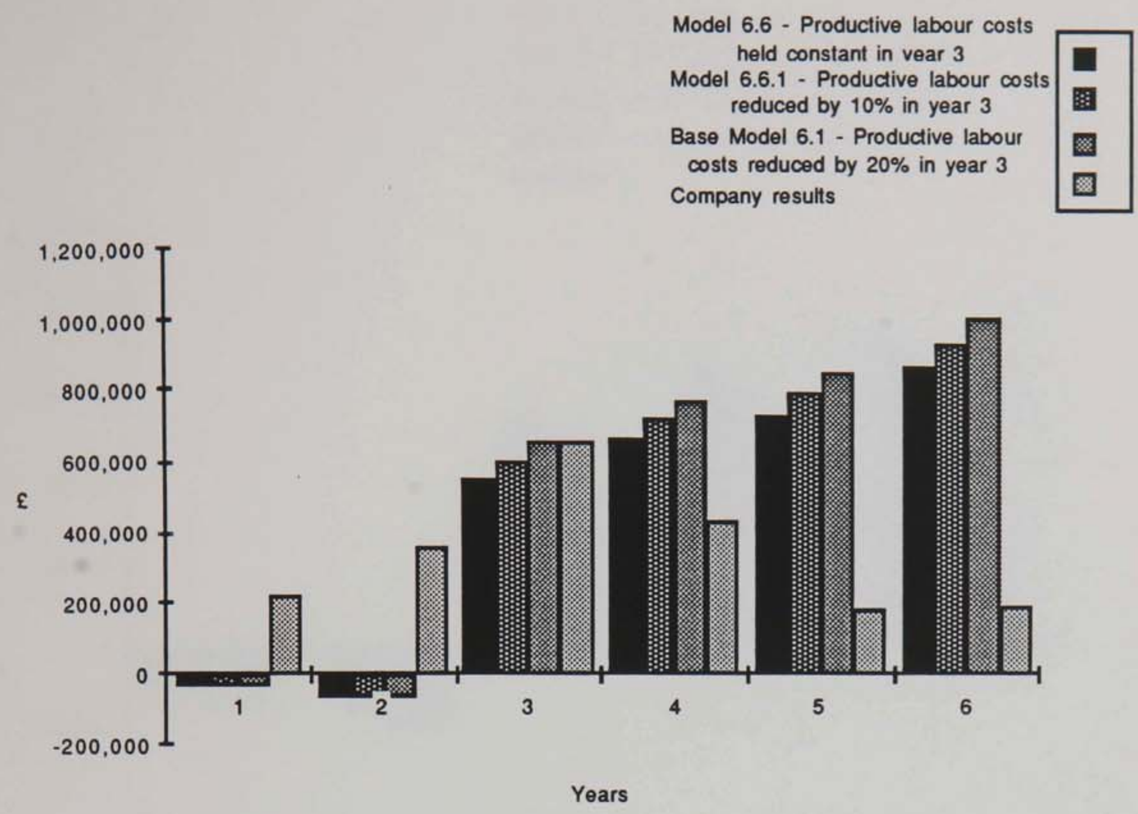

Figure 6.18 - The effect upon net profit of varying the reduction in productive labour planned as a result of the FMS

Model 6.7 - With a substantial increase in output the sales manager suggested that additional marketing expenses would probably be required in exhibitions and commissions to agents in order to obtain export orders. Increased emphasis would need to have been given to developing the profile of the company abroad two years prior to the FMS becoming operational and in model 6.7 around £100K is added to the sales department budget spread over various categories of costs. Originally, the company expected that the increased production could be sold with a similar level of overhead, but as the technical director pointed out there is a tendency for overhead costs to rise disproportionately. While direct labour costs may go down with more automated machines, the company requires new skills in design, computing and technical customer support which are relatively more expensive to obtain. Model 6.7.1 is as 6.7 except that around £50K extra is added to the overheads per annum allocated over various cost categories. Model 6.7.2 takes the values from 6.7.1 and combines these with the effect of finance costs being 10% higher, as may occur for higher development costs. Model 6.7.3 portrays the effect of superimposing a 10% lower unit sales cost on model 6.7.2. Figure 6.19 shows the projected net profit results of these models and figure 6.20 the cash flow. Models 6.7 and 6.7.1 are reproduced in appendices 6.2 and 6.3.

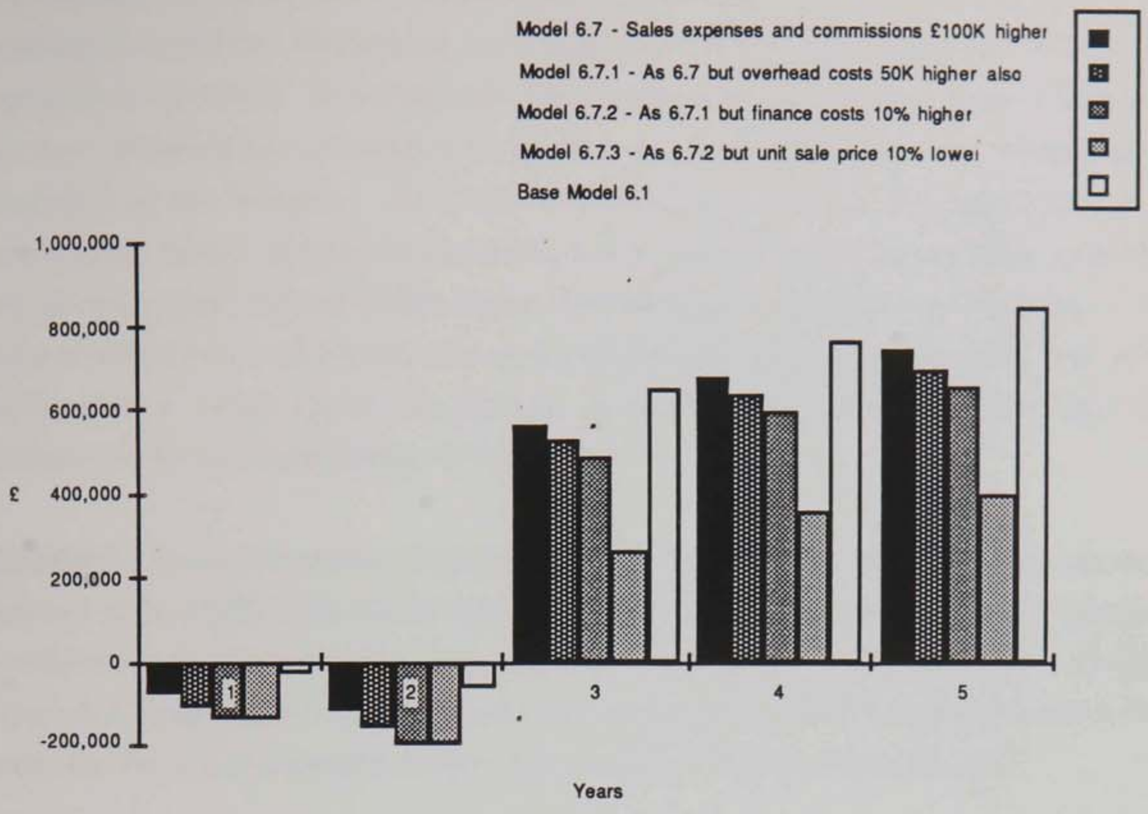

Figure 6.19 - The effect upon net profit of higher overhead costs

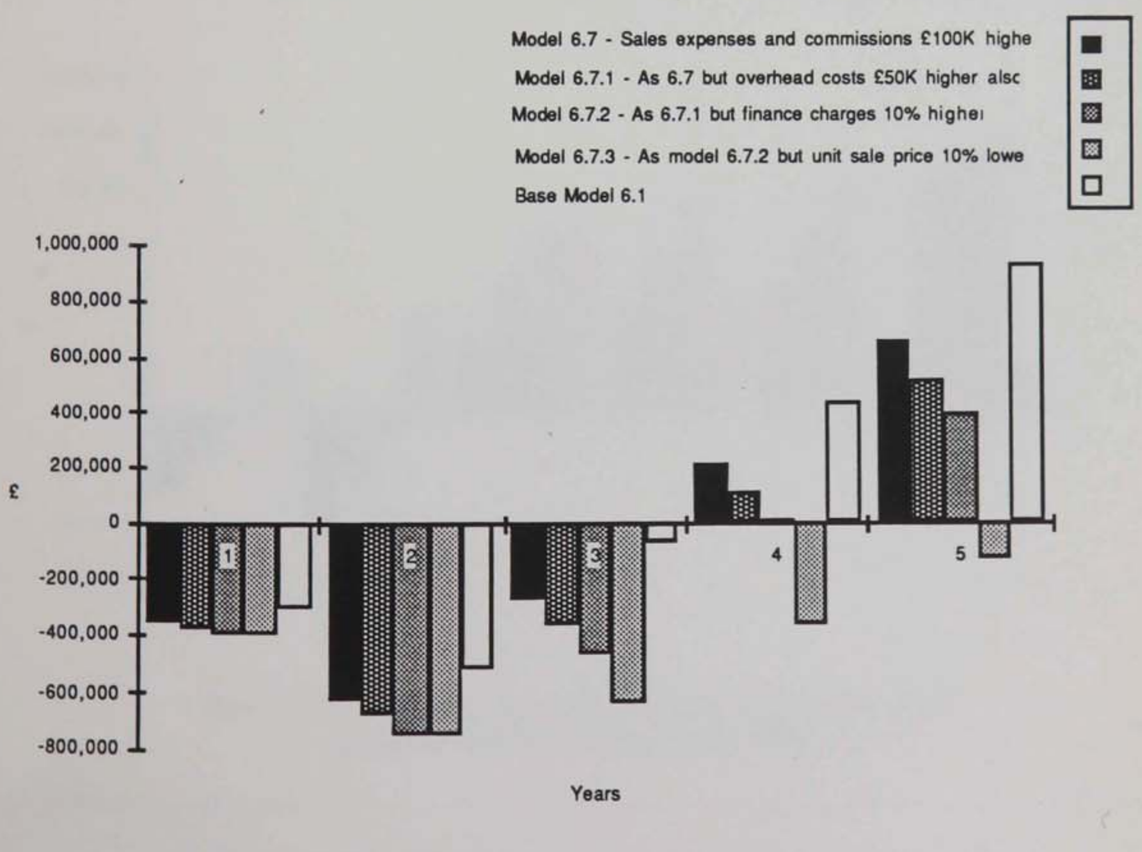

Figure 6.20 - The effect upon cashflow of higher overhead costs

In evaluating the cost of new investment plans, there is an understandable need to spend considerable effort on identifying, to a high level of precision, the costs of the main capital items involved. However, care also needs to be given to the wider cost effects that new technologies can bring to a business, many of which are often realised in the overheads of the business. As model 6.7 illustrates, and as the experience of the company has shown, increasing competition often makes export markets less profitable, and the non-capital costs are often higher than anticipated and erode profitability. Also since overhead costs are usually spread across a whole range of items rather than being attributed to a single capital investment, the gradual buildup of overhead costs in a business can be less immediately obvious.

Model 6.8 - To test the relative importance of the 50% government grant to the financial viability of the FMS, in model 6.8 the company is assumed not to receive any grant aid so effectively doubling the financing costs. In model 6.8.1 the grant level is only 25%. Figure 6.21 shows the projected net profits compared to the base model (with a 50% grant) and the actual company results, while figure 6.22 shows the cash flow.

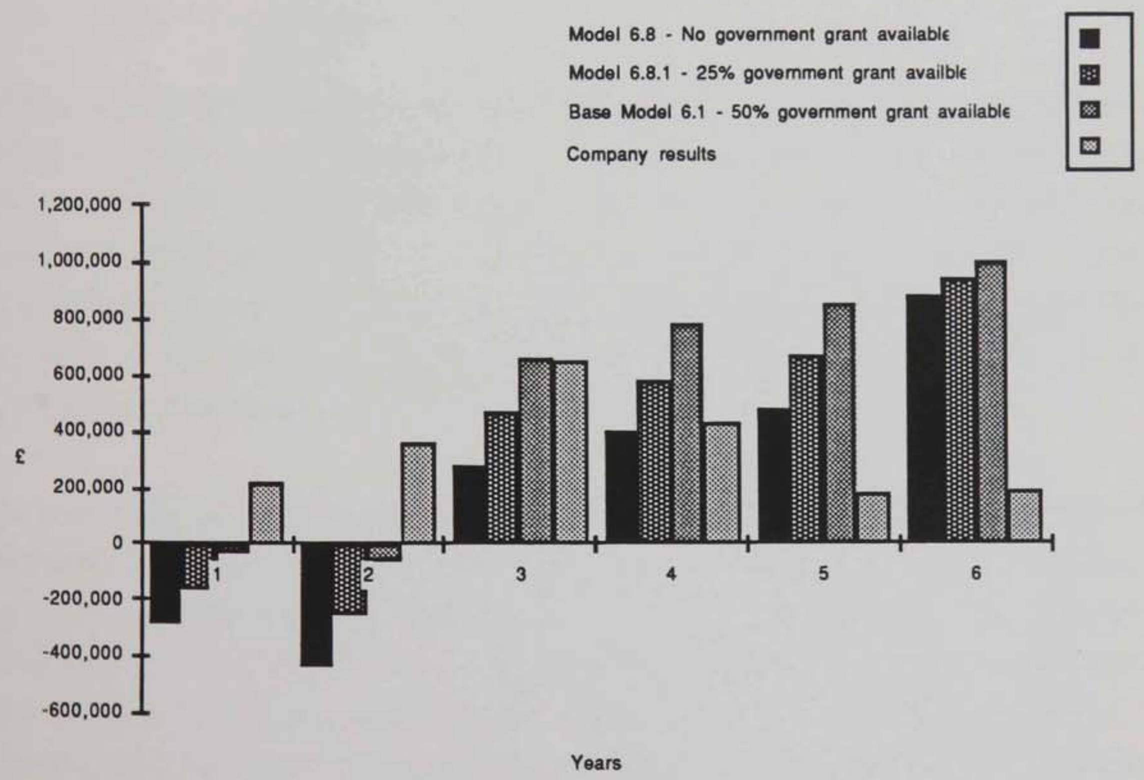

Figure 6.21 - The effect upon net profits of differing levels of government grant support for the FMS

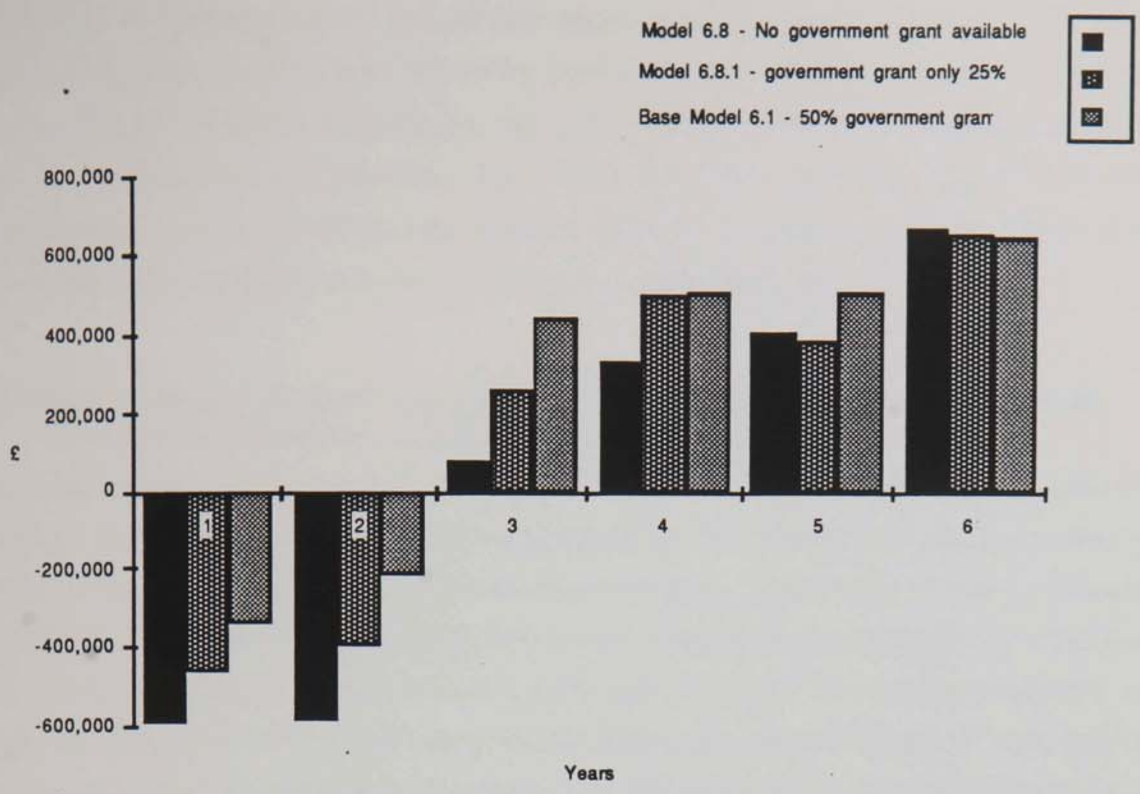

Figure 6.22 - The effect upon cash flow of differing levels of government grant support for the FMS

Without government support, the profitability of the FMS is substantially reduced and the period of negative cash flow increased. An interesting question that arises is whether Government grant money is well spent on making viable, projects of this kind which would not otherwise be so. It is noticeable that the grant scheme for advanced manufacturing has now changed to placing less emphasis on subsidising the capital costs and more on assisting with the cost of the initial feasibility study stage of a project. (Source: discussion with the DTI in Birmingham).

The results of the models indicate that the FMS in the long term could have been profitable, but that it may have taken longer than expected, and involve considerably more expense than planned. During the discussions with the individual managers involved in the FMS study, several shortcomings of the project as outlined in the models were identified which were not fully appreciated at the time. The most critical part of the project would have been the strain placed upon the cashflow in the two year development period. Any problems during this stage which added substantially to the cost or reduced output and revenue when operational, could have have extended the period of negative cash flow. However, strictly in terms of the profit and loss budget, it may well have been in profit. The history of advanced engineering projects is littered with examples of cost and time overruns due to unforeseen problems. In view of this, the author would have liked to perform some form of risk analysis on the models, but the information available for this purpose was felt to be inadequate to produce any really meaningful results. With the benefit of hindsight, the author believes that the management made the correct decision not to introduce the FMS, the risks involved would have been considerable, and as shown by the models, difficult to quantify, and for a firm of this size without the resources of a major company, unacceptably so.

6.6 Wider Effects of FMS on Company - The Introduction of CAD in Production Planning and Design

Since the majority of the company's output of ballscrews are manufactured to individual customer requirements with no real standard range, the company expends considerable effort in the design and production planning processes. The length of time required for design is a key factor in determining the overall manufacturing leadtime of a ballscrew and forms a major part of the overall cost of manufacture. The company already used desk-top computers which had some simple Computer-Aided-Design (CAD) facilities which were used for design calculations and for generating process plans and CNC programs. However, the large growth in demand the company had experienced in the the 1980's meant that the design department was already under strain in keeping up with the demands placed upon it, even without the higher volumes of production envisaged by the introduction of the FMS. Company management saw the reduction of design leadtime as a key objective, which could be achieved through the introduction of a *second generation* CAD system. This shows how change in one technological system in a company, can have wider effects in other aspects of the company's activities.

While computer support has long been available for design work, it was not until 1968-69 that companies such as Calma, Applicon and Computervision started to market internally integrated systems such as computer-aided-design (CAD) based on large mainframe computers and later on mini-computers. However, the prohibitive cost of the early systems precluded their adoption except by large companies. By far the most remarkable development in CAD during the 1980's from the point of view of smaller and medium sized firms, has been the appearance and growth of personal computer (PC) based systems. Given that the cost of a basic CAD system, including software, PC and plotter, can now be purchased for around £20,000, this puts the technology within the range of many smaller companies. In many respects the process of technological diffusion has parallels to those of CNC lathes and machining centres, which began several years earlier. Users are finding that 'personnel computer-based systems often give them 70 per cent of the benefits for 20 per cent of the cost....' (*Design Graphics World,* 1985). The result of this has been the emergence of a whole new market segment, and it is estimated (Edquist & Jacobsson, 1988) that more than one third of all CAD stations now in use are PC-based. The move to PC-based systems is expected to increase rapidly as more powerful and sophisticated machines with improved displays are marketed, and by 1990, it is estimated that 'personal computer power will have increased so much that more than 9 of every 10 CAD/CAM, CAE seats will use a personnel or desktop computer' (*Design Graphics,* 1985).

The most frequently cited reasons for introducing CAD are usually given as:

(1) Improved productivity of designers and draughtsmen

(2) Reducing the leadtime from order to delivery or from conception to production

(3) Performing work which is too complex for manual design and drawing

The main reasons for introducing CAD vary between different industries. In the electronics industry for example, the level of complexity involved in the design and production of integrated circuits makes CAD technology essential. In the automotive and aerospace industries, where CAD has had a relatively long application, the main objective is to shorten the leadtime and perfecting product design. In these industries, the cost of using CAD is relatively insignificant in relation to the total production cost. By contrast, in the mechanical engineering sector, Arnold & Senker (1982) suggest that while reducing leadtime is still important, the use of CAD in this sector had two other characteristics. Firstly, there is a larger element of experimentation, with firms acquiring CAD to learn about the technique, rather than for immediate productivity gains. Secondly, a significant amount of the output of this sector is from machines tailored to the demand from each customer, where the firms produce variants of the same basic design. The property of CAD in enabling the reuse of computer data, means that the design and particularly draughting work can be greatly rationalised. In terms of productivity increases, comparing design work performed manually, with that carried out using CAD, Hatvany et al (1981) suggest 'typical' higher labour productivity ratios are 4.5 to 1 for simple design and draughting with dimensioning and 2.5 for more complex designs using CAD. In a survey of 34 firms Arnold and Senker (1982), calculated the mean of the claimed productivity increases attributed to CAD in relation to manual draughting and found it to be 2.74 to 1. Analysing only the firms with several years experience with CAD resulted in an increase of this ratio to 3.33 to 1. In terms of financial justification, 25 of the firms had exclusively used projected labour savings to justify the investment, 5 had not conducted any financial analysis, while the remaining companies gave no reason for their investment decision.

6.7 Existing Company Ballscrew Design Process

When a customer approaches the company with a requirement for a ballscrew, the sales staff will provide them with a quotation from the design section based on the technical information supplied by the customer. The price will be determined by the size of the ballscrew, the number required and the amount of design and planning work likely to be required. If an order is placed, the customer's drawings are sent to the design section and preliminary design work begins. The design manager has three designers working for him and the majority of their work is the design and detailing of high precision customised ballscrews. Although orders are sometimes repeats, most of the work begins with drawings supplied by the customer, who will dictate the space envelope including the length of the shaft, the length of the nut and the end detail of the shaft, together with the pitch and loading and life requirements, to produce a basic skeleton design.

The company maintains a ballscrew data file on computer in which assemblies are classified by basic information such as the PCD, the pitch, the ball diameter, the type of return and the preload details. This ballscrew data file can be used to match customer orders against previously manufactured designs. The design of a ballscrew will usually start with the use of a computer program to calculate load ratings from the basic parameters according to BS6101. If these are satisfactory, another program calculates more parameters concerning the type of return, and whirling, buckling and loading. These programs together allow a design to be specified that meets the customers requirements. Other programs are also used to help define the ballscrew and nuts. Perhaps the most time efficient is that used to calculate the details of the inserts for nuts with internal returns. The program also calculates the coordinates of the 3D profile of the track of the insert which is then stored on a floppy disk. The disk is then transferred to the planning section for CNC programming, while the insert details are printed and passed to the designers.

On average, most ballscrew design work take about four days and consist of a number of fairly small items. The range of drawings produced in a typical month breakdown as follows:

Drawing Size	Number Produced
A0	6
A1	35
A2	13
A3	9
A4	30

Nearly all the drawings that are produced are variations on themes. Most of the shafts are very similar but with different end detail, and the nuts tend to come in a limited number of configurations. Much of the draughting time is spent redrawing very similar components. The completed drawings and corresponding parts list are then the basis on which assemblies are manufactured; subsequent modifications are monitored with drawing office instruction forms. Every six to eight weeks, whenever a hundred or more drawings have been accumulated, they are sent for microfilming and insertion in aperture cards. A procedure has been set up for refilming modified drawings and ensuring that old aperture cards are removed from the files when they are replaced by the new ones. One of the main problems facing the design section was that of leadtime. Sometimes the delay in preparing a design arises from such factors as the time lag between asking a customer to approve modifications and receiving the approval. Thus, it was felt that although the CAD system would reduce the overall design leadtime, the full possible reductions would still not be fully realised.

6.8 Existing Company Production Planning Process

The planning engineer has two major tasks. The first is to produce the production plans for all manufactured components, and the second is to write the CNC programs needed to make the components. Ideally, the production planning will be started before final approval of the design, but often last minute changes in design delay the planning. Production planning involves the preparation of a route-card and the majority of this work is done on a desk-top computer. The planning engineer has several Basic programs which by asking a series of interactive questions, produces planning information tailored to the component in sufficient detail for manufacture. Thus, a route-card for a nearly standard component can be generated very quickly indeed and only needs additional modification if there are any non-standard features. About 50% of customer orders received require new CNC programming, and it is this work that occupies most of the time.

At the time of the introduction of CAD the company had a variety of manual and CNC machine tools. For turning there were six manual lathes (mostly Dean, Smith & Grace); there are two Huskeys with GE1050 controllers which are used mainly for machining nuts, and two Butlers with Westinghouse controllers which are used mainly for shafts. For milling there is a Bridgeport CNC 5-axis machine with a Bridgeport controller (where the 5 axes comprise three ordinary axes, a rotary table, and a movable knee); a Matrix V50 3-axis machine again with a GE1050 controller; a Bridgeport 3-axis mill with a retrofitted Anilam Crusader controller and also two Kearney & Trecker manual milling machines for general components. CNC programs for turning are produced utilising a series of Basic programs written by the planning engineer which are generic. To produce an NC program for a particular turned component is merely a matter of editing a Basic program, inserting some numerical values, running the program on the computer and punching the tape. The NC programs for milling are written using the facilities of an AP100 CAM system. This is used largely for two things; first, for milling slots in nuts for inserts, and second, for milling the inserts themselves. The AP100 package was used because it has geometric construction facilities, useful for finding the coordinates of obscure points on slots for inserts. However, the AP100 package was no longer efficiently supported by its supplying company, ECS, and there were no post-processors for the Anilam controller. For milling inserts, the NC program generated by the system is modified and then has the coordinate information from the design computer appended as a subroutine.

From the survey of the design and planning sections, the design manager considered that there were two major benefits arising from CAD which could be quantified with a high degree of certainty. The first would be a substantial saving in time taken to draw any component and the second is, that any activity down-stream of the design will take less time if it is done on the a CAD system. Other benefits that were thought to accrue were improved quality, fewer errors, more reuse of previous designs, and more quotation drawings to present to customers. These benefits were very much in line with the literature on the subject.

In the design section the majority of draughting work performed was of a fairly limited range of components, most of which vary only slightly from previous designs. This type of work was evidently suited for CAD systems because its efficiency in being able to recall previous drawings, modify them sightly and re-issue them. The design manager estimated that a productivity improvement of 3:1 could be achieved, if the section could develop general designs for most of the common components, which only need modifying to add specific customers details. It was also considered that if it was was possible to install design calculation programs on the computer that operates the CAD system, then it would be possible to link design calculations and draughting. This could be achieved through the use of a parametric design system in which a general design is recalled, the values of the parameters fed in, and the CAD system does the processing to produce the required drawing. The parameters can be either calculated inside the CAD system by rewriting the design programs in macro language, or by establishing an interface between an output file from the design programs and parametric facility of the CAD system. Such a system would offer great potential, but it was decided that since such an innovation would take some time to establish, the company would therefore initially invest in CAD without such an facility and add it at a later date.

6.9 Analysis of Benefits of CAD system

As with other advanced manufacturing technologies, there is a large volume of literature discussing the economic justification of CAD/CAM (ie. Currie, 1989; Fatheldin et al, 1981; Primrose et al, 1985) much of which centres of the perceived *intangible* benefits. Using a DCF NPV analysis, table 6.11 shows a projected cash flow for the CAD system based on the company's financial assumptions. The company budgeted for a cost of £30,000 and assumed that support and maintenance would be 10% of the capital cost per year with the investment being written off after the fifth year. £10,000 was allowed for staff training costs. Capital allowances were not taken into consideration, but would have improved the cashflow position. Included in the table is a figure of £15,000 for a Computer-Aided-Manufacture (CAM) facility which would be added at the start of the third year. This would be a second workstation linked to the first with additional software for use in CNC programming. The transfer of existing programs was estimated to cost £3,000 for CAD and £1,500 for CAM. In quantifying the economic benefit of the system, this was based on the equivalent extra manhours through increased productivity that the system would provide. This was estimated at £20,000 per annum for the CAD system and £10,000 per annum for the CAM system. Figure 6.23 shows graphically the project cashflow at discounted rates of 10, 15, and 20 percent, with the investment moving into profit in year 4. This illustrates how with advanced manufacturing technologies, the payback period can often be longer. If the company required an investment to pay for itself inside the standard two year payback period, which applies to many companies, then this project would have been rejected.

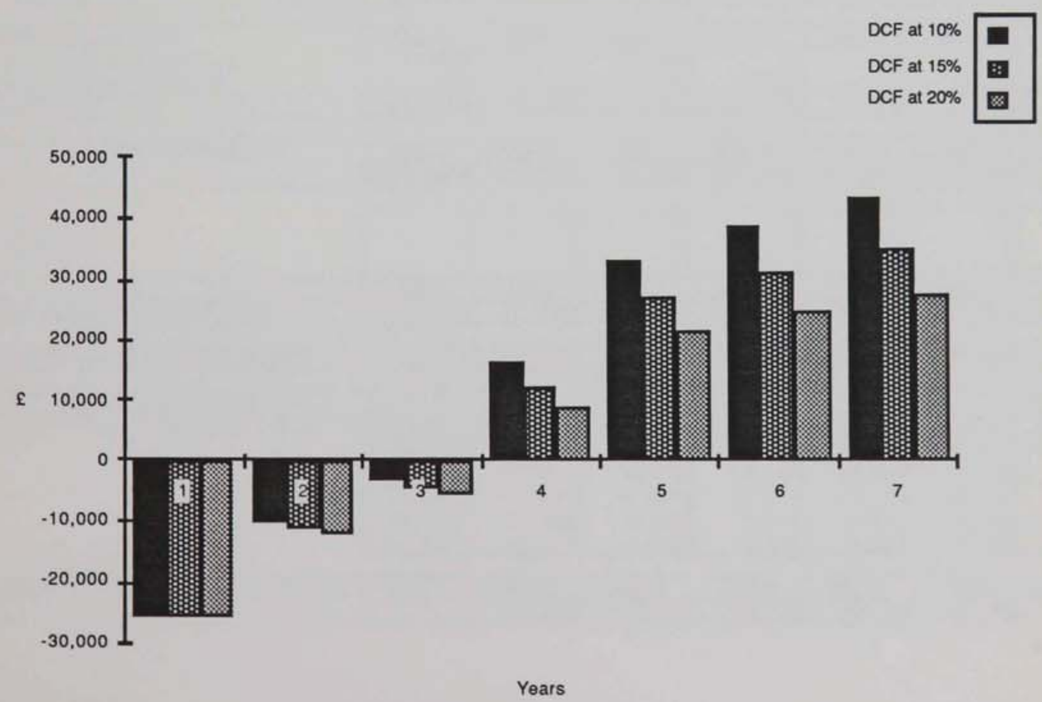

Figure 6.23 - DCF analysis of CAD cashflow using NPV

TABLE 6.11

DCF CASHFLOW ANALYSIS OF COMPUTER-AIDED-DESIGN SYSTEM

1	SECTION ONE - CAPITAL INVESTMENT	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
1.1	Capital Cost of Computer-Aided-System	30,000						
1.2	Capital Cost of Computer-Aided-Manufacture System			15,000				
1.3	Installation costs							
1.4								
	Total	30,000	0	15,000	0	0	0	0
	Less:							
1.5	Capital expenditure avoided							
1.6	Capital grants							
1.7	Capital assests sold							
	Total	0	0	0	0	0	0	0
	Total capital outlay	30,000	0	15,000	0	0	0	0
	NON -CAPITAL START-UP COSTS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
1.8	Transfer of Programs to CAD System	3,000						
1.9	Transfer of Programs to CAM System	0		1,500				
1.10	Staff Training Costs	10,000						
	Total	13,000	0	1,500	0	0	0	0
	Less:							
1.11	Consultancy grants	0						
	Total non-capital start-up costs	13,000	0	1,500	0	0	0	0
	TOTAL INVESTMENT	43,000	0	16,500	0	0	0	0
2	**SECTION TWO - PROJECT COSTS**	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
2.1	Support Costs of CAD System @ 10% of Capital Costs	3,000	3,000	3,000	3,000	3,000	0	0
2.2	Support Costs of CAM System @ 10% of Capital Costs		0	1,500	1,500	1,500	1,500	1,500
2.3			0	0	0	0	0	0
2.4			0	0	0	0	0	0
	Total annual project running costs	3,000	3,000	4,500	4,500	4,500	1,500	1,500
3	**SECTION THREE - PROJECT SAVINGS**	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
3.1	Estimated Benefit of CAD System	20,000	20,000	20,000	20,000	20,000		
3.2	Estimated Benefit of CAM System			10,000	10,000	10,000	10,000	10,000
3.3								
3.4								
	Annual project savings	20,000	20,000	30,000	30,000	30,000	10,000	10,000
4	**SECTION FOUR - PROJECT CASH FLOW**	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	CASH INFLOW							
4.1	Number of units sold		0	0	0	0	0	0
4.2	Selling price of unit		0	0	0	0	0	0
	Annual revenue from project		0	0	0	0	0	0
	Annual project savings	20,000	20,000	30,000	30,000	30,000	10,000	10,000
	Total cash inflow before capital allowance	20,000	20,000	30,000	30,000	30,000	10,000	10,000
4.3	Annual capital allowance (%)		0	0	0	0	0	0
	Capital Allowance on investment		0	0	0	0	0	0
	Tax saved on allowance		0	0	0	0	0	0
	TOTAL CASH INFLOW	20,000	20,000	30,000	30,000	30,000	10,000	10,000
	CASH OUTFLOW (Before Tax)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	Capital Investment Costs (from section 1)	43,000	0	16,500	0	0	0	0
	Project Running Costs (from section 2)	3,000	3,000	4,500	4,500	4,500	1,500	1,500
	TOTAL CASH OUTFLOW	46,000	3,000	21,000	4,500	4,500	1,500	1,500
	TOTAL PROJECT CASH FLOW BEFORE TAX	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
		-26,000	17,000	9,000	25,500	25,500	8,500	8,500
	TAXATION							
4.4	Taxation rate on profits (%)		0%	0%	0%	0%	0%	0%
4.5	Tax Saved on Depreciation		0	0	0	0	0	0
	Tax Payable		0	0	0	0	0	0
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	TOTAL PROJECT CASHFLOW AFTER TAX	-26,000	17,000	9,000	25,500	25,500	8,500	8,500
	TOTAL CUMMULATIVE PROJECT CASHFLOW	-26,000	-9,000	0	25,500	51,000	59,500	68,000
5	**SECTION FIVE - FINANCIAL ANALYSIS**							
	Financial analysis using net present value	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
5.1	10%	-26,000	-10,545	-3,107	16,051	33,468	38,746	43,544
5.2	15%	-26,000	-11,217	-4,412	12,355	26,934	31,160	34,835
5.3	20%	-26,000	-11,833	-5,583	9,174	21,471	24,887	27,734
5.4	25%	-26,000	-12,400	-6,640	6,416	16,861	19,646	21,874
5.5	30%	-26,000	-12,923	-7,598	4,009	12,937	15,227	16,988
	Financial analysis by Internal Rate of Return	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
			-34.6%	0.0%	40.1%	54.9%	57.4%	58.9%

The introduction of CAD/CAM has been generally agreed to have been very successful and the financial analysis shown underestimate the benefits obtained. Indeed, the design section would not be able to cope with the present volume of design work under the previous manual procedures, and the company has since upgraded it facilities to a *third generation* CAD system. The company is presently involved with a CAD software company in developing the parametric facilities previously described. It is believed that the successful development of such a facility will achieve very significant benefits for the company in terms of productivity and could be sold to other companies. In many respects, it could be said that regardless of the financial justification figures, this technology was one which the firm clearly required on a long-term strategic basis.

As with many companies, a post introduction audit had not been conducted, but it was estimated by the Design Manager that in terms of reducing design leadtime, the effect of introducing CAD was equivalent to employing two extra draughtsmen (a three-fold increase by the operator), although this is an increase in capacity, and therefore not a saving in cost.

However, In discussion with the design manager it was suggested that while the system had substantially reduced design leadtimes, it had not reduced them to the original extent that was anticipated, two reasons were given for this. Firstly, the savings in time were being taken up by the designers spending more time experimenting with more innovatory ballscrew designs. The design manager commented how, when designing with CAD he '...starts out with a clear idea, but ends up with something quite different'. This often resulted in an overall better designed product. Clearly, this is one of the most important, yet probably the most *intangible* aspect of the technology to justify economically, and shows how a company while justifying a technology primarily on a productivity measure, actually gained substantially in a way different from that originally envisaged.

Secondly, the design department found that the learning curve of the CAD system was much longer than anticipated. The design manager stated that for the two operational years of the system, it was still quicker to do a fresh ballscrew design manually. Table 6.11 shows the number of new ballscrew designs performed manually, and those on the CAD system over the last four years and this is compared graphically in figure 6.24. This shows that it is only in 1989 that the number of new designs performed by CAD has reached the level of those performed manually. However, it needs to be noted that the ones performed on the CAD system were of much greater complexity and does not include design work on modifications to repeat designs. It is only when a large library of previous designs have been built up, that the company anticipates gaining the full benefit of the system. In using the CAD system the design department has tended to place most of its new aerospace ballscrew designs in the system, since these tend to be the most complex. By maintaining a program library of standard parts that can easily be recalled, the CAD system enables the designers to concentrate their effort on the parts of a ballscrew design that are new. The use of standard parts is a key aspect of *designing for ease of manufacture*. Another unexpected benefit of the system has been that the quality and presentation of the drawings have greatly improved and drawing errors are very few, which has helped in reducing the material scrap rate. The high presentation of the drawings has also facilitated communication with the sales department and customers. The eventual objective of the sales department is to be able to fax an "outline" design to a customer enquiry for a previous or standard design, on the same day as the enquiry.

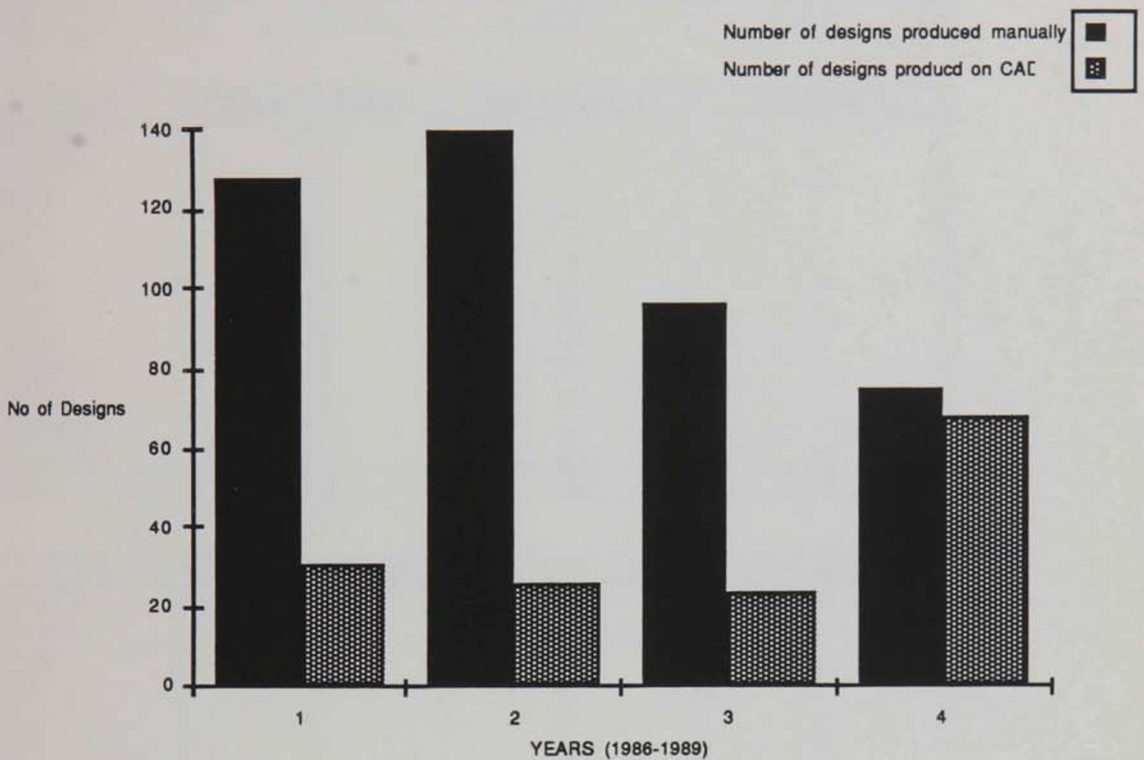

Figure 6.24 - Number of designs produced manually compared with those performed on CAD system

When asked to put a figure on the benefits of CAD, the design manager replied that he would find this difficult to do with any great reliability, but that '....without CAD, we would not have been able to compete for contracts in the first place' and suggested that the only real way the benefit could be quantified, is by looking at the increase in sales turnover of the company, through orders obtained as a result of the increased competitiveness of the company to which CAD contributed.

TABLE 6.12 COMPUTER AIDED DESIGN PROGESS

Number of CAD designs versus manual designs

1986	Total No of Designs	Manual Designs	CAD Designs
January	11	11	0
February	11	9	2
March	15	11	4
April	15	12	3
May	14	10	4
June	17	10	7
July	11	7	4
August	10	10	0
September	9	9	0
October	14	8	6
November	18	18	0
December	14	13	1
Total	159	128	31

1987	Total No of Designs	Manual Designs	CAD Designs
January	11	9	2
February	15	14	1
March	16	14	2
April	19	18	1
May	10	10	0
June	18	16	2
July	15	10	5
August	18	16	2
September	26	19	7
October	12	8	4
November	4	4	0
December	2	2	0
Total	166	140	26

1988	Total No of Designs	Manual Designs	CAD Designs
January	9	9	0
February	16	12	4
March	8	5	3
April	7	6	1
May	7	6	1
June	11	8	3
July	3	- 1	4
August	9	8	1
September	9	8	1
October	22	21	1
November	5	1	4
December	14	13	1
Total	120	96	24

1989	Total No of Designs	Manual Designs	CAD Designs
January	6	2	4
February	9	3	6
March	30	12	18
April	5	5	0
May	12	3	9
June	10	10	0
July	7	3	4
August	3	1	2
September	23	18	5
October	15	8	7
November	10	4	6
December	13	6	7
Total	143	75	68

In many respects the experiences of the company bear out the comments by Senker (1984) of the Science Policy Research Unit at Sussex University:

> 'In Britain, DCF capital investment appraisal techniques have been widely used to justify investment in CAD on the grounds of its potential for savings in the costs of employing draughtsmen. But the real justification for CAD is usually strategic - for example, that its use can be a key factor in ensuring that a company is early enough to market with new products to secure its survival. For most manufacturing companies CAD is also an essential first step into CAD/CAM which can help them to secure their long term future.' '.....CAD/CAM can confer increased flexibility and quicker response on the whole firm. A high proportion of the benefits may be conferred on departments outside the one in which the automation facilities are installed'.

While the cost of the CAD system is relatively small in comparison to the cost of the FMS and was not taken into consideration in the financial justification for the FMS. It would have been essential to have the technology to reduce design leadtime in order keep up with customer demand. However, since the CAD was to be used for all the company's ballscrews it is difficult to allocate specific costs. This illustrates the integrated nature of advanced manufacturing technology, which make discrete financial justifications of each individual technology difficult. In using a series of company spreadsheets models to try and represent the overall effects of the FMS and the CAD system upon the company, the direct benefit of the CAD system is assumed to be realised in making possible the growth in sales, from the increased productive capacity of the FMS. The direct costs of using the CAD system in terms of hardware and software and running costs being included in the design department overheads.

6.10 Discussion

What was particularly interesting when setting up the models, was discussing with the management their original motives and expected benefits of the FMS, and comparing these with their current ideas of such a system based on their "learning experiences" obtained from using modern production equipment over the period since the FMS was considered. The author was fortunate in this task since the main managerial positions were still occupied by the same individuals. Figure 6.25 shows the author's interpretation of the conceptual model of the motivations and expected benefits of the FMS at the time of the study. The main impression obtained from these interviews was that the FMS was seen as basically a "technical solution" to achieve the company's business strategy of moving towards higher volume/lower variety output to compete with growing foreign competitors. It was noticeable in the FMS study document, that while the standard justification factors were given, ie. reduced direct labour, higher rate of productivity, reduced stock and WIP, etc, there was little consideration of the wider effects that the system might have on the business. While it could be argued that this was just a shortcoming of the study, the author considers that it well fitted the technical orientation of the DTI scheme from which it had obtained a grant.

Boddy and Buchanan (1987, p.22-23) comment on the scheme:

> 'At the end of 1983, John Butcher, Under-secretary at the Department of Trade and Industry, forecast a "quantum leap" in applications of automated manufacturing in Britain. He claimed that these technologies were a powerful weapon in the fight to maintain British competitiveness. The Governement's scheme to support flexible manufacturing systems began in 1982 with a budget of £35 million. By the end of 1983, over £10 million of this money had been spent on 42 consultancy projects and 16 installation projects. None of this government money has been directed at the human, organisational and managerial dimensions of technical change. These schemes rely on the simple argument that all that is required is enough money and the right equipment. This argument is incomplete'.

When asked in view of the possible problems highlighted in the models whether the company had been really serious about the FMS, the Technical Director (TD) stated '....we came within a cat's whisker of implementing the system'. Undoubtedly the main instigator for its introduction was the company chairman, who was (and is) very keen that the company stay ahead of the competition. Indeed, the TD remarked '....if it were not for the chairman we would never have even thought about whether flexible manufacturing was applicable to us'. While on this occasion the rest of the company management was somewhat apprehensive as to whether the company ought to be following the FMS route, the TD was insistent that it was a considerable advantage to have someone like the chairman, who confines himself to long term strategic planning and who maintains a high degree of technological awareness from other business interests. This has enabled him to play a key role in developing new ventures and act in a supportive way as an unofficial "project champion" on several occasions. In the event, despite the support of the chairman, it was decided not to proceed with the FMS project, the TD thought that basically the other managers believed there were too many "unknowns" involved. The management buyout then taking place would involve changes in key staff and existing organisational procedures and it was felt that a period of consolidation was needed to allow the company to settle down. The significant technological and organisational demands of developing an FMS would be unlikely to contribute to this. The company would also no longer have access to the investment funds of its large US parent company. Being newly independent, the management were reluctant to commit the company to large capital projects which involved a substantial element of risk that was difficult to quantify.

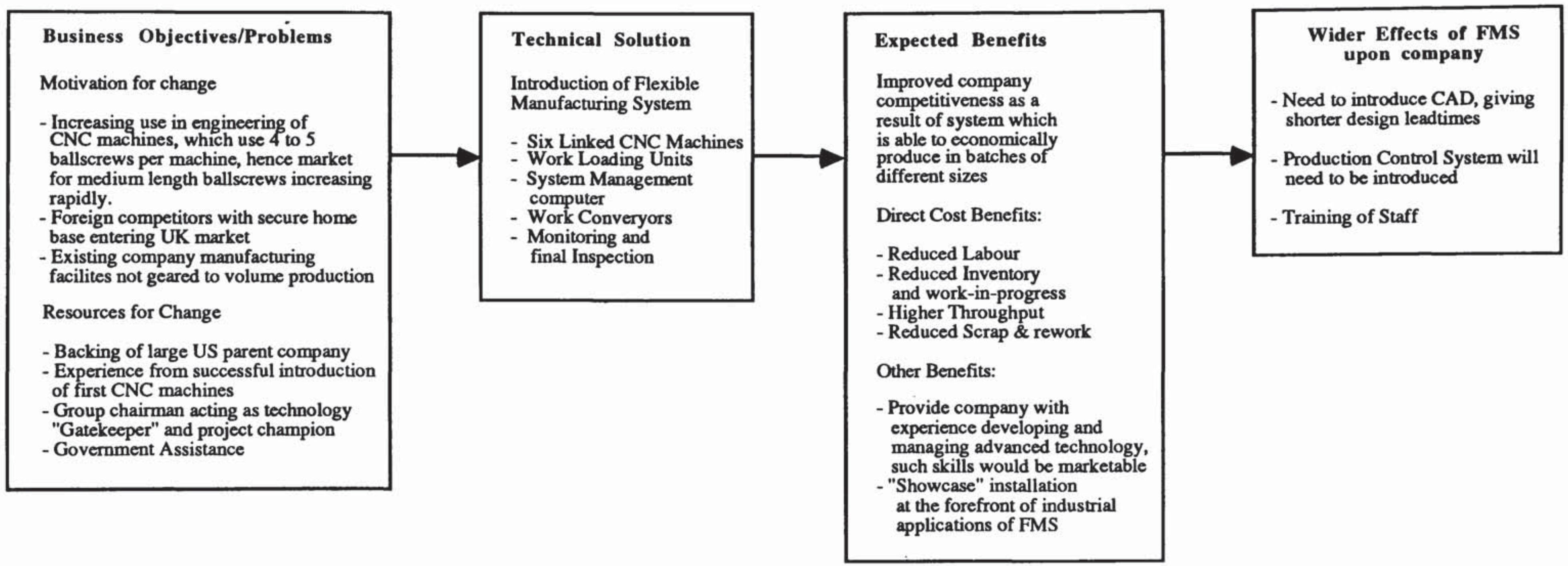

Figure 6.25 Conceptual Model of the Motivations and Expected Benefits of the Introduction of FMS

Figure 6.26 shows the author's interpretation of the conceptual model of the motivations and expected benefits of, the FMS, but modified to take account of the potential sources of disadvantage which were identified from the company's experience of using new technologies since the FMS study. Although it was only just over seven years ago, even in this short period of time it was surprising how managers thought their ideas had changed. Several key issues were identified as follows:

- Although the company had much experience of the core CNC technology required for the FMS, this was on the basis of using them as stand-alone units with no automatic linking. The linking of machines was thought likely to represent a considerable innovative leap on the part of the company, especially as there are no previous situations to learn from where FMS has been used to manufacture ballscrews. A key aspect of ballscrew manufacture also is the heat and chemical treatments usually required, where the ballscrew shafts are sent out of the factory for specialised treatment. The balancing of the work flow through the factory could have presented problems if shafts had to be continually removed from the FMS for such treatments.

- The FMS would have entailed committing a considerable amount of management time and expertise in developing the system, which in a smaller sized firm would be a heavy burden. The TD doubted whether the technical problems could be resolved within the time scale envisaged and to the estimated cost. This supports Holland's (1984) comment that:

> 'In any project designed to achieve a payback against a time frame, do not use any equipment which is not genuinely developed. To become involved in the development of a device on which such a project depends is to court disaster'.

Another interesting consideration is the increased vulnerability the company would be exposed to, in the event of a serious system breakdown. At present with its standalone manual and CNC machines, in the event of a machine breakdown, work can quickly be rerouted elsewhere. With the FMS this option would no longer be available, since several of the existing machines would need to be disposed of in order to make room for the FMS.

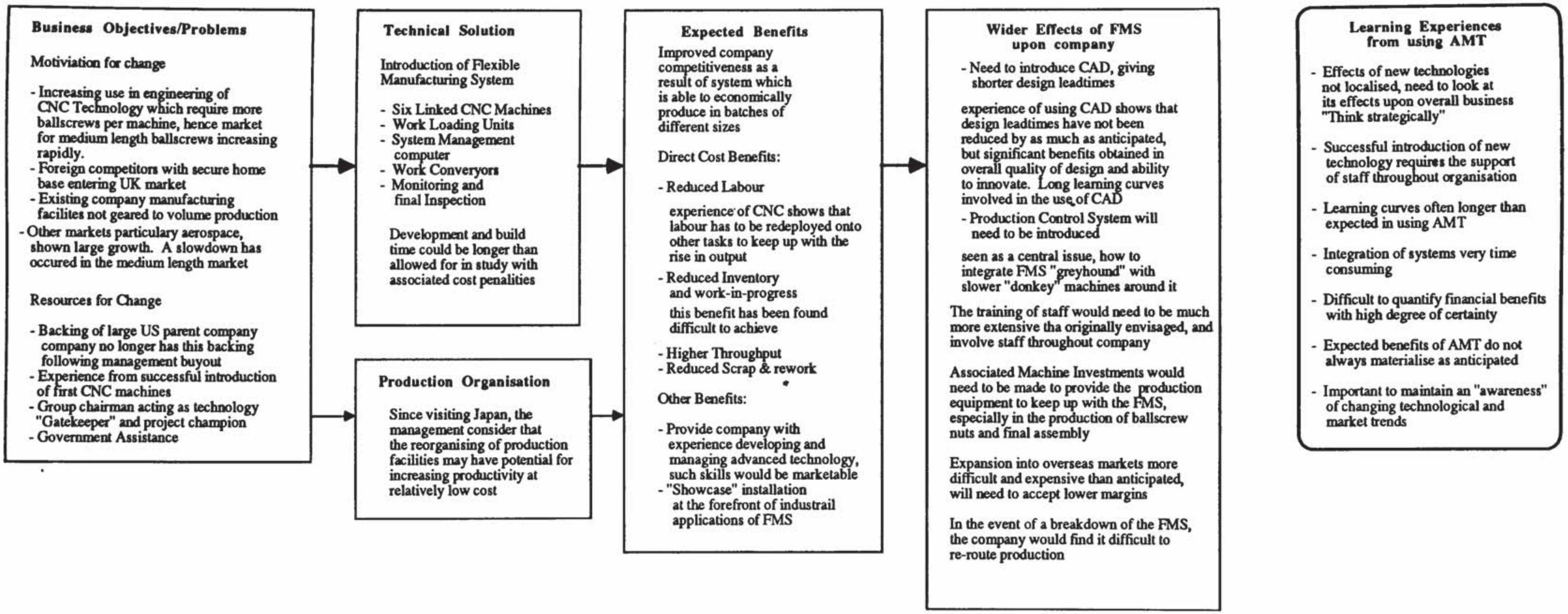

Figure 6.26 Conceptual Model of the Motivations and Expected Benefits of the Introduction of FMS modifed to show the potential areas of problem shown in italics which have been identifed from the company's learning experience of using AMT since the original FMS Study.

- The TD expressed reservations about whether the rest of the non-integrated standalone machines would have been able to keep up with the production rate of the FMS. He likened this to a *greyhound* machine surrounded by *Donkey* machines, and referring to model 6.5 suggested that in order to upgrade the *Donkeys,* a considerable sum would have had to be spent (£1 million upwards) in addition to the cost of the FMS. Asked why this addition expenditure had not been foreseen in the original technical study, he replied that at that time, the company was then relatively low on the learning curve of using more advanced CNC technology and just did not anticipate the integration and "interfacing" problems that with the benefit of hindsight he now appreciates.

- Several managers commented on how the benefits of new technologies did not always manifest themselves in quite the way suggested in most of the engineering literature. The company's experience of CNC and CAD were seen as examples of this. In justifying CNC the TD pointed out that much of the literature suggests that this is done on the basis of reductions in direct labour and being able to use less skilled operators. However, from their experience of CNC it was not usually quite that simple. Where CNC machines have replaced manual ones, operators have tended to be redeployed onto other tasks which require more attention, in order to keep up with the higher productivity of CNC machines, often to inspection and assembly tasks which are still labour intensive and difficult to automate. In addition, with the high level of skill required in ballscrew manufacture it was usually necessary to retain a one operator per machine manning level. At the time of the FMS study it was thought possible to eventually automate many of the operations involved in ballscrew manufacture. There was now a better realisation of the likely limits to this process, and the TD is convinced that even with the gradual introduction of modern machines, there will still be a continuing need for skilled operators. The limits to deskilling were further illustrated in a number of "technology transfer" contracts the company has with Eastern European countries. A significant problem in dealing with the managers in the state run firms according to the TD was that, '....they thought it was just a simple case of buying the right machines and you could then use semi-skilled labour to make ballscrews, they were somewhat taken aback to learn that you still need skilled men to get a good quality product'. The design manager pointed out that the introduction of CAD was made on the basis of increased productivity, but in practice it was found that productivity gains were slower than expected as a result of the learning curves involved and the main benefits for the company have tended to be in improved design work.

A useful insight into how to improve productivity without simply buying more new machines, arose from a visit that the Managing Director and Production Manager recently made to Japan to see how a Japanese machine tool company manufactures its own ballscrews. An interesting observation by the Managing Director was that while the Japanese plant has a higher rate of productivity than their own company, in terms of the level of technology employed, the two company's are very similar, indeed he thought his company perhaps had the edge in this respect. The key to this higher productivity was seen as resulting from the greater organisational efficiency of the production facilities in the Japanese firm, which used principles from group technology and Just-in-Time and adapted them to suit their own circumstances. In particular, it was noticed how little inventory, in the form of work-in-progress could be seen around the shopfloor of the factory, and the general tidiness and cleanliness of the working environment. The Managing Director felt that the lesson to be learnt from this is, that before investing in more advanced technologies, the potential benefits a company might obtain from improvements in the organisation of its production facilities needed to be considered. Many companies may not be getting the best out of their existing facilities. Edquist & Jacobsson (1988) make a similar point in suggesting there are a number of ways to obtain the economic benefits of FMS of which only one is applying the FMS hardware.

Market Changes - although the FMS would allow for flexibility of production within the medium size range of ballscrews, the large investment would have required the company to concentrate its R &D, design and sales and marketing in this size range. This would limit funds which could have been used to upgrade production facilities for other ballscrew sizes. At the time of the FMS study, the economic recession of the early 1980's was affecting the UK machine tool industry, and demand for the medium length ballscrews used in machine tools was affected to some extent. In addition, the market for ballscrews was changing, with aerospace ballscrews gaining in importance. Thus while the FMS would have provided production flexibility in one size range, looking at the company in terms of its overall output, the flexibility to respond to market changes would have been reduced. The sales manager has found it much harder to break into overseas markets than anticipated, considerable commission often has to be paid to agents and in many countries it is difficult to break a strong preference for home manufacturers. Considerable cost is also incurred in attending overseas trade exhibitions, which is essential if the company are to establish their presence in the international market.

In many respects the company is still facing similar problems to the ones it faced at the time of the FMS study - the management are still looking at ways to move towards the higher volume/lower variety ballscrew business by looking for a larger share of the medium length ballscrew market, and a return to the higher operating margins for the first half of the 1980's. Figure 6.27 show the author's interpretation of the conceptual model of the existing/optimal business and production objectives currently held by management. Comparing this with figure 6.1 a key difference between then and now is, that they believe that it is possible to achieve higher productivity with less advanced systems than the FMS. The Managing Director said that their immediate machine investment plans are

Figure 6.27 Conceptual Model of Existing/Optimal Business and Production Pattern of Midland Ballscrew Company

	EXISTING BUSINESS/ PRODUCTION PATTERN	OPTIMAL BUSINESS/ PRODUCTION PATTERN
Business Objectives	- Have seen a substantial reduction in operating margins to around 5% - At present in a low volume/ high variety market and able to manufacture across complete size range, much of output is customerised to individual requirements - Cost of Sales rising faster than turnover	- Return to high operating margins, 15% + - Want to move into higher volume/ lower variety market for medium length ballscrews - Increased emphasis upon standardised range of ballscrews - Production Costs reduced as a Percentage of turnover
Sales/ Marketing	- Large number of sales derived from a few key customers - Machine tool market is still largest single market - Aerospace market static at present but expected to grow	- Company sales spread accross a wider base of customers - Larger proportion of output is exported - Devlopment of new ballscrew applications
Product Design	- Use of CAD progressing, but long learning curves and manufacturing leadtime still long	- The introduction of Parametrics and CAM with reduced manufacturing leadtimes
Production Technology/ Organisation	- Do not have production facilities for long production runs - Mixture of CNC machines and older manual machines. - Grinding machines which are central to production of ballscrews getting worn and becoming more difficult to keep in tolerance - Manual machines have long setup times - High dependence on operator skill - One man per machine operation High Maintainance Costs	- Equipment better able to handle longer production runs - All CNC machine shop - Several key CNC Machining Centres - Introduction of CNC Grinding technology. - Low rate of scrap & rework - Continuous monitoring of toor wear and breakage, with ability to take corrective action automatically so machine can continue - Automatic in-process guaging - Automatic swarf removal - Reduced skill requirements - Multi-Machine operation by operator - Facility for minimally manned operation - Minimum maintenance on a planned programme
Production Control	- Rudimentary Production Control	- Compter Based Production Control System with analysis of previous performance and linked to stock control, production planning and other key variables

the purchase of two advanced CNC thread grinders each costing £700,000. Asked if the FMS would be reconsidered, it was suggested that the emphasis in technology as far as their company was concerned had moved away from large *do-it-all* integrated systems, to advanced CNC machines with driven tooling. For example, a grinding centre with a 4-axis turret allows the user to have four grinding spindles on a turret which can combine the internal, external, face and thread grinding operations without losing the datum. The MD described such machines as "...an FMS on its own", the problem being that "....when the FMS was considered such technology wasn't developed" The MD considered that the capital costs of advanced CNC machines are quite reasonable compared to an FMS and allowed the company to progressively acquire more advanced machines which placed less strain upon the cash flow. Most importantly, the investment emphasis in the business is now, not so much focussed on large single capital investments, but to try and " ...spread the cost of the technology across the whole of the company", so as to obtain improvements across a broader spectrum of functions, rather than in just particular machine operations. In particular, as discussed previously, considerable effort has been made to improve quality at the design stage through CAD.

The next stage is the development of a production control system to replace the manual one in operation. Such changes are seen as being part of a general trend towards a hoped for "integration of systems" within the business and between other companies in the group. The MD admitted that the company had been backward in their use of computers. This was partly due to a bad experience with a large IBM system installed in the company before the management buyout, which in the words of the TD:

> '...produced reams of paper, but very little in the way of useful information. The system just was not suited to our needs, and was costing a fortune in maintenance, so eventually we just decided to pull the plug'...'best thing we ever did'

The problem facing the company as the MD admitted was that there had been no person in the management or supervision level with any in-depth knowledge of computers. Rather usually for the MD of an engineering firm, he had come from a personnel background, while the technical director had acquired his engineering knowledge before the widespread use of computer systems. In an effort to overcome this problem a graduate management trainee had been appointed, who would hopefully as he became more familiar with the business, be able to take on the role of "championing" the development of systems within the business.

In summary, the FMS project illustrates the kind of problems that managements in many companies are faced with in evaluating a new technology project that is outside their immediate experience. In this case, the FMS would have represented a major process innovation in a company that was used to incremental manufacturing innovations. With the benefit of hindsight, the author agrees that the management made the right decision at the time, given the large number of "unknowns" associated with the project. However, the point to note is how the management have moved away from the "technical solution" model of change, to one in which it is acknowledged that new technology will have wider implications for the business, a key part of which is the need to develop a "systems strategy" for the business. The setting up of the spreadsheet models proved to be an effective means of trying to understand the motives, reservations and experiences of the management of the company regarding investment in new manufacturing technologies.

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Chapter Seven
PP Print Company Limited Case Study

'We realised too late that we had mismanaged the introduction of the new press' Financial Director

Preamble

In contrast to the previous two case studies in the engineering industry, this chapter discusses the case study of the PP Print Company Limited, which in adopting new technologies faced many similar problems. In order to retain competitiveness in a market calling for more elaborate print features and shorter delivery times, the company decided to introduce a large computer controlled press, which was seen as essential to the company's future, the financial effects of which the author intended to model to demonstrate how the equipment affected overall company performance. In the event subsequent technical problems prevented the press becoming operational for nearly a year, causing considerable financial problems for the company, and which meant that the original objectives of the investigation were in this case not capable of fulfilment. However, the discussions held with the firm did throw useful light on the consequences and expectations of innovation of this kind.

7.0 Introduction

The PP Print Company Limited is a medium-sized printing company located in the Home Counties employing some 100 personnel. The company turnover for 1989 was just under £6M based primarily on the printing of general and engineering cartons, with general printing contributing to a lesser extent. The company has experienced relatively slow growth in recent years, partly due to the extreme price-competitiveness in the print industry. In the last two years managerial change has been made with the aim of implementing a policy of growth, based on the introduction of new technologies offering new print features. A key element in this decision is, the change in market trends with customers demanding shorter leadtimes, Just-in-Time deliveries, tighter prices, more colours and elaborate finishes. These demands resulted in a study which showed that the company's existing four large colour presses were becoming increasingly less appropriate to meeting them and hence less competitive. The study therefore concentrated on evaluating alternative machines which could fulfil the company requirements. In addition, this was seen as an ideal opportunity to review a major portion of the factory layout to try to improve workflow and gain more space to reduce outside storage costs.

7.1 Changing Technology in the Print Industry

As with the two previous case studies in engineering, the printing industry is itself undergoing radical change as a consequence of the introduction of new technology. Perhaps the most visible expression of this change is the movement of several of the major daily newspapers from Fleet Street to new factories in the London Docklands. This change has not been without strife as the industrial problems of Wapping demonstrated. The effect of new technology in the print industry has also been the subject of considerable academic interest (Cockburn, 1983; Love & Walker, 1986) much of which has tended to focus on the changing skill requirements of new technology and the adjustment to it of a workforce which has traditionally been employed within a well organised trade union structure and which until recently had maintained a rigid code of demarcations in the workplace.

In contrast, comparatively scant attention has been given to the effect of technological change on the less glamorous small printing firms and sub-contractors which make up much of the printing capacity in the UK, except in trade literature and journals (eg. British Printer). In many respects, the sub-contract print industry has parallels with the automotive components industry where there tends to be a large number of small/medium sized firms each dependent upon a few key customers and operating on very tight profit margins. In terms of the level of technology they employ, this is bounded by two extremes. Firstly, low technology firms where investment in new technology is minimal and which compete for volume business with basic print requirements, their relatively low overheads maintaining their competitiveness. Secondly, firms which compete for more specialised print business which requires complex print features and are thus able to charge a higher price, but which requires technologically a relatively high level of investment. Lying somewhere between these extremes are the majority of companies of which the case study firm is one. Here the company has adopted what the financial director described as a 'middle strategy' and has a collection of old, (15-30 years), presses operating alongside several large modern ones. New investment is seen as being for two main reasons:

(1) To achieve production savings, usually through labour reduction and to a lesser extent material savings

(2) To allow the company to enter a specific market

In many regards firms such as PP Print fit in well with the concept of *manufacturing innovation* described by Bessant (1986) where the company does not have the resources (or is in the business) to become involved in significant process or product innovation, but is able to make incremental improvements to its manufacturing facilities through the innovative ways in which it acquires and uses its productive technologies. For example, the company recently purchased a small press costing £40,000 in order to enter the market for printing computer manuals. While the sophistication of print features required in this market is comparatively basic, computer firms tend to place small, irregular, batch orders and computer manuals tend to have a large number of pages. Based on the economics of conventional presses, such orders would be very uneconomical, due to the large number of setups required for each page. However, the new press uses paper plates which are much quicker to make and can print on both sides which greatly improves the production rate. Metal plates could take up to 30 minutes to change, but paper plates only require about a minute, although the quality of finish is slightly reduced. The company is introducing this technology onto its other presses. In addition, the new press is managed by a single operator, whereas a conventional press would require two, and also took up more factory space. Thus the purchase of the press incorporating new technologies has enabled the company to enter successfully a market which was previously closed to it.

The company had on one previous occasion attempted to directly innovate when it was involved with a manufacturer of presses, to retrofit an ink damping system (which reduces material wastage) to an existing press, in a way which had not been done before, and which could have commercial possibilities if successful. Although, the collaboration did eventually result in a working system, these benefits were felt to have been outweighed by the considerable cost incurred during the development and modification phase, during which time the company lost the use of the press. This was originally estimated at two months, but in the event took over six. As a result the management decided not to become involved in any similar ventures, and as the financial director commented, to become a "fast follower" of print technology trends rather than getting involved in any direct innovatory activities itself again.

In terms of innovation, the computer controlled 3B press discussed in this chapter can be said to represent a similar technological step for the company as for an engineering firm adopting CNC technology. Indeed, the diffusion of such technology in printing, parallels that of CNC in that while computer systems were applied to the control of printing presses in the 1970's, its prohibitive price confined its adoption to mainly large firms. With the dramatic reduction in the relative cost of computer power, made possible by developments in microprocessor technology, such technology was put within the price range of smaller firms and this led to its widespread adoption in the 1980's.

The machine is able to print in a variety of shades of six basic colours and has facilities for alcohol damping and ultra-violet print. The operator first has to programme the settings of the various inks and ducts, which are recorded onto computer tape and, as with CNC machines, a library of customer jobs can be built up. Thus the real benefits of the machine are realised when a customer requires a rerun of a particular job and the operator simply has to reload the original tape record of the settings. Whereas with conventional manual presses of a similar size, the operation could take up to an hour, the plates on the 3B can now be changed over inside 15 minutes. The computer is also able to monitor the in-process performance of the press, which can be run on a minimally manned basis with a single operator. The machine is much more geared to the shorter delievery times which the sub-contract industry is increasingly having to adjust itself to. This is the result of customers not wanting to maintain large stocks of printed material on their own premises, but requiring to be able to obtain supplies of printed material at relatively short notice. The pressure thus exists for customers to "push down" their inventory onto the suppliers like PP Print, who have to adapt to this as the market is very price sensitive (the company has lost orders for less than a 1% price differential), and there are many other small printers willing to take the business. As in the automotive industry, the needs of moving towards a "just-in-time" type environment are causing firms like PP Print to plan their future technology investments with this in mind, and highly flexible computer controlled presses are seen as the way of reacting to this need. While the workforce have been naturally somewhat apprehensive about the introduction of new technologies and it's effects in the possible reduction of the number of jobs, this has been mitigated to some extent by the knowledge that the firm has struggled to be profitable in recent years, and that it has to invest in new technologies in order to remain competitive. The policy of natural wastage has also ensured that no redundancies have so far occurred.

Two other market factors which the management have had to take into account in recent years are firstly, the growing competition it faces from European printers for UK print business. While traditionally, competition for print contracts was essentially between printers in the same country as the customer, the growth of modern communications technology is leading to growing competition from Europe (especially France). Loyalty among customers to home based printers can no longer be relied upon as price becomes ever more important. This situation is expected to intensify in the run up to the single European market in 1992. Secondly, the refusal of large customers to accept annual price rises in line with inflation. A major automotive customer of the company for whom it prints vehicle sales brochures has stated that it expects its suppliers to achieve their profit through productivity improvements by investing in new technology and will not accept the supplier passing on annual price rises. This is now a growing trend among all automotive manufacturers and is being increasingly copied by other engineering and industrial sectors whom the company supplies.

Other uses of new technology in the company include the introduction of page-layout personal computer terminals. While previously, each page had to be individually type-set using metal plates, the user is able now to view a whole page at a time on a terminal and has a whole variety of desk-top publishing facilities available to modify the type font and text size in addition to a standard word processing package. As well as the entry of text onto the computer by keyboard, printed material (provided it is of high enough quality), can be scanned by computer directly onto disk. As with word processing, the original document can quickly be called up and modified. The system was originally purchased on the basis of "improved productivity", which the management described as a "defensive move" against competitors who already had the technology. As with the justification of CAD described in the chapter 5 case study, the management have been pleased with the benefits obtained from the system, but expressed difficulty in quantifying them in financial terms when asked to do so. As with Computer Aided Design in engineering the real justification was that it '....made the difference between getting a contract or not'. Other applications of computer based technology include the introduction of a mini-computer for the processing of sale and purchase ledgers and the development of a software "estimating" package unique to the company. They are also now beginning to use standalone PC's on a wider basis and are using spreadsheets for financial control, an area in which the author has been able to participate through the use of the company models and the introduction of the *Excel* spreadsheet package.

7.2 Financial Performance of Company

In developing the spreadsheet financial models, with the intention of identifying and measuring the effect of technological innovation upon all aspects of the business, the financial performance of the company in recent years was discussed with the financial director and management accountant, with whom the models were developed (both joined the firm in 1988). During the first half of the 1980's it had been fairly profitable for a printing company, but a lack of investment, inadequate financial controls and not taking sufficient account of changing market changes in the industry, had led to losses in 1986. The financial director saw a simple model of the company cost structure as follows:

100% Sales

50% Variable Costs (Materials)
17% Variable Costs (Productive Labour)

33% Gross Profit

Looking back over the performance of the company in recent years a simple model of its cost structure as shown in Table 7.1 emerge:

	1986	1987	1988	1989	Aim
Sales	100%	100%	100%	100%	100%
Variable Costs (materials)	54%	53%	50%	46%	45%
Variable Costs (overheads)	4%	4%	4%	4%	4%
Fixed Costs (personnel)	30%	28%	26.5%	27.5%	26%
Fixed Costs (other)	15%	15%	14%	16%	16
Total	103%	100%	95%	94%	91.5%
Net Profit	(-3%)	0%	5%	6%	8.5%

Table 7.1 - PP Print Company Cost Structure

1986 - The company was losing money as a result of bad purchasing which kept material costs high and the company was overstaffed in terms of direct labour and office staff. Total costs exceeded profit by 3%. At this time the company was engaged in volume seeking, so the prices were pushed down lower than was healthy for the business . In response a policy of natural wastage was started.

1987 - Slight reduction in material costs and staff, allowed the company to break even. This was assisted by the company acquiring a major order for packaging from a foodstuff manufacturer, which reversed the downward price trend. (This shows the extent to which the fortunes of a small company can change rapidly through a few key customers).

1988 -When the current financial director took over he instigated a review of existing customer contracts, which led to several unprofitable ones being dropped. This resulted in drop in turnover, but a return to a small operating profit. The policy of natural wastage was continued. The company undertook to make a major investment in a computer controlled press.

1989 - In January the new printing press was expected to become operational. However, as result of technical problems in its installation it did not become operational until July and even then was not performing to expectation. This caused considerable problems. The trading situation has also not been helped by high bank interest rates which has resulted in a reduction in orders. This comes at a time when the company was hoping that the new press would assist growth.

Figure 7.1 shows the authors interpretation of the conceptual model held by management of the business as it is at present, and the "optimal" company which they are trying to move towards.

7.3 Introduction of Computer Controlled Press

Faced with the market trends discussed, it was decided at company strategy and management meetings in 1988 to investigate the replacement of one of their existing presses with a modern computer controlled one. In evaluating the financial viability of the new press, the financial director, who played a central role in bringing together the different ideas of the management, saw the following questions as arising:

- Should the company purchase a general printing machine able to cope with all main print products, or one more suited to a particular product. If the former course of action is chosen, how can the idea be made acceptable to the printing department to make them want to use a general purpose machine?

- Does the new machine justify itself?

- Does the proposed new machine, compliment or conflict with the marketing strategy which had identified packaging and general printing as growth areas?

- What would be the effect on the profit and loss account on the balance sheet if this major investment were made?

The decision was taken to conduct a study to assess the technical options available. The study identified two alternative four year old printing presses (referred to as the 3B and SRA2) being sold by suppliers of high quality second hand machines as being suitable for their requirements, both having the following features:

(1) 6 Printing Units
(2) Alcohol Damping
(3) Computerised Ink Duct Control
(4) Quick Release Plate Clamps (for fast plate changes)
(5) Sheet De-curler and Antistatic-Devices
(6) Non-Stop feed and delivery
(7) Preloader
(8) Anti-ghosting rollers

Figure 7.1 Conceptual Model of Existing/Optimal Business and Production Pattern of PP Print Company

	EXISTING BUSINESS/ PRODUCTION PATTERN	OPTIMAL BUSINESS/ PRODUCTION PATTERN
Business Objectives	- Operating margins under great pressure due to extreme price sensitivity of print market - Company needs to reduce direct labour costs - Need to invest in new technologies just to stay competitive - Print machines require long production runs to achieve economies of scale	- Operating margins approaching 10% - Company is price competitive, with costs of direct labour and material under control - New technology maintains price competitiveness of company, - Modern print machines are able to operate cost effectively on shorter production runs
Sales/ Marketing	- Need to be able to offer more sophisticated print features to customers - Under increasing pressure from customers who want to order on a just-in-time basis	- Able to offer a wide range of modern print features to customers, retain existing customers and attract new business - New technologies offer the opportunity to enter 'niche' markets - New press offer opportunity to take on sub-contract work from other printers
Page Layout	- Recent introduction of computer based page layout	- Extensive use of computer based technology in type setting
Production Technology/ Organisation	- Wide variety of print machines, mainly manual with only one advanced computer controlled machine - Presence of more than one operator required to work manual machines - Manual machines require long setup times - High maintainance costs - Use of metal plates, which can only print on one side - High material Wastage - Company is forced to sub-contract out work when operating at full productive capacity - Overload on key presses	- A print shop using mainly computer controlled print technolgy - One man per machine operation - Reduced setup times - Minimum maintainance on a planned schedule - Machines have the facility to use paper plates which can print two on two sides at once - Low Material Wastage - Company does not need to sub-contract work - Presses have the productive capacity to cope with increased work load
Production Control	- Has a basic computer based production control system	- Computer -based system which is able to schedule production taking into account capacity contraints, and which is linked to stock control and can also provide information for cost estimates

Both machines had a 6 months guarantee for single shift operation and, although four years old, were both essentially the same state-of-the-art technology as a new machine, but costing £500,000 and £355,000 respectively, as opposed to the £600,000 upwards for a new machine.

The study was to show that while neither of the presses under consideration could print the whole company range of cartons, the 3B could satisfy the vast majority of requirements. It was also found that one modern technology press could cope with the majority of the work from the company's existing presses (referred to as the Sovereign, Nebiola, Roland and Perle 429). It was thought possible to replace the Sovereign and Perle 429 with the new press to produce the general packaging, print and software multi-colour sales requirements, leaving the Nebiola to print engineering and heavy general cartons.

To simulate the effects of introducing either the 3B or SRA2 machines into the factory, all work then performed on the Sovereign, Nebiola and Perle 429 together with sub-contracted multi-coloured work for the first six months of 1988 was listed. This was then theoretically loaded onto both the 3B and SRA2 machines assuming double shifts with the results as shown in table 7.2

	3B (Hrs)	SRA2 (Hrs)
Loading from Sovereign & Nebiola Outwork	1222	1341
Loading from Perle 429	263	288
Outwork Print	347	497
Total Needs	1832	2126
Capacity	1725	1735
Overload	107	401

Table 7.2 - Comparison of loading on 3B and SRA2 presses

From this it could be seen that a small overload occurs when working double shift on either presses. This could be comfortably accommodated either by overtime or subcontract or a combination of both. Out of 164 jobs studied, the 3B could print all but two 2 (1.2%) and the SRA2 all but 24 (14.6%). All of these "unsuitable" jobs could be accommodated on the Nebiola.

7.4 Effect of New Investment upon Company Competitiveness

In order to ascertain how competitive the new machines would be against the existing ones, a randomly selected number of jobs, both print and general packaging, were estimated on both the 3B and SRA2 presses and the total costs compared against actual on existing presses with the results as shown in table 7.3. The great advantage of either press over the company's existing presses is that being able to print in 6 colours as opposed to the company's existing 2 colour presses, this means that for a job requiring 6 colours, this can be done in a single pass, compared to the three passes required for a 2 colour machine, thereby reducing threefold the considerable plate setting and inkup times involved.

	Existing Cost (£)	3B Cost (£)	Saving (£)	(%)	SRA2 Cost (£)	Saving (£)	(%)
Gen.Packaging	124,957	115,419	9,538	7.611	9,274	5,685	4.5
Print	18,138	19,587	(1,449)	(8)	19,184	(1,046)	(5.8)

Table 7.3 - Comparison of print cost estimates on 3B and SRA2 presses with actual

The results of the study showed the increased competitiveness on general packaging that new investment could bring to the company and was also seen as greatly enhancing the chances of gaining new business. Although savings of 7.6% and 4.5% may not seem great, it needs to be borne in mind that the print industry is very price sensitive. In addition, the facility of Ultra-Violet Varnishing is seen as an innovative step, as it offers the possibility of opening up new markets in the fast-food, toiletries and cosmetic markets. While at first sight the results of the print estimates were seen as disappointing, these needed to seen in relation to the existing 4 colour presses which were not performing to estimate. These were experiencing large quality variations and excessive wastage. The above figures were also based on very cautious estimates.

7.5 Wider Cost Effects of Investment

The introduction of either the 3B or the SRA2 presses was seen as having wider effects in several other aspects of production as follows:

Platemaking - The price of plates depends upon size and both the 3B and SRA2 use smaller plates thereby offering savings, with the SRA2 machine offering slightly larger savings in this respect. However, more plates will be needed for general packaging due to there being less composite sheet runs. In print, more plates would be needed for the

SRA2 press than for the 3B press due to an increased number of smaller sections necessary in brochure and booklet work. In addition, for jobs where the company hold standing plates, there would be a one-off cost as new plates would need to be made.

Cutting and Creasing - There would be more sheets to cut creating longer running times. However, to an extent this could be offset by shorter make-ready times because more pre-make-ready can be done and there would be a reduction in the number of composite sheets. Either of the new presses would substantially increase the use of the existing 1080 machine and reduce the need for the 1420 machine. An assessment was made on this situation and it was suggested that by selling the 1080 and 1420 machines, sufficient cash could be raised to enable the company to purchase a new appropriately sized machine which would be able to produce the work currently performed on the two existing machines.

Stripping - The main effect in this area would be the reduction of composite sheet work which is currently a major problem.

Bindery - The 3B would reduce the number of sections for folding and collating, however, this would not be significant.

Work-in-progress and manufacturing lead times - The reduction in the number of composite sheets was seen as offering substantial reductions in general packaging WIP and production leadtimes.

Work flow - This was expected to be greatly facilitated and production planning made easier. Although management found this effect difficult to quantify in cash terms, its potential effect on cash flow was seen as being greater than any of the other items mentioned.

Storage - The effect here was that there will be more pallets to handle and store per job, but the average job would flow through the factory more quickly. There will be fewer partially stripped pallets to store which are dangerous and waste creating.

Extra sales potential - While the introduction of either press would offer production savings, a key element in their justification is the potential they offer to generate new and increase existing business. To obtain some indication of how effective a new press might be in this respect, in General Packaging 53 potential customers expressed interest and if the normal strike rate of the company (1 in 4) was achieved, this could be expected to yield 13 new accounts. Based on the average account yielding a turnover of £50,000 per annum, the potential from the list of 53 alone could produce an extra £650,000 per annum. On the general printing side of the business which tends to be less price sensitive, the bad performance of the existing machines in terms of output, quality and wastage had resulted in a situation where the company was losing business. It was felt that unless the sales department believed the factory could produce effectively, they were somewhat reluctant to search for new print work. With the new machine such problems should be overcome and it was planned to recruit an extra salesperson to generate new accounts.

7.6 Costs & Payback of Investment in New Printing Press

The study showed the effects on costs to be as shown in table 7.4

New Print Press:	**3B**	**SRA2**
New Machine Cost (plus 5,000 plates):	£500,000	£355,000
COST ASSUMPTIONS (see notes below)	£ per annum	£ per annum
(a) Decrease/increase in operator costs	22,000	(6,000)
(b) Decrease depreciation	5,000	5,000
(c) Decrease repairs	10,000	6,000
(d) Decrease outwork	146,000	124,000
(e) Profit on extra sales on 150,00 with 3B and 75,000 with SRA2	52,500	27,000
(f) Increase depreciation (7 year life)	(71,429)	(50,714)
(g) Increase in extra finance (14% interest rate)	(70,000)	(49,700)
(h) Savings on stripping/die/cut crease	22,000	8,000
(i) Savings on board	10,000	10,000
(k) Savings on Plates	5,000	5,000
Total Extra Profit	**131,071**	**79,586**

Table 7.4 - Cost effects of 3B Press

Notes on Assumptions:

(a) **Decrease/Increase Operators** - The 3B needs 3 operators per shift, so double shift operation requires a total of 6. These operators would also need to be given a pay increase due to the extra skills required. However, 2 operators would be lost from the Perle 429 and a further 6 from the Roland giving a net saving of £22,000 per annum. With the SRA2 machine 6 operators would also be be needed, against which 2 operators on the Perle 429 and 3 on the Roland would be lost.

(b) **Depreciation** - The saving will be made on the Existing Perle 429 machine

(c) **Repairs** - This is an estimate since the existing machines are performing badly and the new ones are based on state-of-the-art technology.

(d) **Outwork** - Due to the extra capacity the new machines provide, outwork would be greatly reduced offering substantial cost savings.

(e) **Profit on Extra Sales** - The extra sales projected in 7.3 would yield an additional 35% gross profit to company turnover.

(f) **Depreciation** - The new machines starting from a high initial value will therefore have a higher value of depreciation. It is assumed that they are depreciated over 7 years.

(g) **Extra Finance** - borrowed to pay for new machine, assume 14% interest rate

(h) **Strip/Die/Cut & Crease Savings** - The reduction of composite and large sheets would result in the lost of 1 operator on stripping. Die making time would be reduced by 15% on the 3B and 20% on the SRA2. The savings achieved on cutting & creasing and make-ready would only partially offset the extra running time. The overall cost effects can be summarised as follows:

	3B (£)	SRA2 (£)
Cutting & Creasing	(2,378)	(20,892)
Die-making	14,364	19,151
Stripping	10,000	10,000
Total Savings	**21,986**	**8,259**
Say	22,000	8,000

(j) **Board Savings** - Estimated 1% Savings on materials

(k) **Plate Savings** - Large plate savings are slightly reduced by longer platemaking times. From these figures it can clearly be seen that either machine is potentially a good investment. Using conventional (non discounted) appraisal methods, the years to payback on the 3B would be 2.47 with a return on investment (ROI) of 40.5%. With the SRA2 the payback would be 2.72 with an ROI of 36.7%.

Using the cost data, a discounted cash flow analysis on both machines was made using the *Investment analysis Spreadsheet* (shown in appendix 7.1). This is summarised in table 7.5 and the NPV shown graphically in figures 7.2 and 7.3.

Discounted Cashflow Analysis (£)	**3B**	**SRA2**
Cost of Machines	500,000	355,000
Cash Inflow		
Extra profit	131,071	79,586
Add back non cash depreciation	71,429	50,714
Cash Generated	202,500	130,300
4 year payback required and the cost of capital is 14%, therefore multiply annual income by factor of 2.914	590,085	379,694
Positive NPV	18%+	7%+
Sensitivity Analysis		
Income would have to shortfall by:	36,450 p.a.	9,121 p.a
If the expected rise in sales was only 50% of that estimated, ie. £75,000 for the 3B in year 1 and £37,500 for the SRA2 in year 1 the NPV would reduce to: (see the *What if?* facility in tables 7.1 and 7.2)	67,064	1,015
	13.4 %	0%+

Table 7.5 - Summary of DCF Calculations of 3B and SRA2 Presses

The results of the study showed clearly that the purchase of either machine was worthwhile, the question facing management being which one. Although the DCF analysis show that the 3B machine was favoured, other factors needed to be taken into consideration. A key one for choosing the SRA2 press was that it is more suitable for general print work, whereas the 3B is better for packaging and general printing which

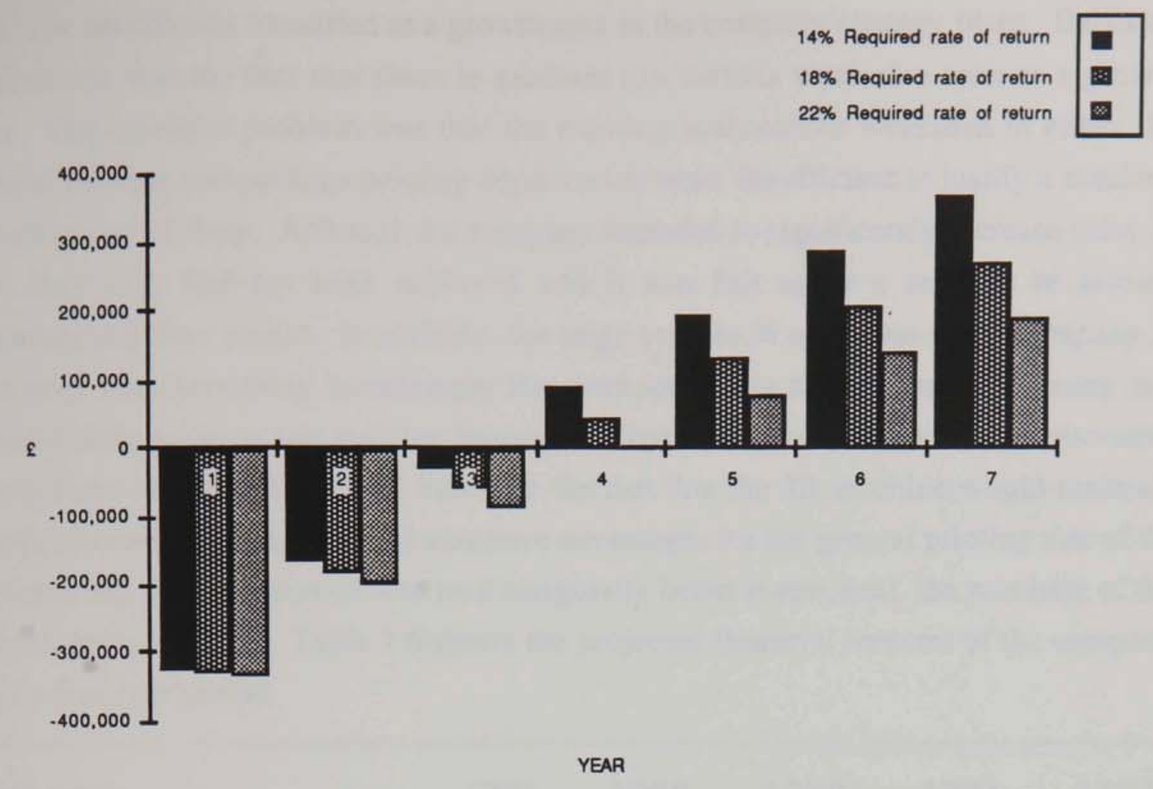

Figure 7.2 - DCF analysis using NPV of 3B press investment

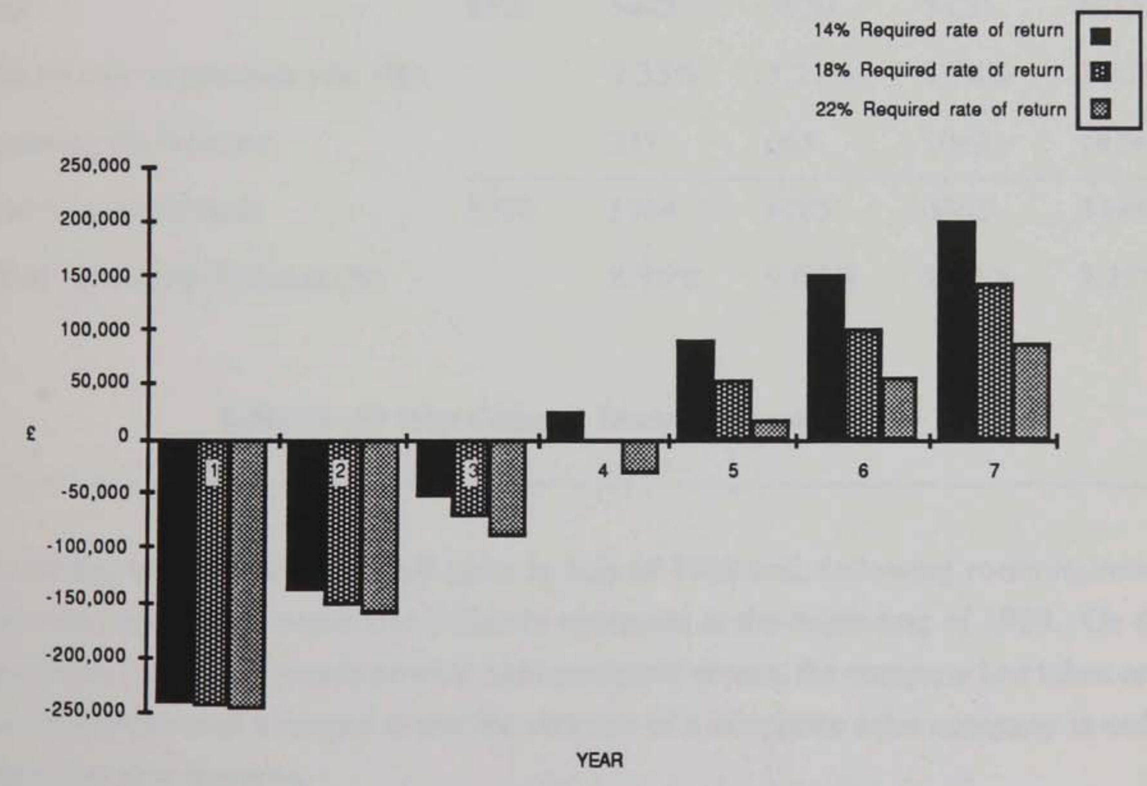

Figure 7.3 - DCF analysis using NPV of SRA2 press investment

had been specifically identified as a growth area in the company strategy plans. Balanced against this was the fact that short to medium run cartons were also seen as a growth area. The essential problem was that the existing multicolour workload in either the general printing and package printing departments were insufficient to justify a machine for either one of them. Although the company intended to significantly increase sales, at that time they had not been achieved and it was felt to be a mistake to assume automatically they would. In addition, the large presses in operation at the company at that time were becoming increasingly less competitive in the packaging industry and could shortly begin to lose existing business, whereas the company was still reasonably competitive in print. Therefore, based on the fact that the 3B machine would maintain competitiveness in packaging and also have advantages for the general printing side of the business and its DCF showed it to be a marginally better investment, the purchase of the 3B was recommended. Table 7.6 shows the projected financial forecast of the company over a five year period.

Turnover	1988	1989	1990	1991	1992
Base Turnover	5320	5320	5320	5320	5320
Extra Telesales Companies		125	200	275	350
Extra Salesperson			100	225	375
Total	5320	5445	5620	5820	6045
Real growth on previous year (%)		2.35%	3.21%	3.56%	3.87%
Assuming 6% inflation		319	665	1042	1454
Total Organic Growth	5320	5764	6285	6862	7499
Growth including Inflation (%)		8.35%	9.04%	9.18%	9.28%

Table 7.6 - PP Print Company Financial Forecast (£000s)

Installation work began on the 3B press in July of 1988 and, following commissioning work was expected to come into fullscale operation at the beginning of 1989. On the assumption that the 3B would provide extra competitiveness, the company had taken on a new salesperson and arranged to use the services of a telephone sales company in order to generate new business.

7.7 Company Models

Having performed the localised DCF analysis of the proposed 3B investment, the original intention of the research was to monitor its effect upon overall business performance over several months to compare against the planned performance, to see if the managements expectations were realised, and to model future investments being considered. While the problems with the commissioning removed all opportunities for the looked for demonstration of technological innovation effects upon performance in the broader sense, it has been decided to demonstrate by means of models developed for the purpose - and themselves constituting an integral part of this interdisciplinary thesis - the effects of variables affected by the non-availability of the press, primarily the sales of general cartons and outwork.

While the financial director performs DCF calculations as a matter of course in evaluating any new investment of a significant size, he admitted that this is only one part of the financial evaluation, other key factors being how well the investment "fits in" with the long term strategy of the company. The main limitation of DCF calculations was seen as that a new investment would have a whole "web" of economic implications for *overall* business competitiveness, and it is not always easy to represent these in just a DCF calulation. In particular several of the benefits, associated with the introduction of a more technologically advanced printing press, were seen as difficult to quantify directly in economic terms, (this again can be referred to the "intangible" benefits argument usually discussed in relation to the use of AMT in the engineering industry, but is equally applicable in other industrial sectors), examples being, the considerable improvements in workflow as a result of the 3B machine and the "enhanced" image among customers of the capabilities of the firm.

Another advantage of the 3B machine that it was found difficult to quantify, but which would improve *overall* business performance, was the removal of more complex print work from less sophisticated presses, not suitable for this type of work. Print capacity could be released for work for which they are better suited, and be more competitive. As with the use of CNC machines discussed in the previous case studies, in order to get a good return on the use of more expensive automated machines, different production management skills are required to ensure that they are used intensively and that the most cost-effective work is placed upon them.

At present, the financial planning procedure used in the company is that, at the start of each year a "rough" outline of the operating budget is prepared using sales based on firm customer orders, and what the firm is considered likely to obtain, given the current state of the market. A more accurate projection is made on a quarterly basis by the Management Accountant, which is reviewed at management meetings to monitor progress throughout the year. The FD does prepare some general longer term projections of the company's performance, but does not use spreadsheets or other quantitative analysis techniques to assist in this task.

Figure 7.4 shows the conceptual model used to analyse how the company would be affected by new investment. At the production level, the economic effects, were expected to be those described in table 7.4. and were taken into account using NPV. The detailed model acts as a further level of analysis of overall company performance. In particular, it was intended that any indirect effects of technological change such as the need for more technical skills would also be included. Initially, the company envisaged that there would be no need to increase the level of technical expertise within the company, but subsequent events were to change this view. The hoped for improvement upon financial performance would also be reflected in the financial ratios of the company.

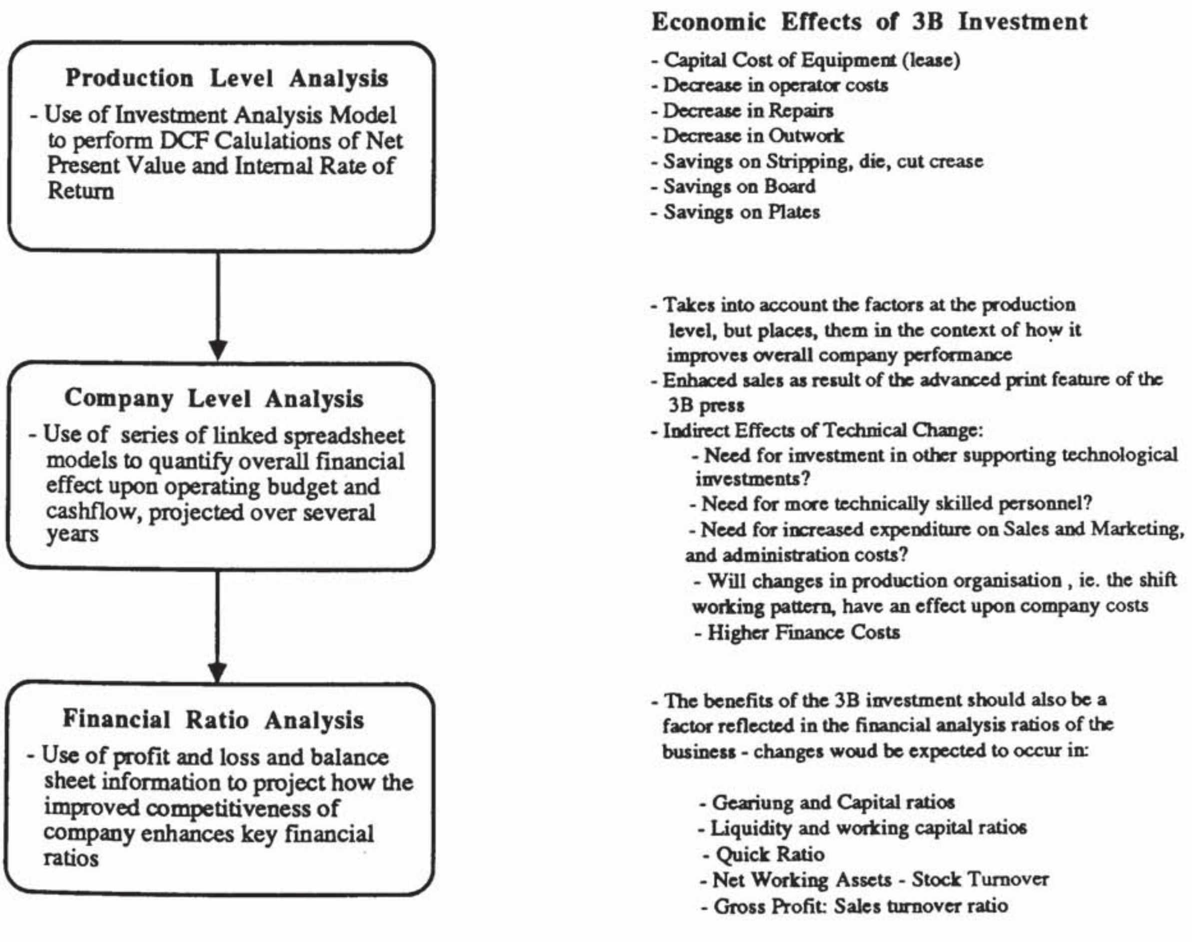

Figure 7.4 - Model of how the 3B Machine would affect the PP Print Company

The model structure used in this chapter is the *detailed company model* described in chapter four and shown in figure 7.5 consisting of a series of linked spreadsheets. The model was designed originally for use with a larger company than PP Print and where detailed modelling of a series of investments was required over several years. However, in the event no suitable opportunity arose to use it, and so it is used in this chapter to model the PP Print company for demonstrative purposes. Each spreadsheet as shown in figure 7.5 has a years's operating budget and cashflow on a monthly basis, with a summary spreadsheet, linked to a balance sheet summary, which in turn is linked to a financial analysis spreadsheet. An advantage of using linked spreadsheets is that it enables models to be modular in design, so that the user can remove and insert alternative spreadsheets.

Although the model has the capability to make projections over four years on a monthly basis, due to a lack of reliable data on which to do this, the author decided to only analyse year 1 (1989) on a monthly basis. A key feature of this model is that it provides a *What-if* facility. The bottom part of the 1989 spreadsheet (rows 470 to 762) has the planned financial projection of the operating budget and cashflow, taking into account the costs benefits of the 3B press and acts as the base model against which actual performance is compared.

The top part of the spreadsheet (rows 1 to 466) has the same format as the bottom and copies the values across from it, but has the facility to enter a percentage difference from the plan below each cost category. For example, in the base Model shown in appendix 7.1.2, the planned sales figures of general cartons in January 1989 was £180,000, (row 484, column C). To find out the effect of a 10% reduction in this value on the net profit and hence on the cashflow, the user would enter "-0.1" in the *What-if* facility (row 26, column C) and the result would be calculated (and displayed in row 16, column C). Although, the model has the capability to vary all the values in the plan, it is not suggested that this facility would actually be used in all cases, since many of the cost categories contain very small figures. Instead, the user can set the model so that a change in one cell is copied to all other cells automatically, and so the user is able to tailor the model to suit the level of detail required. For example if the user wish to specify that all the materials costs values (rows 83 to 92) would be 5% lower than plan throughout the year, the user could set the model up so that for example, a "-.05" entered in row 97, column C, would be copied across the rest of the cells in the materials category. The model was originally designed to represent most smaller to medium sized companies, and so has a degree of built-in flexibility for adapting its use to individual firms.

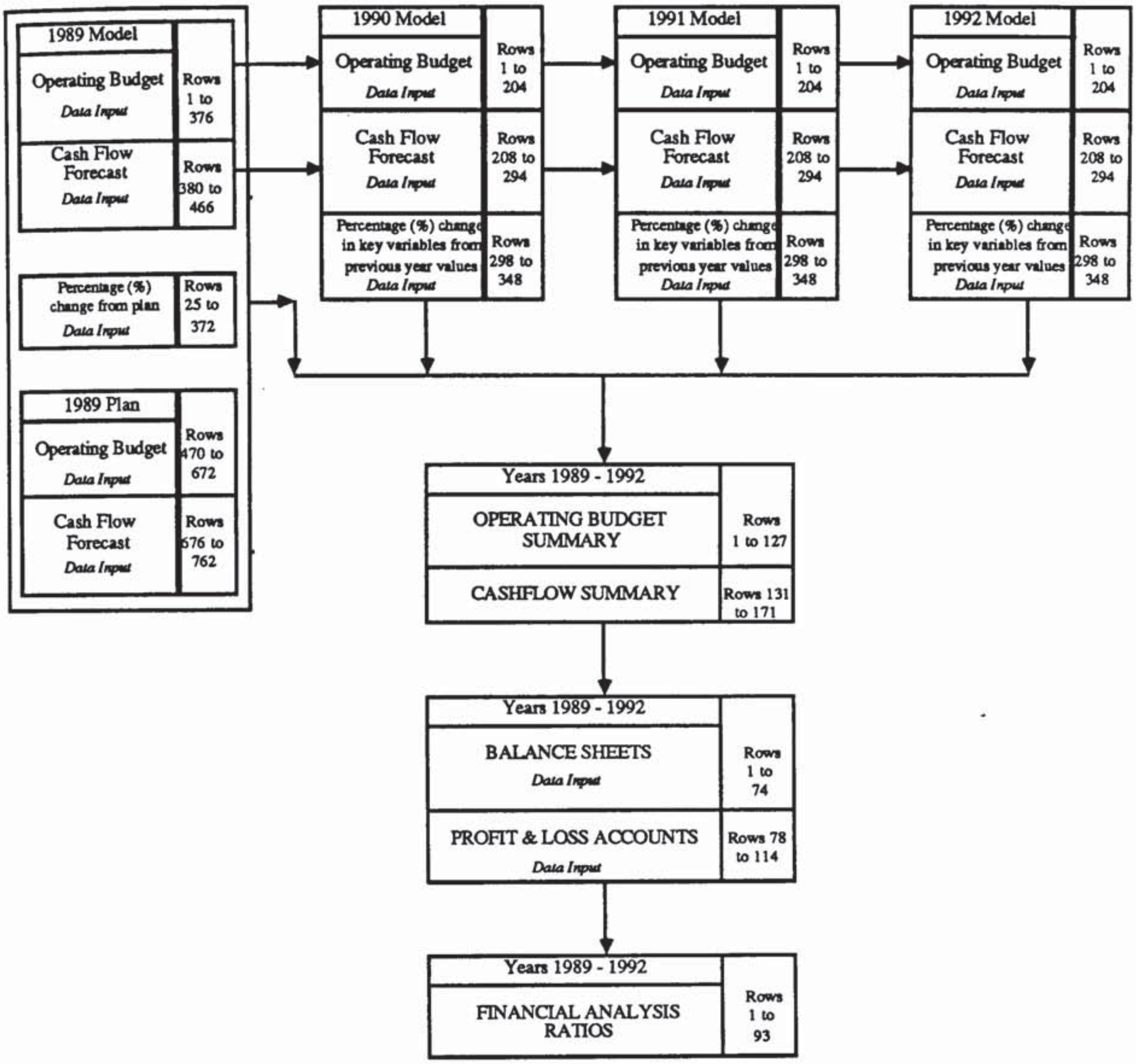

Figure 7.5 - Structure of PP Print Company Spreadsheet Model

Years 2 to 4 (1990 to 1992, appendices 7.1.3 to 7.1.5) are projected on an annual basis by means of the parameter change facility at the bottom of each spreadsheet (rows 298 to 307) although the yearly figures are divided by 12 to give some indication of the monthly profit and loss, and cash flow in these years. For example, the 1990 sales figures (rows 16 to 21, column C) are copied across from the 1989 spreadsheet (same reference) and again multiplied by a user defined value in rows 302 to 348, column E. This figure is made up of a factor for real growth and one for inflation.

7.8 Expected Financial performance of 3B Press

When the author first began working with the company at the end of 1988 there was considerable expectation of the new press, due to become operational in February 1989. The management felt that it had certainly had the effect of raising the morale of the workforce, after several years of underinvestment and struggling to be profitable, and was seen as the start of a progressive upgrading of production facilities. The management did not envisage that the press would require any organisational changes to manage the press and its day to day operation would be left to the present supervisory structure. It was felt that there was enough technical competence within the company to cope with this technological step.

At the end of 1988, the base model operating budget was set up with the Financial Director and the Sales Director projecting the financial performance of the company over 1989 on a monthly basis. Figure 7.6 shows the projected net profit before tax over this period. A full printout of the model is given in appendix 7.1. Although the print business is not a seasonal one, there are discernible trends, most notably, peaks around April and November, and in a business of this kind it is quite common to have wide fluctuations between months. This is also reflected in the predicted cashflow as shown in Figure 7.7.

Being in a market in which they have to be able to respond quickly in order to win contracts, the company can often find itself in the position of winning a contract but without sufficient print capacity to perform the whole job itself. In such a situation, work is subcontracted out to other printing firms. The disadvantages of outwork are that the firm loses direct control over the production of the work and incurs a price penalty, since the profit markup of the subcontractor has to be taken into account. In order to keep outwork costs down, the company tries to ensure that as much as possible, it is only the cheaper, less sophisticated work that is subcontracted. This is a particular area of the company's operations where new technology would greatly assist. In this respect the advanced print facilities of the 3B would assist in ensuring that the elaborate work is kept inhouse. Based on the 1988 figures for outwork the FD planned to reduce the outwork by £146,000 through the use of the 3B machine. In the overhead figures given in the operating budget summary in appendix 7.1.1 it should be noted that the company has changed the categories in which it allocates costs and so it was not possible to have a direct comparison with the 1988 and 1987 figures.

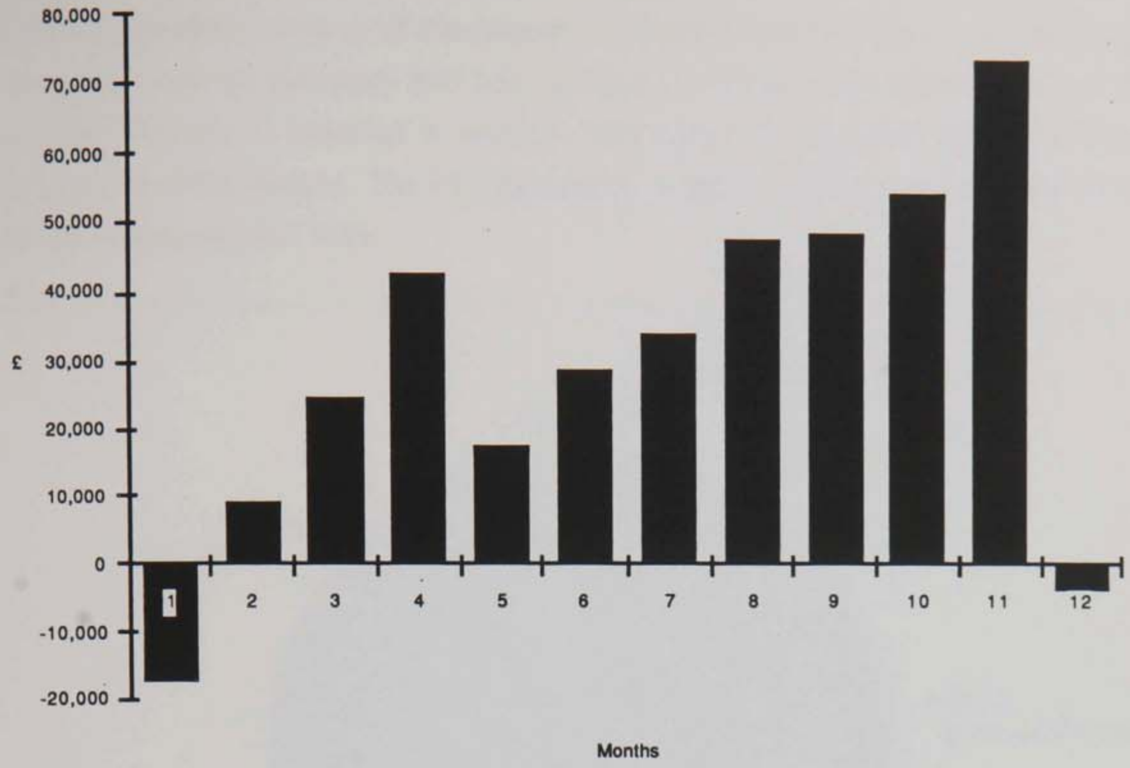

Figure 7.6 - Base model 7.1 1989 projected net profit before tax

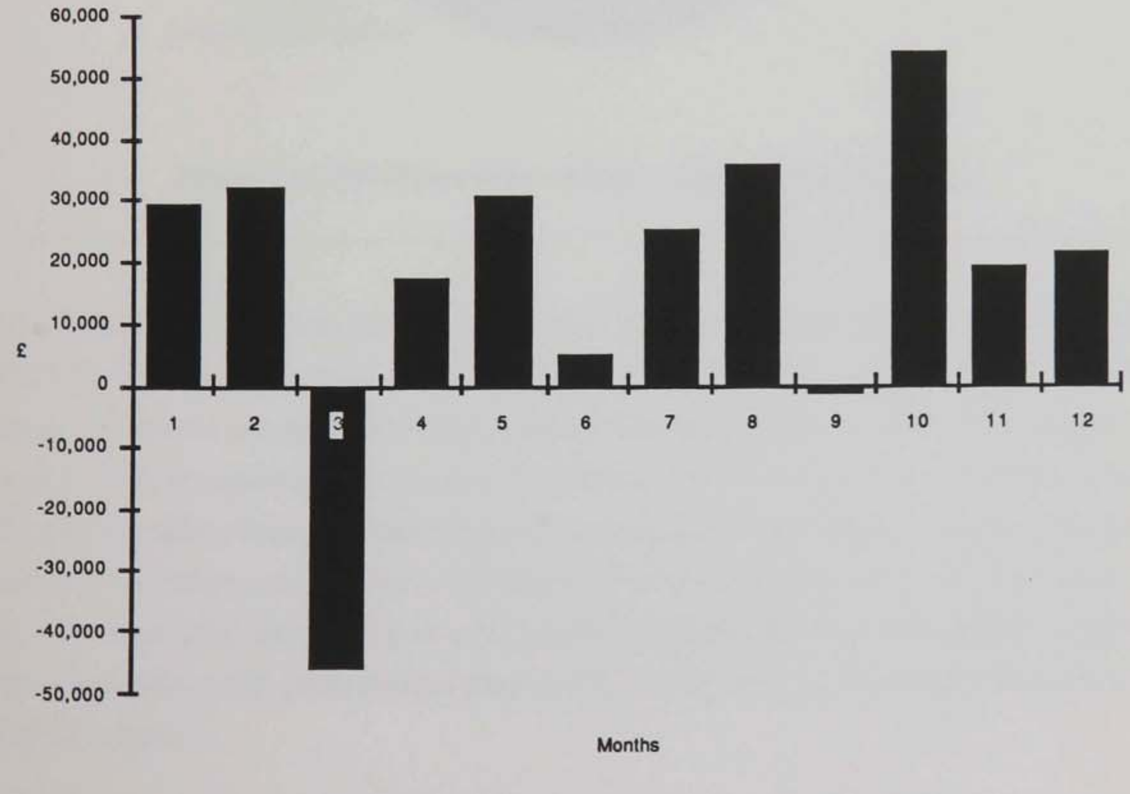

Figure 7.7 - Base Model Predicted 1989 cash flow

The expected sales breakdown by product category in 1989 is shown in figure 7.8. The largest sales product category of the company is general cartons, and it is in this category in particular that the company had been gradually losing its competitiveness, a trend which the 3B press is intended to reverse. The market for general cartons is also the most price sensitive market. The FD planned for roughly a 10% increase in overall sales turnover compared with 1988.

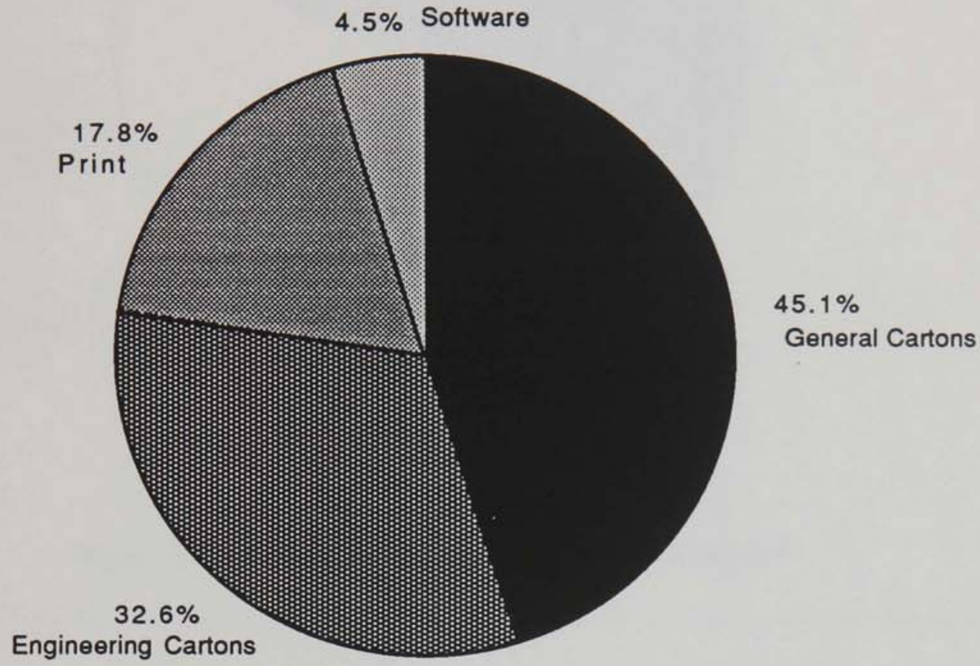

Figure 7.8 - 1989 Planned percentage of sales turnover by product

The 3B machine was scheduled to produce approximately £578,000 of customer sales, £398,000 of which would be replacing existing plant gaining extra sales of £150,000. Figure 7.9 shows the planned breakdown of company costs in 1989. The largest cost category is direct materials accounting for around a third of all costs. Materials costs are difficult to predict since considerable variation can occur according to how successful the material purchasers are, and the particular mix of contracts the company has at any one time. For example, the gaining of a large print contract and the consequential need for a larger materials order gives more scope to the purchasers for obtaining discounts from material suppliers.

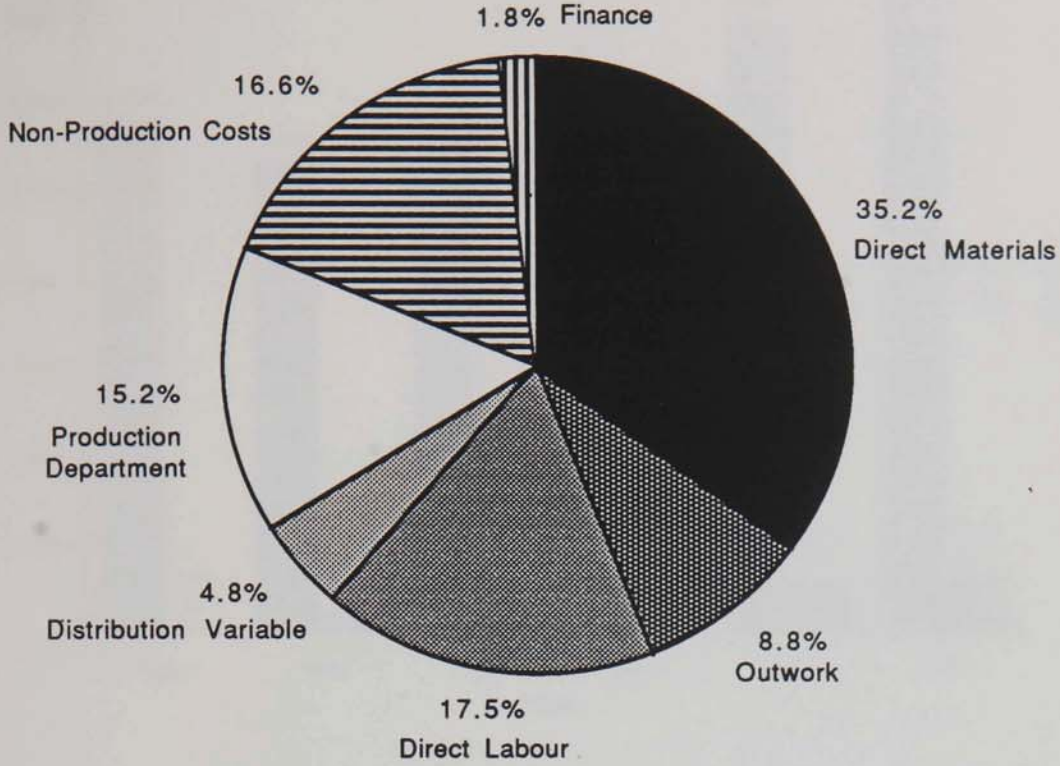

Figure 7.9 - Breakdown of planned company costs in 1989

In projecting the strategic business plan over 1990 to 1992 as shown in the operating budget summary in appendix 7.1.1 at the time of setting up the models, the FD assumed a general rate of inflation of 6% which is included in the models from 1990 across all categories. Based on this plan, general cartons and general print work were identified as the main growth areas, and therefore in the base model it is assumed that general cartons show real growth of 3.5 % in 1990 to 1992, (row 16) with 1.5% for Engineering cartons (row 17) and 3% for general print work (row 18). In the models it is assumed that the associated costs of production will also rise in line with the real growth and inflation rate of the sales categories. In reducing outwork it is assumed that the company is able to increase its turnover in general cartons, without needing to increase the real value of its inventory in this category over 1990 to 1992. The objective is not only to increase turnover, but profit as a percentage of sales, with an eventual objective of approaching 10%. Figure 7.10 shows the projected sales turnover and net profit between 1989 to 1992 and figure 7.11 the cashflow. Appendix 7.1.7 shows the expected improvement in the financial ratios of the business, based on key items from the balance sheet summary shown in appendix 7.1.6.

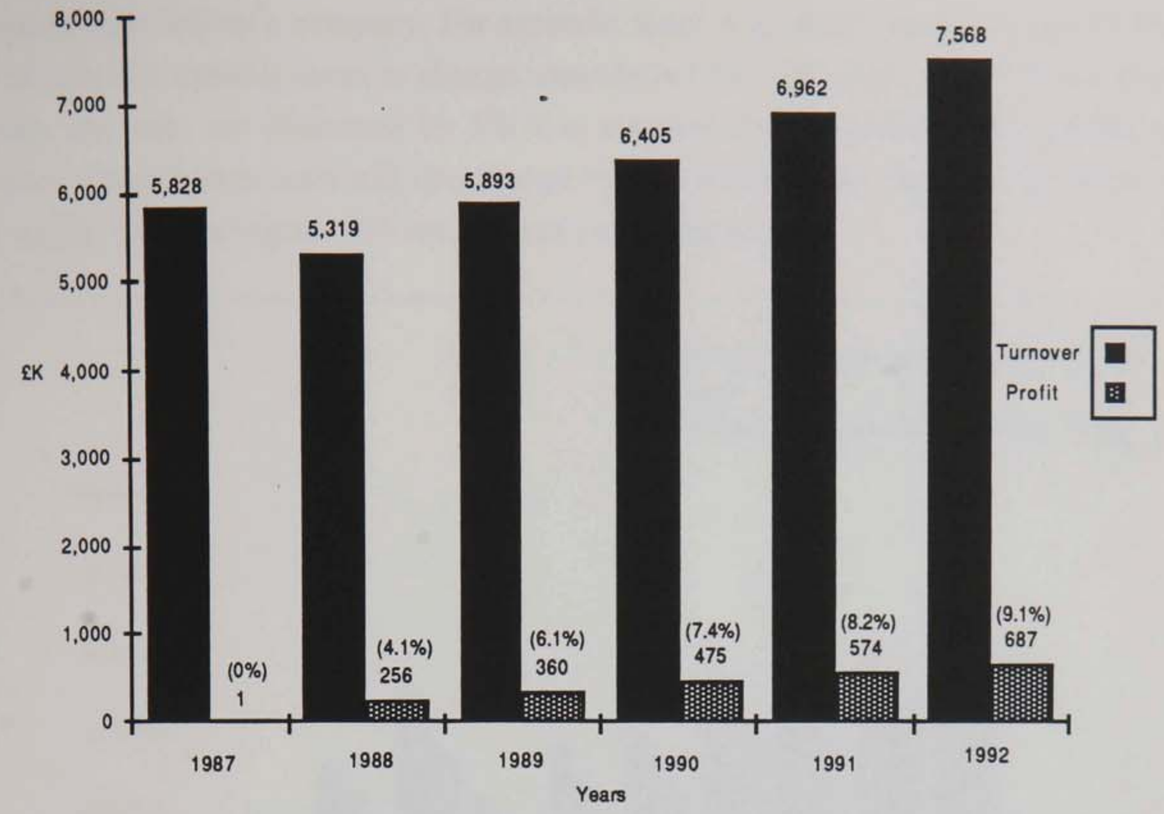

Figure 7.10 - Base Model 7.0 projected sales turnover and net profit Before Tax 1987 to 1992 with profit as a % of turnover in brackets

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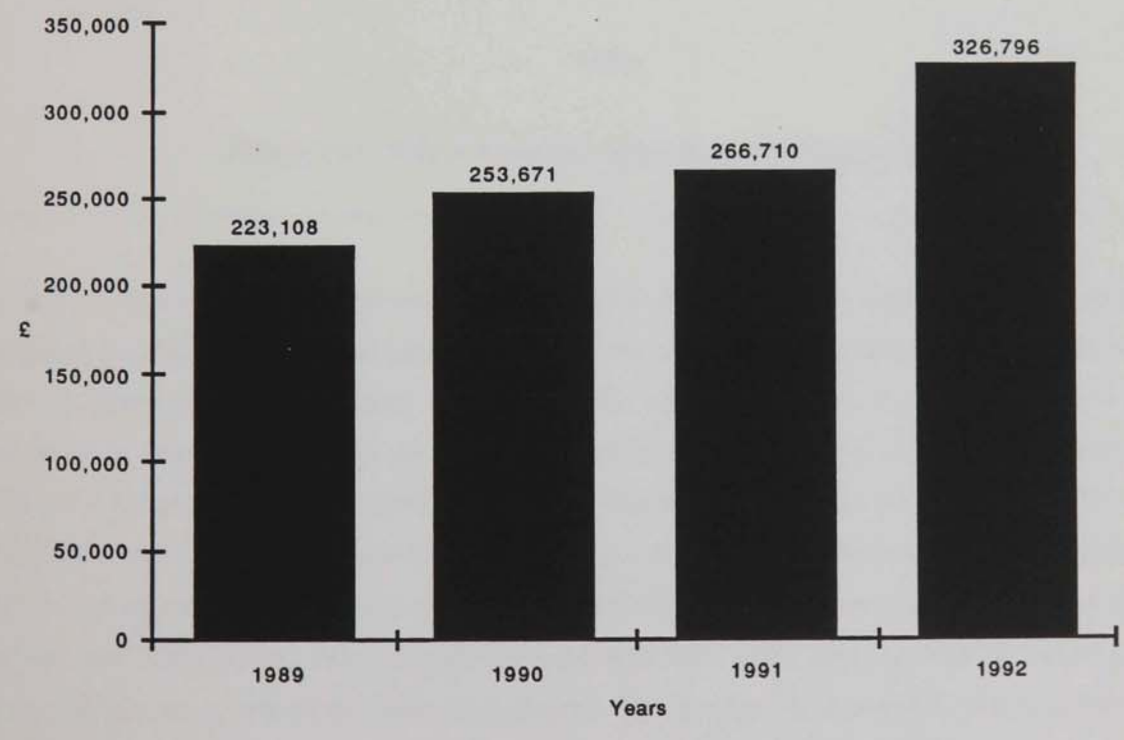

Figure 7.11 - Base Model Projected Cash Flow 1989 to 1992

An advantage of the spreadsheet models is that the logic can be set to reflect all cost relationships within a company. For example, there is a general pattern in the PP Print company for variable costs to change roughly in line with sales, and so in the model when the sales are decreased by 5% it is assumed that materials, direct labour and variable distribution costs will also change by a similar amount. Figure 7.12 shows for example, the effect upon 1989 net profit of such a change.

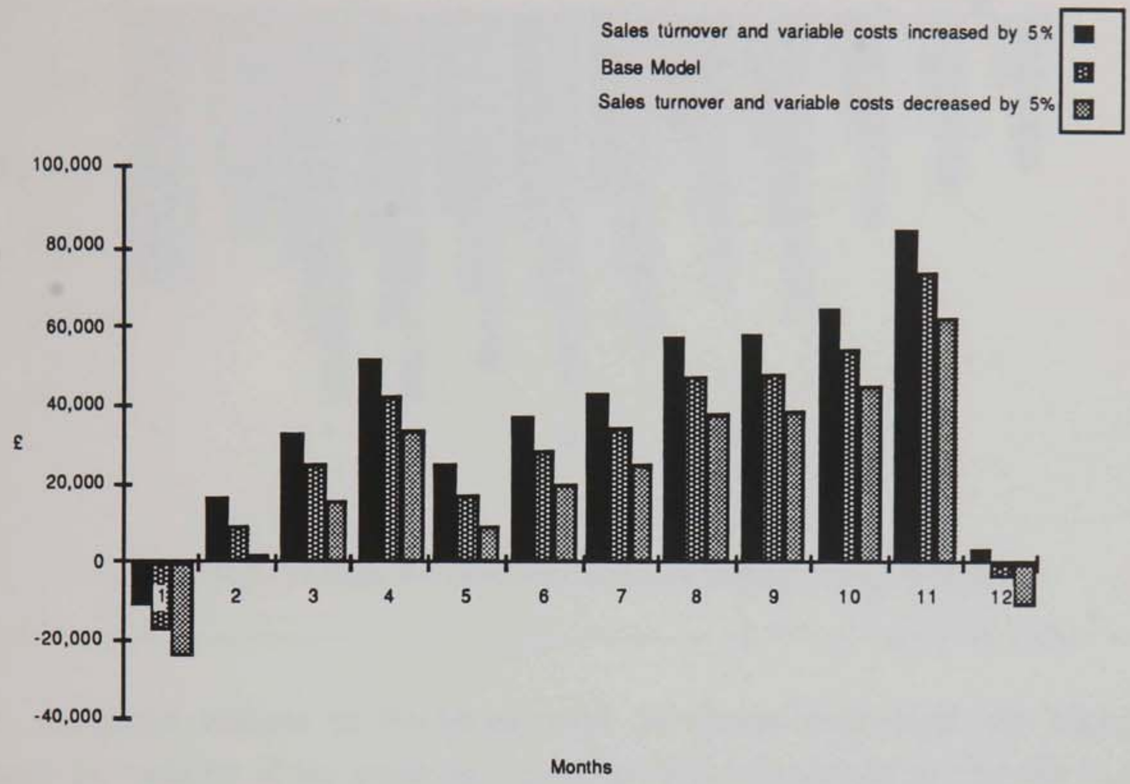

Figure 7.12 - Effect of varying sales turnover on net profit

In order to illustrate the importance of the cashflow in the small business, a feature of the model is its ability to vary the credit periods given and taken by the company. The credit periods given by the company are set at the top the cash flow in rows 210 to 218, columns in the 1990 to 1992 spreadsheets, (appendices 7.1.3 to 7.1.5). At present the firm as with most receives payment from its debtors on average about two months after the despatch of goods. Likewise the company pays its creditors after two months. To test for example the effect upon cashflow of getting 10% of its trade debtors to pay after 1 month, and 90% within two months the user sets the credit terms of the model to match these credit terms, which are then calculated. The results illustrate the potential benefits to the cashflow of ensuring that debtors pay as soon as possible. Figure 7.13 shows that the cumulative effect over the span of a year can be quite significant on the closing balance. The model by incorporating this feature enables the company to plan ahead to analyse critical periods of the cashflow in greater detail.

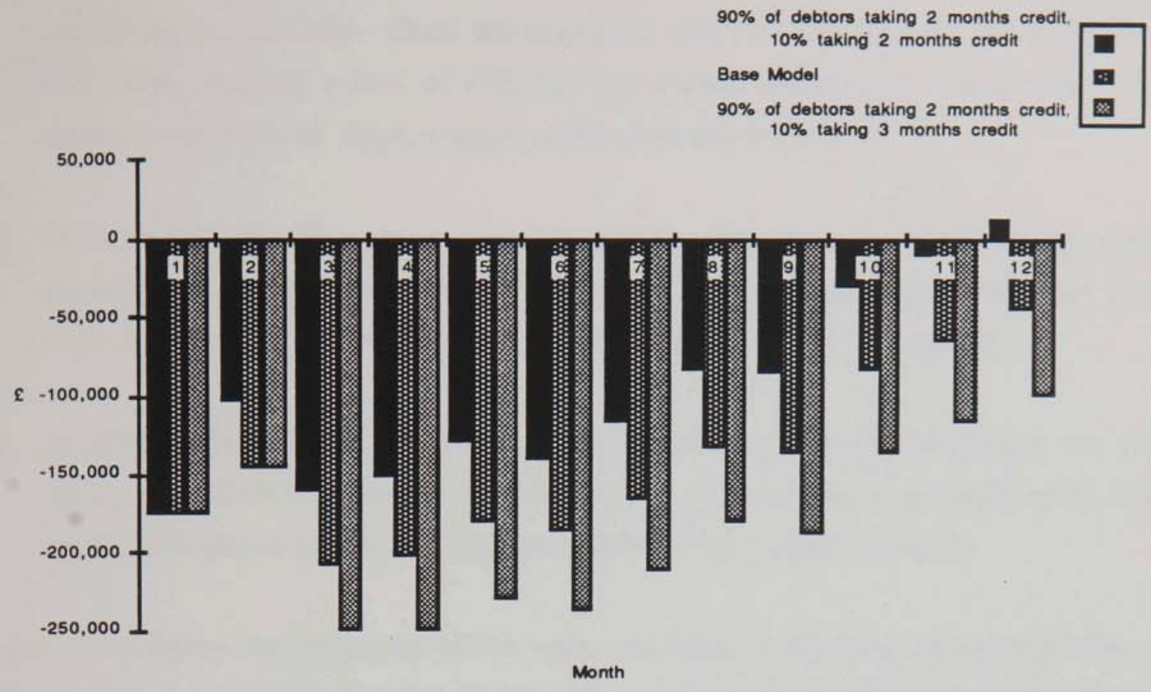

Figure 7.13 - Varying of credit period given on monthly closing balance

7.9 Financial Effects of Problems with 3B Press over First Six Months

Despite the viability of the investment from its DCF analysis and its key role in the company's strategic plans for the future, considerable problems were experienced in its commissioning. The supplier of the 3B machine had originally stated that it would be operational by the end of January 1989. Despite repeated assurances from the suppliers that the machine would be made operational within a short period of time, it soon became clear that the machine had serious technical deficiencies. Given that the press had taken several months to install, it was felt that the overcoming of these problems could make the press unavailable for between 4 to 6 months. In terms of the overall effect upon the company the main problem was that since the company had disposed of one of its older presses to make space for the 3B, this meant that the print capacity of the company was reduced and that work scheduled for the 3B would now have to be outworked. Although this presented problems in fulfilling the original objectives of the research, the author was able to try and project what the effect upon the company would be over the period to June and how the final end year results would be affected. This is based on the following assumptions and is shown in the spreadsheet in appendix 7.2:

(1) The sales turnover estimate for 3B work was estimated at £578,000 for 1990 beginning in February. Thus, the expected sales to June were 5/12 x £578,000 = £192,666, roughly a loss of £38,533 per month would have been expected to occur, a reduction of approximately 19% over this period.

(2) In terms of the effect upon outwork saving, the 3B was scheduled to reduce outwork by £146,000 in 1990. Thus, 5/12 x £146,000 = £60,833, roughly a loss of £12,166 per month, approximately a 66% increase over this period.

(3) In terms of the effect upon materials costs, assuming that approximately one third of the extra £150,000 would be taken up by material costs, a saving of £12,844 could be expected per month, approximately a 20% reduction in cost

Figure 7.14 shows the projected effect upon the sales turnover to the end of June of general cartons (row 16) assuming that the 3B press is not available, compared with the actual results (shown in appendix 7.3) and the base model (appendix 7.1.2). These show a model projected sales value of £107.1k to the end of June compared with an actual value of £100.3k. The forecast base model sales was for £195k. In terms of the effect upon outwork as shown in figure 7.15 (row 89) the actual result to the end of June was £157k, some £52k up to on the base model value, compared with a model projection of £167k. (It should be noted that in setting up appendix 7.3 a full cost breakdown of all categories was not always available throughout the year and extrapolations were made where necessary based on existing trends within the business).

In terms of the effect upon net profit before tax (row 367), as shown in figure 7.16 the base model projected value with the 3B operational was for £105k to the end of June compared to the actual company results of 131k, while the model projection was for a £38k loss with the 3B non-available. The reason for this large discrepancy was partly due to the fact that the market for Engineering cartons turned out to be higher than the sales director forecast, and there is a tendency for short term large inventory rises to distort the values. Assuming that the 3B machine became operational at the beginning of July and achieved the original 3B base model figures, the model projected figures were for a profit of £216.3k, some £144k down on the original base model value of £360k.

In order to give some indication of what the performance of the company would have been without these distortions, figure 7.16 also shows the effect upon net profits assuming that base model projected results are achieved, except for general cartons where the actual associated sales and costs are superimposed and financial payments for the 3B are removed. The spreadsheet calculation for this is shown in appendix 7.4. This shows a total net trading loss of -£83.7k to the end of June, highlighting the extent to which the financial performance of the company would have been affected were it not for higher engineering carton sales, and overhead cost reductions. Figure 7.17 shows the cashflow of the model, where a net negative cashflow of -63.7k is projected to the end of June with the 3B non-available.

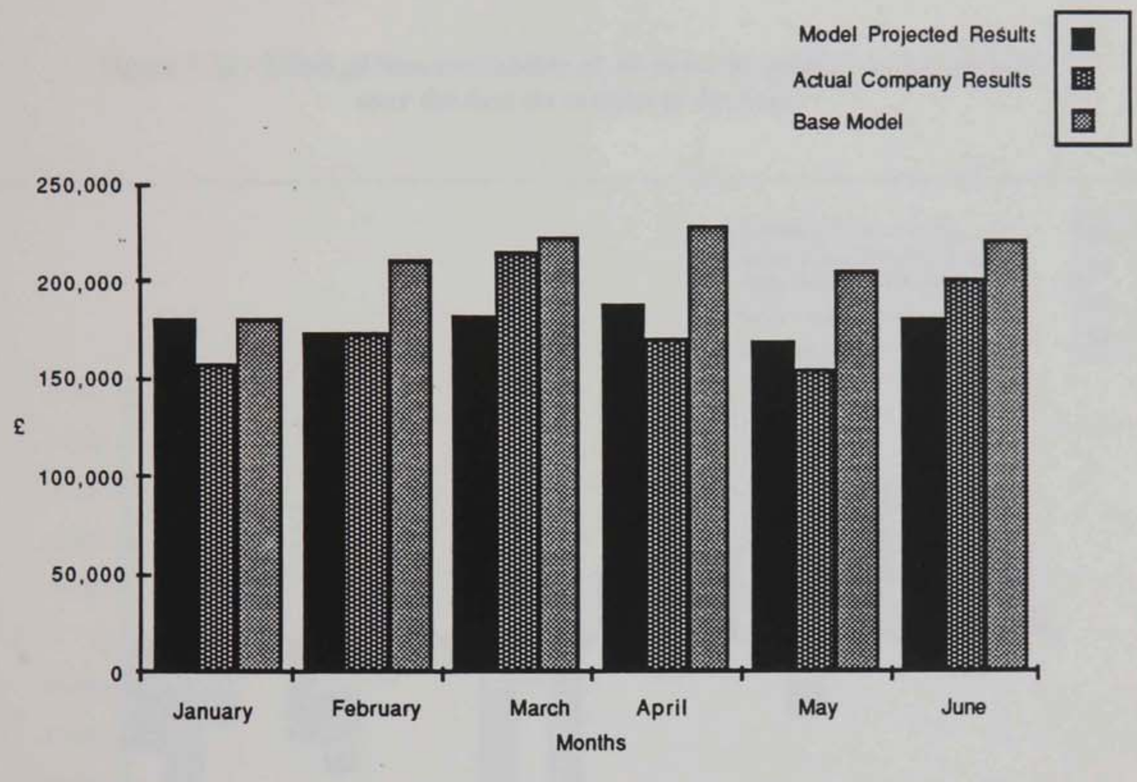

Figure 7.14 - Sales Turnover of General Cartons for first six months of the year with non-availability of the 3B Press

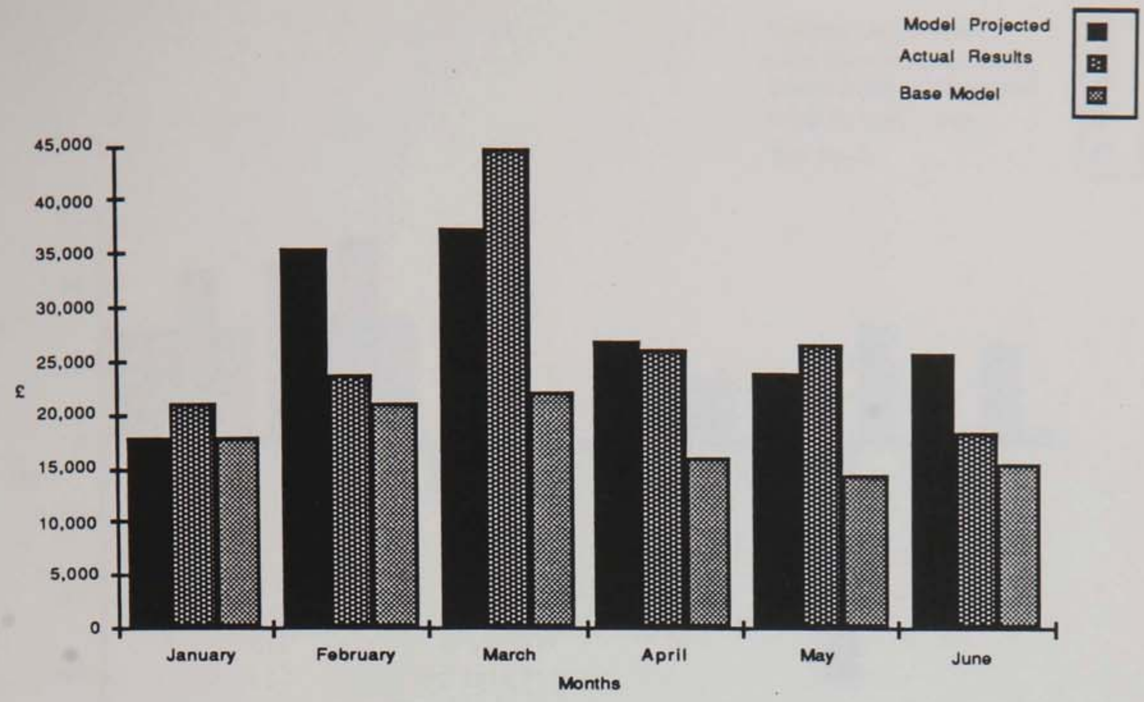

Figure 7.15 - Effect of Non-availability of 3B press on general carton outwork over the first six months of the year

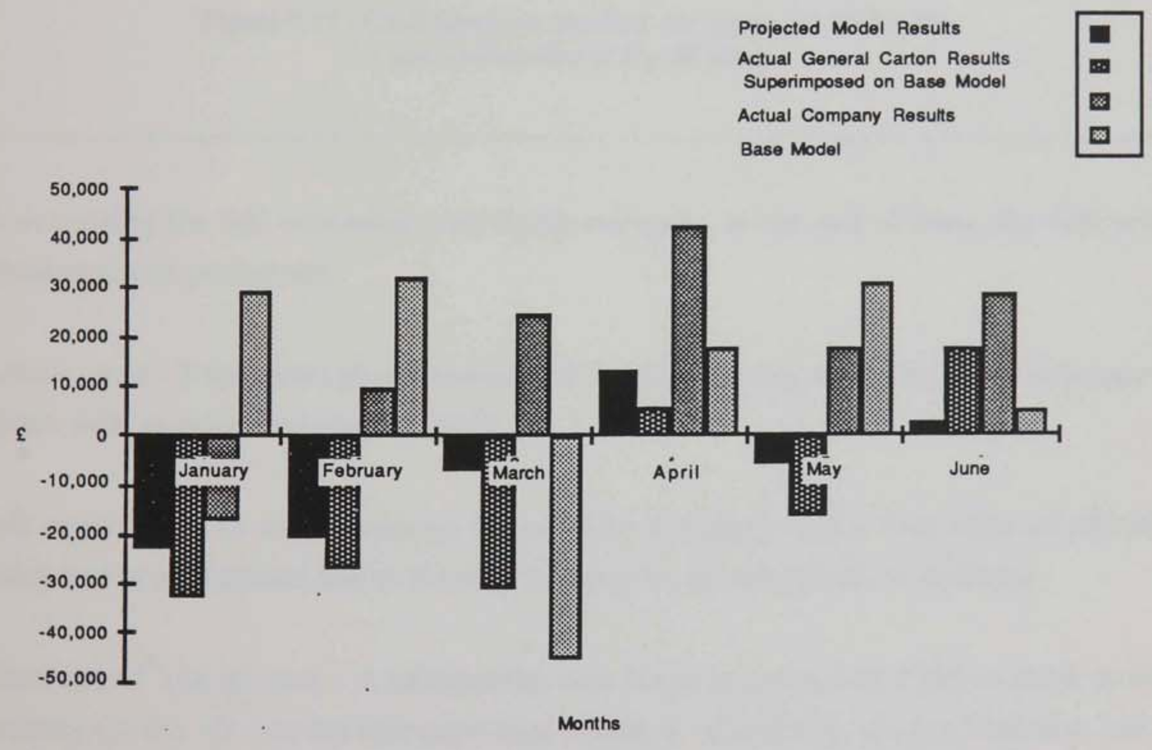

Figure 7.16 - Effect upon Net Profit of the 3B Press being non-available for the first six months of the year

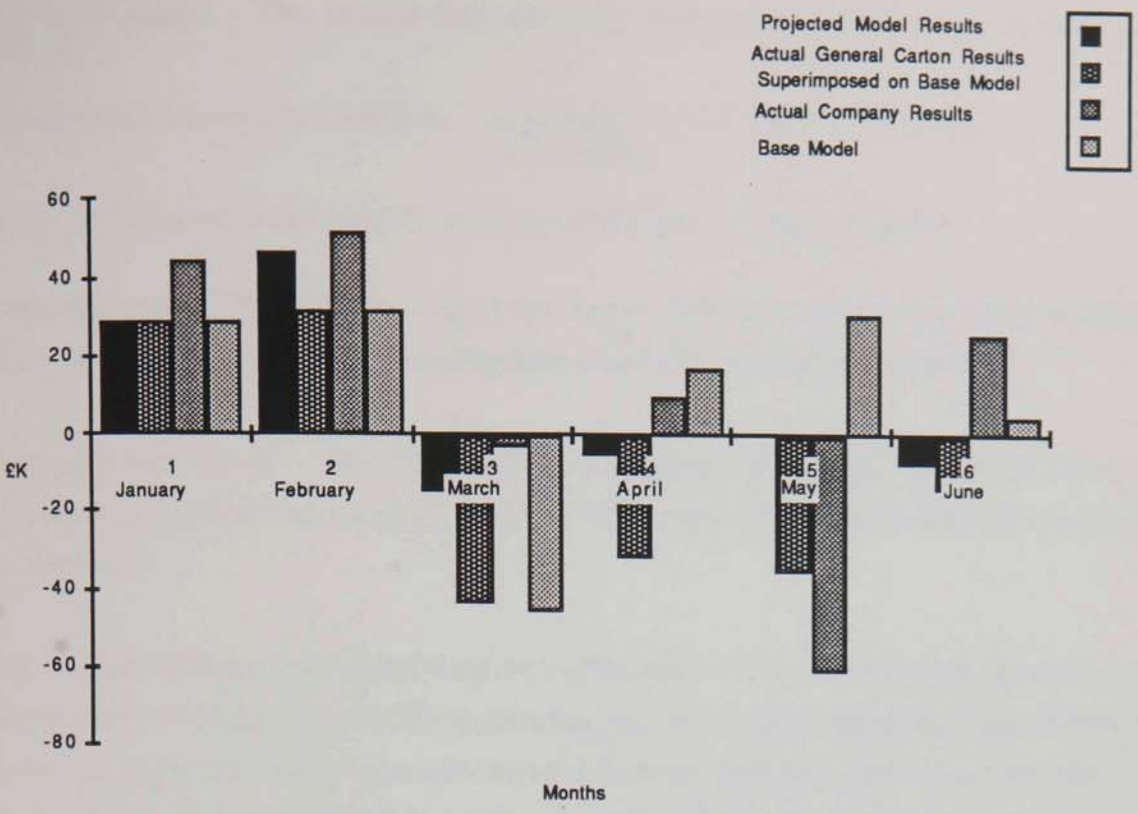

Figure 7.17 - Cash flow over the first six months of 1989 with non-availability of the 3B press

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In evaluating the full economic cost to the company at the end of May, the following calculation was performed:

Labour costs - 2 operators plus 1 assistant tied up producing very little from February to March with an estimated cost £10,230

Lost opportunity to sell Sovereign Press - The company had a firm offer of £35,000 which had to be declined due to the need to keep the existing press in operation

Dismissal of Salesperson - A salesperson was hired at the end of 1988 in order to find business for the 3B, but the company was unable to utilise him, so they therefore had to release him, with a cost of:

Agency Fee	£1,750
Salary	£9,900
Car Expense	£2,600
Loss on Car Sale	£1,000
Cost of aborted employment	£15,250

Loss of Business - The annual forecast from customers for 3B work in 1989 was £578,000.

Therefore the loss in sales terms is: $\frac{4 \text{ months}}{12 \text{ months}}$ x £578,000 = £193,000

The expected gross profit would have been £193,000 x 33% = £64,000

Outwork Costs - The company had to use outworkers to cover for the work scheduled for the 3B machine, with a total cost to date of £49,917 excluding materials.

Demonstration Costs - The 3B supplier company had visited twice to carry out performance demonstrations at a cost of £1,400, which they were unable to accomplish successfully.

Loss of face with customers and loss of staff moral - This was found to be difficult to quantify. For the company the 3B represented the first major new technology investment for several years and much was expected of it both by company staff and customers. The problems encountered resulted in company representatives being seriously embarrassed with customers with a consequent loss of moral within the company.

Production Inefficiency - The non-availability of the 3B resulting in the need to schedule work on inappropriate presses, and the use of outworkers with the consequential loss of direct control over the work has resulted in overall production inefficiencies, estimated cost £32,000

Summary	Labour Costs	10,230
	Loss of Sovereign sale	35,000
	Salesperson Dismissal	15,250
	Loss of Business - Profits	64,000
	- Outwork	50,000
	Demonstrator Aborted	1,400
	Production Inefficiencies	32,000
	Lost of face with customers	?
	Loss of staff moral	?

	Total Cost	207,880

Clearly, the potential financial benefits of investment in new technology are high, but likewise are the economic consequences in the event of problems arising, even with well established technology as PP Print were implementing.

7.10 Projection of Financial Problems over the Remainder of the Year

In June, the 3B press had still not come online, and it was feared that it would not be available for several more months. In particular, the supplier of the press could give no guarantee has to when it would be operational, which only added to the planning difficulties of the management. This however, provided the opportunity to project the performance of the company over the rest of 1989 on the assumption of its non-availability. Figure 7.18 shows the model projected net sales of General Cartons over the rest of the year, and is calculated as shown in appendix 7.5. In order to take account of the sale and cost trends up until that time, the model projects forward using an average value of change from the base model up until that time and comparing these with the base and the actual values. For example, in the sale of General Cartons shown in row 25, sales were on average 16% down on the base model from January to June, this value is projected across the rest of the year, and likewise for all other cost categories. Figure 7.19 uses the same method of taking the average value to project over the second half of the year for outwork. Figure 7.20 shows the effect upon net profit, (with 3B finance costs deleted) of continued 3B non-availability. This projects a final end of year profit of £308k. Figure 7.21 shows the cashflow where a positive cashflow of £223k is predicted. Although the company predicted in the 1989 budget that it would make £360,000 profit (6.1%) before tax off a turnover of £5.87M and finished with a profit of £285,000 (5.1%) before tax off a turnover of £5.49M this was mainly through overhead cost savings and effective purchasing. Had the 3B been operational a profit of around £470,000 was thought possible.

Another factor affecting the firm was that interest rates had risen. The FD thought that this would affect the firm badly and that the print industry may be heading for a downturn in demand, which the 3B machine problems only compounded. Asked at the time, what with the benefit of hindsight he would have done to overcome these problems, he suggested that with future investments, the company would ensure that they had tighter contractual arrangements with suppliers with severer penalty clauses in the event of a machine being non-operational. Being a small company legal action was expensive and would make heavy demands upon management time which they could ill afford. He would also try to ensure that the a new machine is fully operational before disposing of existing machines. An important organisational factor at this time was that the 3B problems were seen as highlighting the need for greater technical expertise in new print technology within the company in order to manage its implementation more effectively.

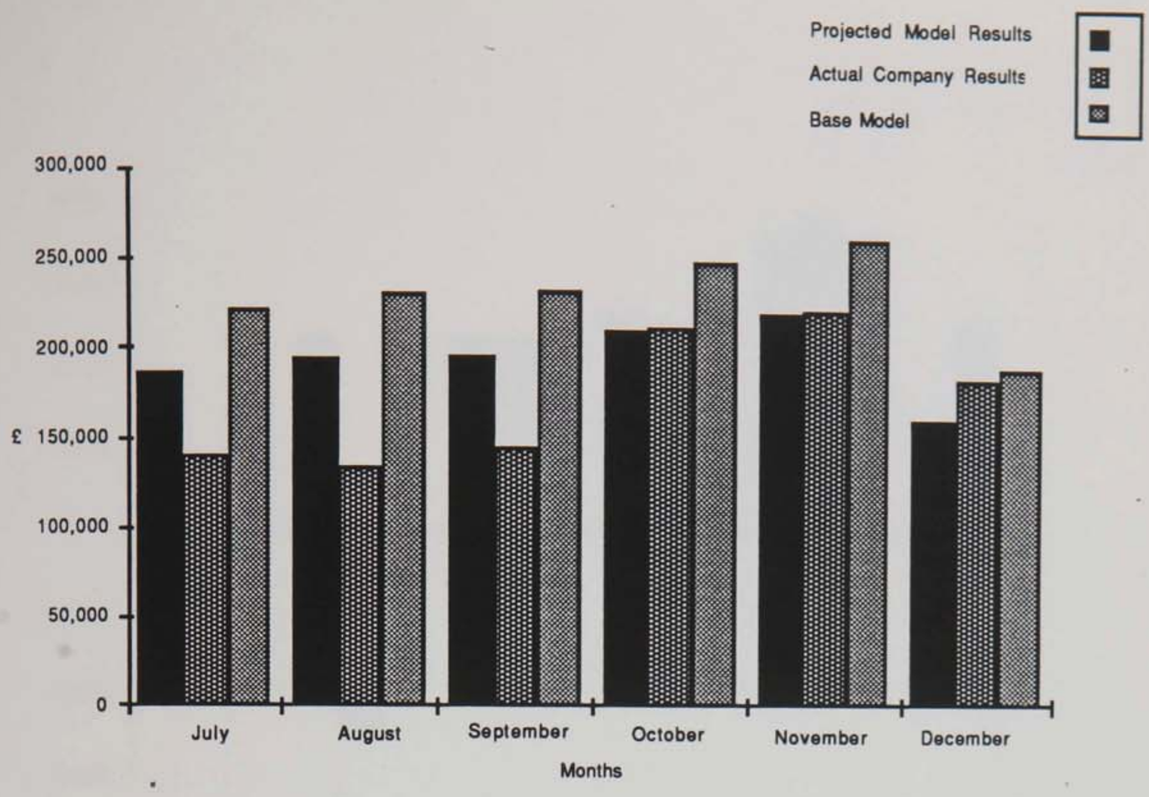

Figure 7.18 - Effect upon General Carton Sales of Non-Availability of 3B Press over the second half of the year

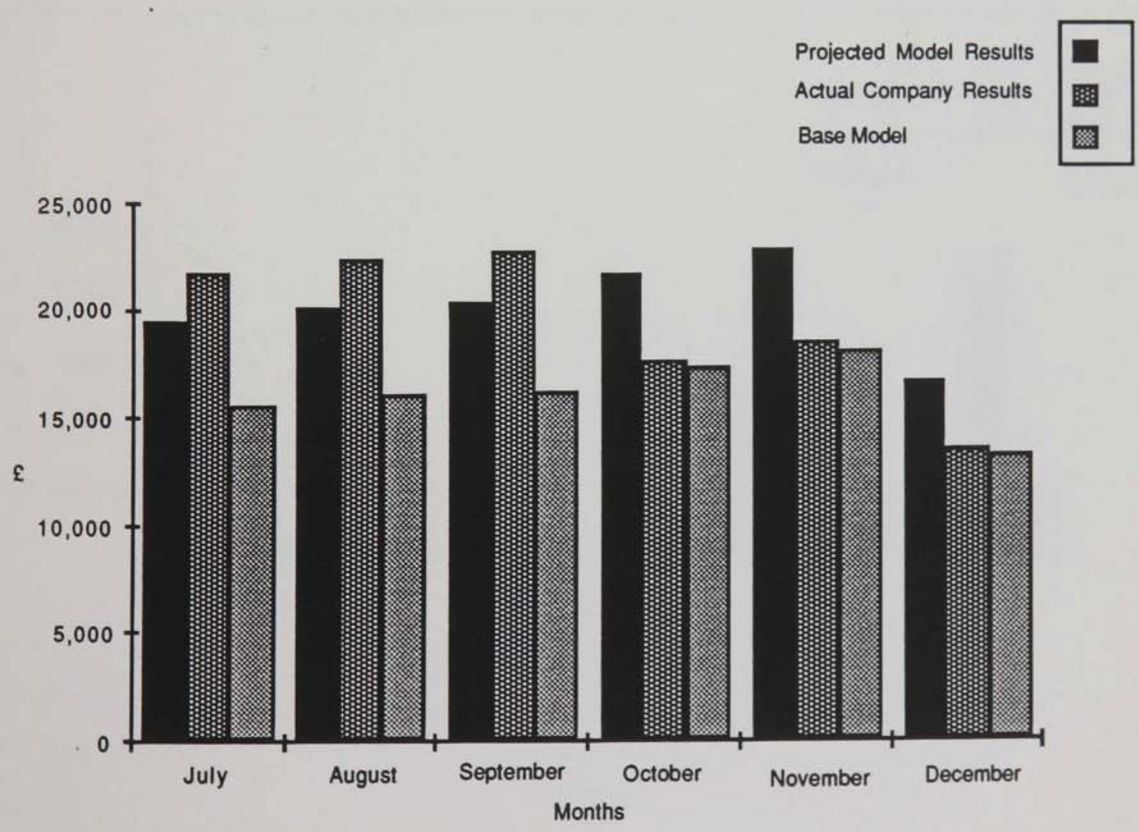

Figure 7.19 - Effect of Non-Availability of 3B Press on General Cartons Outwork over the second half of the year

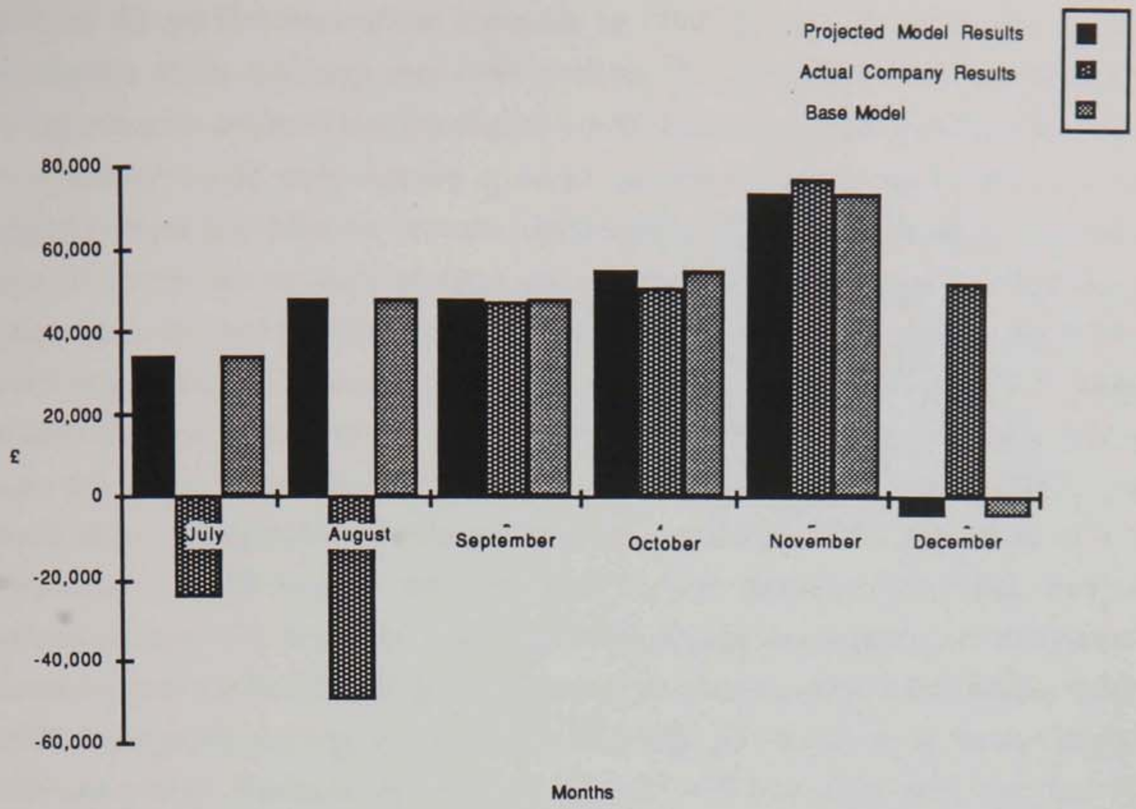

Figure 7.20 - Effect on Net Profit of Non-Availability of 3B press over the second half of the year

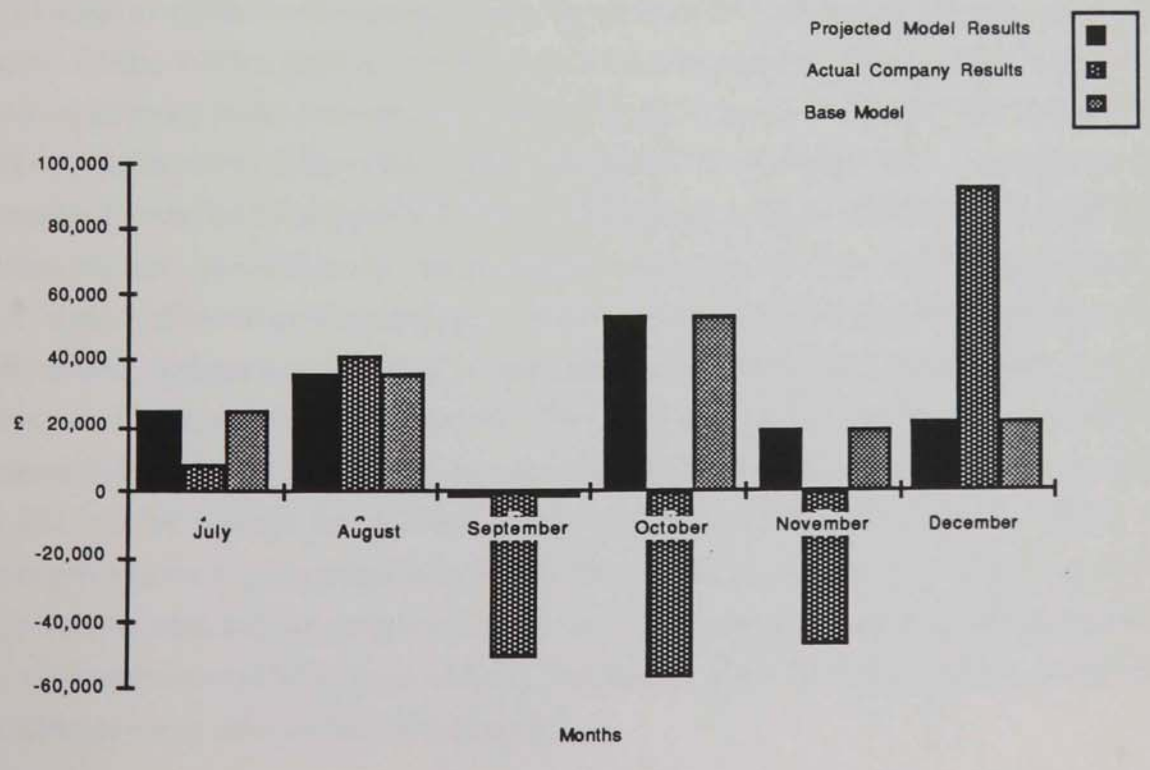

Figure 7.21 - Effect on Cashflow of non-availability of 3B press over the second half of the year

7.11 Future Press Investment

Based on the performance of the company in 1989, figure 7.22 shows the projected performance of the company over 1990 (without SRA2) and is shown in appendix 7.6. The sales director believed that the market would remain depressed during 1990, and that the company could only expect a small growth in sales, even with the extra competitiveness provided by the now operational 3B press. This would provide the scope to obtain the outwork savings not realised in 1989. However it has become apparent over the year that the company needs to further upgrade its production facilities, particularly in relation to general print work. For this reason an SRA2 press is considered the most likely next investment. Based on the assumptions in table 7.4, figure 7.22 also shows the effect on monthly net profit that would be expected from an SRA2 press. This is shown in appendix 7.7. These include an extra £75,000 in print sales, (row 18), approximately a 7% increase and a decrease in print outwork of £124,000, (row 105) approximately a 57% decrease. The cost of the leasing arrangement, estimated by the management would be £95,000 per annum with an extra monthly depreciation charge of £3,000 in the profit and loss account, (rows 183 and 184) and an extra finance charge of £5000 per quarter, shown in the term loan repayment shown in the cash flow (row 424). It is assumed that any savings in materials (row 85) will be cancelled out by the increased sales and materials costs will rise by 7% (row 99).

A factor that the problems with the 3B has highlighted has been the limited technical knowledge available in the management. In an attempt to overcome this it is intended to recruit during 1990 a graduate production manager, together with a senior supervisor, both experienced in the management of technological change to oversee new investments, and reorganise the existing supervisory organisation on the shop floor. The salaries and associated costs for these positions to the company are roughly £20,000 and £15,000 per annum and are included in the indirect labour cost category (row 198) This can be seen as a "wider" effect of new technology and their inclusion in the model demonstrates how a modelling approach can be used to quantify in financial terms indirect costs as a firm moves to a higher level of automation. The results show that the SRA2, providing the expected sales and outwork estimates were achieved would produce a year end net profit of £316.7k as against the £216k for the projected 1990 performance. While the investment is seen as economically viable, the uncertainty at the time of writing with a high interest rates and the prospect of a downturn in demand, means that the management has decided to consolidate their position, especially after the 3B problems, rather than embark upon any new investments at present.

To give an example of how the spreadsheet model can be used for further projections, appendix 7.8 shows the future performance of the company over 1991 to 1993 assuming a 1% real growth rate on sales with a 6% inflation rate, without the SRA2 press. In figure 7.24 this is compared to the performance of the company assuming that the SRA2 press is able to provide an extra 3% of real growth of print work per year, and that there is no growth in print outwork. While this projection would show the investment to be a worthwhile one, as the experiences of 1989 bore out, in a very turbulent environment, any projection in other than general terms has to be speculative. Appendix 7.9 provides an example of the cell logic of the detailed company model by showing the format of the year 1 and year 2 spreadsheets, together with the operating budget summary and the balance sheet and financial ratio analysis.

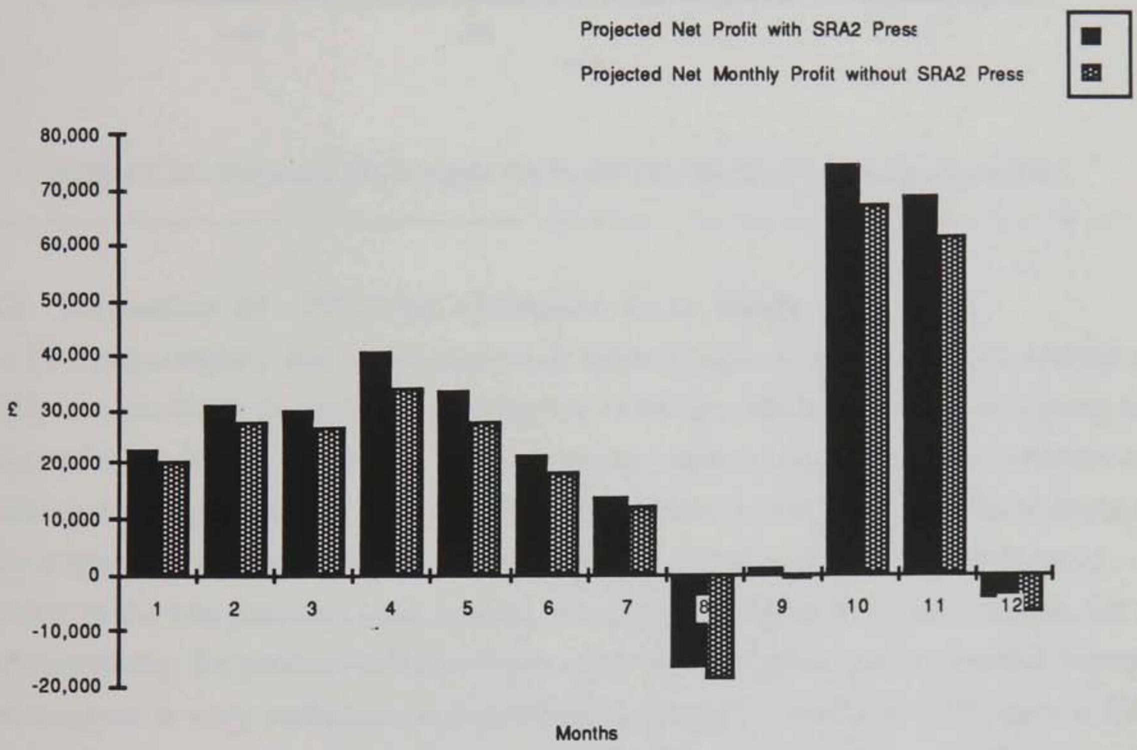

Figure 7.22 - Monthly Net Profit Before Tax Comparing Company with and without SRA2 Press

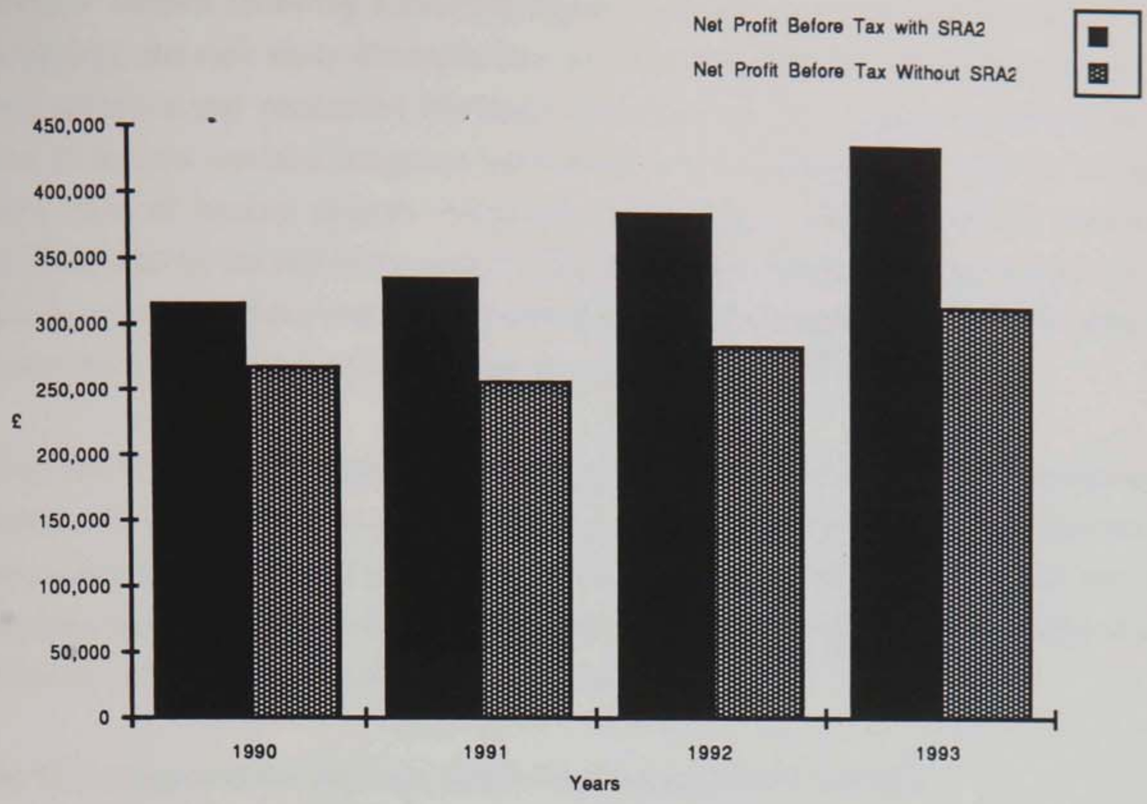

Figure 7.23 - Projected Effect Upon Net Profit with SRA2 press introduced in 1991

7.12 Discussion of PP Print Company Case Study

The PP Print company had for several years been relying on a level of print technology which was declining in performance relative to market needs, gradually becoming less competitive, as shown by its difficulties in recent years in attracting new customers and retaining existing ones. At the same time the company was faced with new demands from customers for just-in-time deliveries and a wider variety of print features. In contrast to the two previous case studies, the company being in a mass market, has no real opportunity for product differentiation other than on price, and its general business environment is very turbulent and difficult to predict. While the FD used a DCF calulation to evaluate the return on the 3B machine the main basis for its justification were the longer term "strategic" needs of the business to take account of changing market requirements, and this was reflected in the fact that the FD allowed the 3B investment to pay for itself over four years rather than the two more typically found in industry. Indeed, if the SRA2 machine, despite its lower DCF return, had been considered as fulfilling the longer term strategic needs of the company better than the 3B, the FD insisted this would have been selected instead.

However, despite following a coherent appraisal procedure for the introduction of new technology, the case study illustrates how as older machines are replaced by fewer, but more advanced and productive machines, this can leave the company vulnerable in the event of the new machine being non-operational, since it cannot easily afford to instigate some form of backup system. Although, the business came through its problems relatively well by the end of the year, during the period of time the author was in contact with the company, there was undoubtedly a real sense of urgency, since at one time the cost of the problems looked like wiping out a whole year's profit.

From discussing with management what had been learnt from the problems encountered with the 3B machine and the introduction of new technology in general in the business, it was suggested that the 3B problems had highlighted the deficiencies in the way the company was managing the introduction of new print technology, and the general lack of technical expertise on more advanced print technology.

The FD commented that the 3B problems had highlighted the fact that:

> '...everyone in the company who will be touched by a new machine needs to be involved - Engineers, Technical, Operators, and Sales'....'By getting everyone involved they feel more a part of the decision making process and you get more commitment for technical change. This includes the operators also, it's not just a case of putting in a new machine and telling them to "get on with it'....'The selection of the (3B) press was made by the managing director and works manager. While the technical and engineering functions may not have the expertise and sales knowledge needed to select the right machine, if we had involved them at an earlier date, they may have been able to identify some of the potential problems of the machine. Also, lacking technical expertise ourselves, we also should have tried to get more outside assistance'.

In particular, the production management side of the business was seen as needing review. At present the factory was divided into several areas each with its own supervisor. While the supervisors had long experience of the industry, this was based on conventional printing technology and they lacked a high degree of technical expertise in new print technology. It was also felt that the present supervisory structure meant that responsibility was diffused among several individuals, which resulted in a general lack of coherence in the way that new technology in the factory was implemented, and that there was a need for someone who would take overall control. To this end the company board has now taken the bold step of seeking to appoint an overall works manager, who ideally, will be a graduate with qualifications in the print industry and who possesses a high degree of technical knowledge. While the smaller firm can often have problems attracting more highly qualified personnel, the board intend that for someone of the "right calibre", the position will eventually lead to their becoming a company director. The individual will have specific responsibility for rationalisation of the factory, improving workflow, and the planning and implementation of new print technology. A key aspect of the job will be the attempt to integrate better the production capabilities of the firm with the market opportunities identified by the sales department, to take full advantage of new investment.

Several of the problems faced by this company in implementing new technology were similar to those reported in the engineering industry case studies. The use of computer controlled presses, as with the use of CNC technology, requires new skills which the company needs its workforce to acquire, and the operators also have to get used to the general pace of work being set to a larger extent by the machine. The company is also moving towards a muiltishift working arrangement as it acquires new machines in order to ensure that they are used more intensively so as to obtain a shorter payback period (the 3B machine is double shifted). Unlike the engineering industry, since most printing operations are completed on a single press, the problem of a component requiring several operations on different machines does not arise to the same extent, although production management needs to ensure that work is scheduled on the most cost-effective basis on the most appropriate presses. As in the engineering industry several of the benefits arising from the use of new technology were seen as difficult to quantify in economic terms, for example, the use of desktop publishing and composing equipment has parallels with the use of CAD in relation to reducing manufacturing leadtime.

In setting up the models through discussion with the managers, one of the main insights gained was the great uncertainty in their environment, and the difficulty of projecting very far into the future other than in very general terms. For example, at the beginning of 1989, the financial director had identified that, as part of the company's longer term sales plan, general cartons was a growth market, and the 3B machine was introduced with this partly in mind. However, within a few months it quickly became apparent that this market was going into recession, and that it would be difficult even without the problems of the 3B to achieve the predicted sales estimates. Such uncertainty however, does not make a modelling approach using spreadsheets inappropriate, on the contrary, in providing the ability to explore a whole series of economic scenarios in a very timely and cost-effective manner, users are in a better position to understand the nature of the uncertainty of their business environment. In any event, it is better to make some effort at rationalising uncertainty than none at all in making business decisions.

The experience of the 3B demonstrated the value of an understandable modelling process to examine the "robustness" of decisions by evaluating the consequences of falling short of expectations. While the models were perhaps somewhat over complex in trying to project over a four year time horizon, they were able to illustrate the ideas of the research. The worth of the model is further shown by the fact that the company has now purchased *Excel* to run it. The Financial Director kindly provided an account of a modelling approach used in the research.

> 'During the research period the information that you required to further your company model has also helped and influenced us in our decision making regarding capital expenditure on expensive printing machinery. In introducing me to "Microsoft Excel" you have helped me in updating my thinking on spreadsheet design and by incorporating your "model", albeit, in a slightly modified version I have been able to show more clearly, over a longer period of time the effects on both profitability and balance sheet and the corresponding integrated cash forecasts for specific expenditure and the related "What If" circumstances.
>
> Although initial predictions (for the 3B) were upset by other influences outside of the normal expected sequence of events, it was still possible to evaluate the results positively. The results were, gratifyingly, shown later to be correct. It is our intention to use this tool, together with other more traditional methods, to evaluate all our intended acquisitions. We have very recently purchased a Cutting and Creasing machine for the carton side of our business costing almost £250,000. The justification for this was to increase factory throughput by relieving the "bottleneck" at this end of the manufacturing run. The immediate effects were obvious, but the financial consequences were more enigmatic. The effect on the Balance Sheet had to be justified by increased turnover as had the significant effect on cashflow. Our predictions (using the model) show that this machinery will increase our profitability and cashflow and improve the return on Capital employed'.

Chapter 7 References

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Chapter Eight
Profiles of Other Companies Supplying Information

8.0 Introduction

This Chapter provides an account of several firms which, although not modelled with spreadsheets, illustrate the problems involved with the introduction of new manufacturing innovation.

8.1 - Describes the planned introduction of a *Just-in-time* system in a small engineering company in response to customer demands for higher product quality and shorter delievery times.

8.2 - Discusses the case of a small engineering firm which experienced considerable problems when a new CNC machine which represented a considerable investment on the part of the company was non-operational. The new machine also highlighted deficiencies in the existing cost accounting practices of the business.

8.3 - Demonstrates how the organisational aspects in a small automotive components firm preparing for the implementation of new technology are vital if sub-optimum performance of new investment is not to occur.

8.4 - Provides several perspectives on the acquisition of AMT from the point of view of a major manufacturer of machine tools.

8.5 - Gives an account of several of the problems involved in the implementation of advanced manufacturing technology from the perspective of a management consultant.

8.6 - Describes the problems facing the management consultant of 8.4 in implementing new technology in a firm , suffering from a lack of investment over a prolonged period.

8.1 IHW Engineering

'The whole company has got to change its way of thinking if JIT is to work'....Production Manager

Faced with growing pressure from its automotive customers for higher product quality, and the trend towards delivering components to them on a Just-in-Time (JIT) basis, most component suppliers are having to reconsider the ways in which they organise their production. This section provides an account of just such a company and how its production and engineering managers are planning to meet these challenges through the innovative step of introducing a JIT system themselves, and the wider implications for the business it has required them to address.

IHW is a medium sized firm established some 50 years ago and manufactures a range of seat reclining mechanisms and door hinges for the automotive industry. Customers include Ford, Austin Rover, Land Rover, Jaguar, Opel, Peugeot and Volvo. The company is spilt on two sites in Warwick and Telford and is part of the larger Adwest industrial group which has interests in a series of diverse metal forming operations. The IHW firm, although part of the group is run on an autonomous basis and has little contact with other group companies. The firm employs around 250 people of which just over 100 are based at Warwick. The sales turnover is just over £12 million per annum and approximately 15% of output is exported. The profit margin before tax is around 8%. The author's contact was with the Warwick site, to which the following discussion relates.

The firm is essentially in the high volume/low cost market. Competition in the automotive components business is very strong with at least five firms in direct competition. Until the early 1980's despite the competitiveness of the market, the general business environment was fairly stable and the firm had been able to remain reasonably profitable. Figure 8.1 shows the organisational structure of the firm which has remained relatively unchanged.

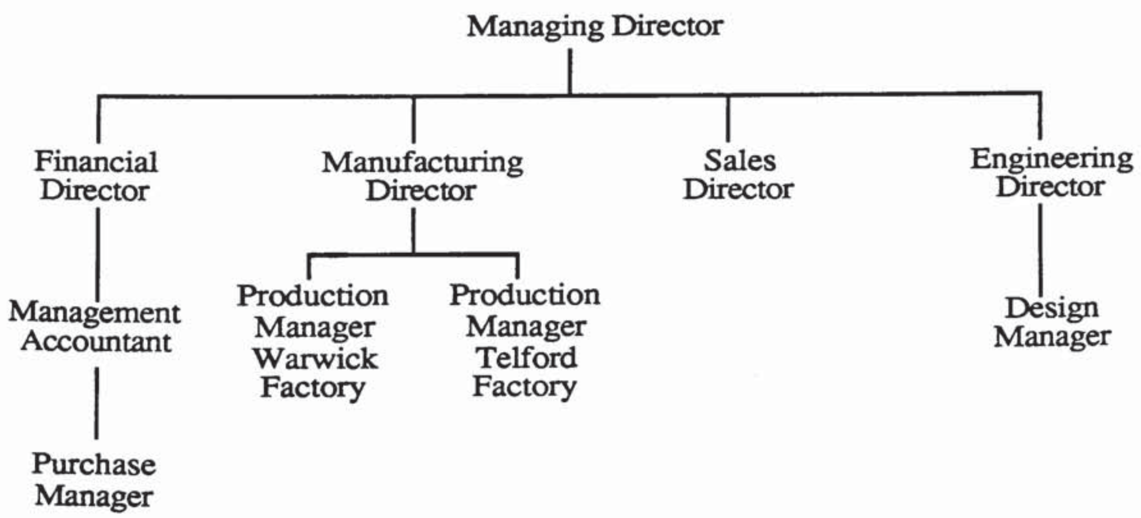

Figure 8.1 - Organisational chart of IHW Engineering

From the early 1980's onwards however, the firm has found that its business environment has become more uncertain due to two key factors; Firstly, the increasing demand for higher product quality by its automotive customers and secondly, the trend among these firms to require their suppliers to deliver on a just-in-time basis. While quality has always been of importance in the automotive component business, it is only in recent years that it has become of overriding importance. Until the early 1980's IHW had always managed to produce good quality components, but the general attitude towards quality was that while it gave the company a useful *competitive advantage* enabling it to win and retain new business, it was not the major priority it is now. However, during the 1980's the major automotive firms have increasingly come to expect high product quality as the *norm* rather than an advantage a particular supplier might have. Leading the way in this respect has been the Ford Motor Company with its "Q100" quality control programme which sets out rigorous specifications that all its suppliers must follow to continue in this capacity. The programme includes specifications on production organisation and control, machine tooling, maintenance, training of operatives, part loading, quality control and record keeping. In effect the programme sets out how it expects each supplier to organise its production facilities to achieve the required level of product quality.

To ensure that suppliers comply, regular inspections are conducted, often without prior notice being given. Any company supplying faulty parts is issued with a "demerit". If two "demerits" are obtained within a year then that company is excluded from seeking any new contracts from Ford for the next year. The programme from Ford's point of view has been extremely successful and is now being developed further with the establishment of the "Q1" quality programme. This sets out even higher specifications, towards which IHW is currently working to meet. While other vehicle manufacturers have not yet become as exacting as Ford, they are likely to do so and the company is preparing now rather than later for this.

Another way in which Ford are changing the way in which their suppliers must operate is the "Ford Network". This is a computer network linking all its suppliers around the country over which it issues production orders. Each supplier is given a six month forward projection of their requirements which is updated monthly. Against this overall schedule Ford download over the network their exact requirements for the next fortnight, although there is some flexibility in this. Eventually Ford intend that all its suppliers will have compatible computer based production control systems so that it can introduce "On Schedule Release". This will enable them to download straight into the manufacturing schedules of suppliers, so that they would in effect, directly control the suppliers production facilities. Although not yet operational the next stage of the "Network" to be implemented will be the 'Advance Shipping Load', which will enable the Ford computer system to compare what they have requested with what the supplier has despatched. Assuming this is correct, Ford will then automatically pay against the despatch note. The effect of this will be to break the typical 30 day invoice cycle, since payment will be almost immediate and will aid the cash flow of suppliers. The overall objective of Ford through these changes is to "weed out" all those suppliers who cannot adjust, leaving them with a reduced base of 'designated suppliers', who will operate on a Just-in-Time type basis, but with whom a closer business relationship will be sought and longer term contracts offered. This will in effect move towards the Japanese 'model' of vehicle building.

Faced with these requirements, IHW Engineering has sought to upgrade its production facilities. The company's main metal forming operations are pressing, milling and drilling using a large variety of manual machines. Given that the basic components of seat reclining mechanisms and car door hinges are generally simple, there is relatively little need for sophisticated machines and CNC technology is not employed. Where automation has proven particularly effective is in the assembly operations and it here that the firm has been able to innovate through the purchase of specially made equipment. An example of this is the equipment purchased from John Brown Automation and W.E.Jones Limited. Previously, production and assembly of car door hinges was a multistage process, involving eight distinct operations using different machines, with an associated large number of setups and multi-operator usage. Between each stage also were stocks of work-in-progress acting as "buffers" to balance the production of machines with different rates of output. The introduction of the new equipment has enabled the rationalisation of four distinct production lines of machines with limited flexibility, into one production line using two machines which have the facility to perform several different operations and are therefore considerably more flexible.

Another way in which the firm has been able to innovate is through the introduction of a small PC based CAD system which has enabled the design manager to improve on existing hinge mechanisms by designing them for ease of manufacture. The benefits of CAD were demonstrated when Ford approached the company to ask if IHW could come up with a new design of car door hinge which could allow a car door to be easily removed during assembly of the car. The problem had arisen because when car doors were fitted to the "body-in-white" they needed to be removed again later in the assembly operation to enable the car body to be painted and also provide easy access to the interior of the car for the assembly of the dashboard. At that time this involved unscrewing the door hinges completely, which was a time consuming operation which they wished to reduce by having a more simple hinge mechanism. This was further complicated by the fact, that when finally assembled and on the road, in the event of an accident, the hinge mechanism must still be secure enough to prevent the doors from bursting open. Using CAD, IHW was able to develop a new design of hinge, which by the use of a simple C-clip and spring held the car door securely to the hinge which fulfilled safety requirements, but by simply removing the C-clip during assembly enabled the door to be lifted off in a matter of seconds. The great advantage of this design is in fact its very simplicity, and it has now been incorporated into other Ford models. IHW have since patented the design and it has been adopted by several other car manufacturers.

While the company has been relatively successful at making incremental changes in its production operations, the winning of a contract from Nissan for complete seat control mechanisms has now led to a more radical appraisal of its operations. Until then IHW had manufactured just the reclining mechanism for the back of car seats. The Nissan contract would involve making the complete seat frame, which includes the mechanism to make the seat slide back and forward. The product manager sees this new business as a unique opportunity to introduce more far reaching changes, both in terms of equipment and the reorganisation of production. Central to this is a plan devised by the production manager and engineering director to introduce a Just-in-Time type production environment into the factory, which given the size of the company would be quite innovative and was described as representing a 'totally new concept of production at IHW'. The reasoning behind this plan is that since the trend among large automotive companies is towards operating a JIT type system with suppliers like IHW being expected to deliver at relatively short notice, the supplier companies will themselves in the long term need to consider adopting features of the JIT philosophy. By using the opportunity provided by the new Nissan contract to introduce JIT, it is seen as a way of gaining a long term advantage over its competitors by gaining valuable experience sooner, rather than later, of operating in this type of environment. In drawing up the plan the production manager and engineering manager initially concentrated on the technical aspects of operating such a system, but found that the effects of such a change on the business meant that the issues that needed to be considered were much wider than originally envisaged. The main points of the plan are as follows:

Production Layout: It would not be possible to switch the entire factory onto a JIT system in one move, given the existing equipment possessed by the company. The shop floor would need to be divided into two main areas; those still working on conventional assembly techniques which would include a John Brown Automation specialised assembly machine, 3 manual assembly lines, a subassembly area and parts storage. The other JIT area consisting of the seat build lines, base plate riveting section, lifter tube assembly section, press and projection welding section. The assembly operations in this area would be performed by specially designed automated equipment.

Finished Stock Holding: A key aspect of the JIT plan is for a greatly reduced finished stock holding. The company has problems in controlling the amount of finished goods at present, but under the new JIT system it is intended that it will carry only eight days of stock, comprising four days of right hand drive car sets and four days of left hand sets, or pro-rata depending on requirements. Given that the firm at present holds around 40 days worth of stock, this represents quite a dramatic reduction.

Seat Build: There are four types of seats to be built. These will be built one type per day on a four day cycle (dependent on call).

Shop Floor Stock: JIT techniques will be used to keep stock to a minimum by having sub-assemblies built the day prior to requirement. Small buffer stocks (10-20 components) of completed assemblies will be held to accommodate small production fluctuations.

Stock Control: In order to control stock, a Kanban type system will be operated based on that associated with several large Japanese automotive firms, most notably Toyota. This will use a two bin system by each machine. When one bin becomes empty, material is requisitioned from the Kanban store. The Kanban store again holds two bins. On withdrawal of one of these bins the Kanban store requests a bin from the main store's stock. One of the likely key problems facing IHW in getting the JIT system to operate effectively is in obtaining the co-operation of their own suppliers, since the whole JIT concept is concerned with achieving a balanced production flow which extends beyond the factory gates back into the factories of their suppliers. Large automotive firms are in a better position to achieve this since they have a lot of "pull" with their suppliers, but for a smaller company considering JIT type production this poses a considerable problem. Fortunately for IHW their main supplier is located close to the factory and it is now being arranged for them to deliver in predetermined lot sizes of components using containers supplied by IHW. The plan is to issue a schedule to suppliers of the forthcoming month's requirements. Against this, the material controller will call off their exact requirements. Some suppliers will be required to deliver daily, some weekly. It is also intended to treat the other IHW factory site at Telford which supplies components, as if it were an outside supplier. The containers provided to suppliers will be colour coded to allow immediate recognition of components and the progress chaser and material controller will highlight and deal with all shortages.

Maintenance and Consumable Tooling: Since many of IHW machines are fairly old a considerable amount of repair work is required to keep them operational and capable of producing components to acceptable quality standards. The maintenance team usually find themselves responding to the latest breakdown rather than performing their work on a more organised basis. Clearly if the JIT system is to operate successfully the machines must be reliable enough to ensure a continuous flow of parts, and to achieve this, it is planned to introduce a planned system of preventative maintenance for machinery and tooling for which the Foreman will be responsible for coordinating. This maintenance programme will be assisted by the introduction of more specialised new automated assembly equipment which is more reliable.

Supervision and Organisation of Operators: It is the proposed reorganisation of the supervisory structure that probably represents the greatest change to existing IHW practices and where the production manager envisages having the most difficultly. Since more modern automated technology has only been introduced in recent years, the workforce is used to a traditional manufacturing environment. Indeed, many of the workforce have "grown up" with the company, especially the production supervisors and foremen who have have experienced difficulties in adapting to the radical changes now being adopted by the company in their continuous striving for higher product quality. Current practice on the shop floor has a strict division between operators and machine setters. Although management has tried to stress that product quality is everyone's responsibility there is still the tendency for quality control to be perceived as laying with the supervisors. One of the main objectives of the new supervisory structure is therefore to make operatives conscious that they are responsible for the quality of their work, by giving them more tasks such as setting the machine themselves. It is intended to facilitate this by organising operatives into "section teams" of five, each with a section leader who like themselves is also an operative. The Section leaders will be responsible for the following additional responsibilities:

(i) producing correct component variant
(ii) producing quantity required
(iii) setting up machines
(iv) quality of finished sub-assembly
(v) motivation and discipline of team

The reorganised shopfloor supervisory structure is shown in figure 8.2

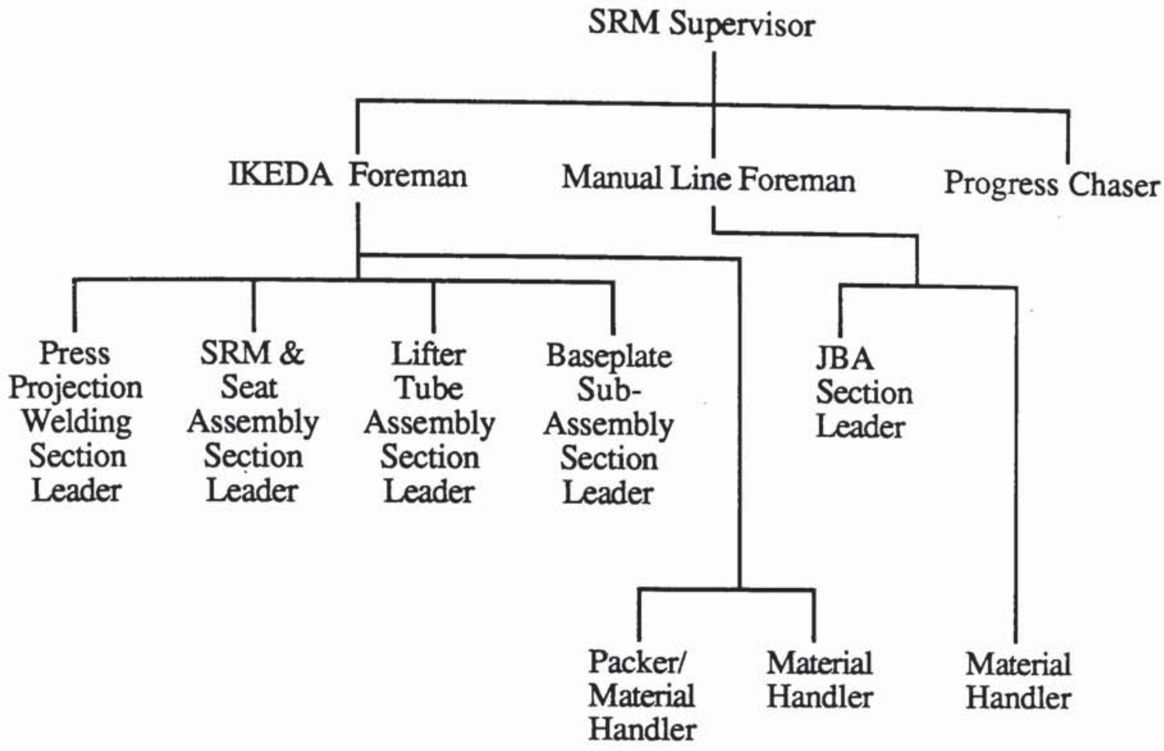

Figure 8.2 - Proposed organisation of shopfloor for Just-in-Time production with "section leader" structure

In order to ensure that operatives have the necessary skills to be able to carry out the new tasks required of them a training programme will be introduced. A side effect that has been noticed previously, when introducing automated assembly equipment, is that many of the operatives dislike operating it because the pace of production is set by the machine, rather than the operator, as is the case on the manual machines which still make up the majority of the equipment used. The reason for this is that the present payment system in the factory is by piecework which provides the operators with some incentive to keep up the production rate. Since the Nissan contract will in the foreseeable future, involve the introduction of more automated assembly equipment giving little motivation to the operator in this respect, the product manager sees the implementation of the JIT system as a suitable opportunity to move towards introducing a measured daywork payment system. It is hoped to be able to introduce this is in such a way that will complement the new section leader structure.

Discussion

Figure 8.3 shows the author's interpretation of the motivations, problems and benefits expected from the introduction of a JIT type system into the company. In discussing the experience gained from introducing previous technologies and the ones likely to be faced in developing a JIT type system, the production manager identified 'the lack of knowledge' and 'communication' as the main problems. In a company of that size it is difficult to attract well qualified managers (the production manager was the only graduate) and much of his time was spent in 'panic management' trying to ensure the daily production quota's were met. This meant that there was little time available, as he commented, to 'step back and plan for the future'. In such a company, technical knowledge was at a premium and the firm did not have any contacts or liaison with outside organisations or consultants who could provide such assistance. He cited a recent example of this at their Telford factory where a recently installed CNC machining centre had broken down due to the repeated breaking of a drill which resulted in over £50,000 of lost production. The problem was later found to be due to the drill head requiring minor adjustment. Unfortunately there was nobody yet in the firm with sufficient knowledge of CNC to be able to diagnose and rectify the problem when it arose. The limited technical expertise available had certainly been a factor in deciding the level of automation to install at the Warwick factory. This was reflected in the decision to introduce specialised assembly machines purchased from John Brown Automation using a "plug board logic" control system rather than a computer based one, as this was seen as a more appropriate level of technology with which the firm could more easily cope with.

In developing the JIT plan the production manager and engineering director had no previous experience of working for a company where the system was used. They had relied on their own background reading and ideas backed up by visits to their automotive customers to put the plan together. The production manager considered that neither the workforce or the senior management had as yet fully appreciated the full implications of the changes that were involved for the business. While the company had successfully managed to introduce incremental manufacturing innovations, these did not really affect the established pattern of working to any great extent. The new plan required not only the use of new machines, but a whole new way of organising production and actually running the company on the basis of a stated philosophy, since as the production manager commented 'we don't really have a philosophy or strategy at present'. With previous changes, as long as each operator knew how to do their particular task on a machine, the factory could carry on production satisfactorily. In contrast, under the new system it is essential that they understand the underlying philosophy and 'think JIT'.

This would be in many respects almost a revolution for the company, since communication between management and workforce needs to be considerably improved to achieve it.

The change in thinking required to operate a JIT system was not just seen as applying to the workforce; senior management are also identified as needing to change their ideas and attitudes. While previously, the management had been able to keep the company profitable without much attention to longer term planning, the demands of its customers for higher product quality require more 'strategic thinking' and the development of what might be termed a "systems strategy" to ensure hardware and software compatibility as the use of computer based technologies developed within the business. The production manager and engineering director have for several years been the main instigators of technological change within the company, acting as "project champions". However, it was felt that more support and ideas ought to be originating from senior management; also the parent company (Adwest), since it is in their long term interests that the company invests in new systems to keep abreast of modern manufacturing technology ,and thereby enabling it to remain competitive and profitable. In particular, it was thought that being engineers, it was often difficult to influence the decision making process within the business, which still seemed to be 'dominated by accountants' who did not fully appreciate the technology.

While only a limited amount can be deduced from any single company's experience, IHW does illustrate several of the typical problems which the smaller company faces in having to make changes to existing making technological and organisational structures in response to changing market conditions. While many of the companies studied by the author have been able to accommodate technical changes reasonably well, wider organisational changes pose a whole new range of problems. In the automotive sector of industry the trend towards using elements of the JIT philosophy is a strong one and the next wave of change to affect smaller firms, may not be simply a technical one, but a more profound one which will require management not just to consider organisational change, but the whole underlying philosophy upon which they run their business.

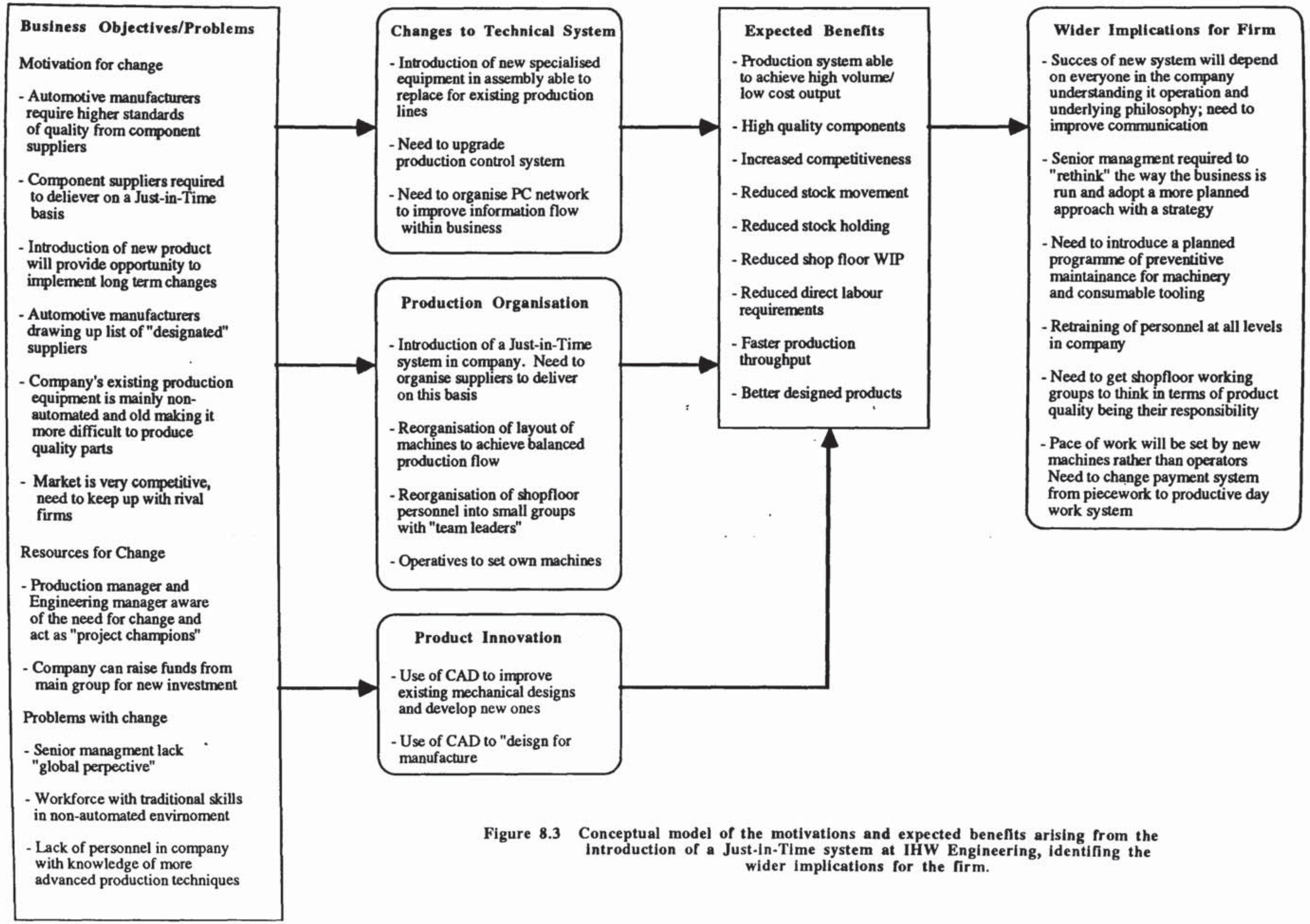

Figure 8.3 Conceptual model of the motivations and expected benefits arising from the introduction of a Just-in-Time system at IHW Engineering, identifing the wider implications for the firm.

8.2 MF Engineering Limited

'The problems with the CNC wiped out the equivalent of two years' investment funds'

Managing Director

This company profile examines a small business which invested in a CNC grinding machine with robotic load/unload facility to improve productivity and product quality. The system represented a considerable manufacturing innovation on the part of the firm and a sizable financial investment. The machine however failed to work properly resulting in considerable losses for a relatively small business and also left it vulnerable in production terms. Fitting the new machine into the existing factory organisation also highlighted the need for a rethink of the existing production costing system and its management information systems

Company Background

MF Limited produce a variety of grinding and finishing products, including tungsten carbide rotary burrs, steel rotary burrs and files, mounted points and contact wheels. The aerospace engineering industry is the main market for the firm's products. The business was originally set up in 1938 by a Mr Morris, an entrepreneurial engineer who identified a growing market for finishing products in the fledgling aircraft industry. The second world war naturally resulted in a considerable demand for such products, a trend which continued in the postwar years with the expansion of the British aerospace industry and the firm enjoyed steady growth. By 1960 it had five factories in the UK with some 1400 employees. The original owner was then bought out by a large industrial concern and, in the words of its present Managing Director, '....a long steady decline began, with no investment whatsoever being made for 21 years'. By 1981, the firm was down to a single site employing only 320 and had lost money for 10 years. The decision was taken by its owners to put the business up for sale, either as a whole or piecemeal. The Present MD first came into contact with the business in 1978 whilst working for its then owners. Believing that the finishing products side of the business was viable if it were better managed and new investment put in, he was able with four others to raise the necessary finance to arrange a management buyout of the core finishing product business in 1981. The firm currently have 75 employees and a turnover of £1.7M.

Since then the management has been able gradually to turn the business around to a profit situation - an arduous and slow task given the 21 years lack of investment, the chronic problem being the relatively high costs of modern production technology relative to the size of the profits the firm was then making. By 1987 the firm had sufficient funds to invest in its first CNC machine for turned parts which is agreed to have been highly successful and was soon followed by another similar investment. One of the strengths of the company is that it enjoys a strong market position in its traditional products. The strategic weakness of the company is that it is almost entirely dependent on mature products in mature, and in some case, declining markets. The company in common with many other traditional West Midlands "metal bashing" businesses badly needs new products.

The management has sought to overcome this problem by acquiring two small businesses making complementary finishing products - one making contact wheels and the other mounted points, which were both doing badly. These have been brought onto the main company site. These acquisitions have assisted the company to make the best of traditional low growth markets and have given a measure of diversification, rounded out the product range, and provided greater volume to put through the sales force and administration.

Existing Production Methods

One of the problems of the company strategy of trying to offer its customers a complementary range of finishing products using different technologies, is that while in marketing terms it may be logical, from a production viewpoint it effectively means trying to manage four distinct sections using different technologies on one site. This presents the firm with considerable information and control problems. Looking in turn at the difficulties associated with the existing production methods:

The production of abrasive mounted points involves five main stages:

- mixing of materials
- pressing to shape
- sintering
- gluing heads to their shanks
- trimming to shape

The problem with the whole process at present is that it is all very labour intensive, and the materials knowledge required is considerable for a company of this size. The management is striving to improve the process, but the problem as the MD described it is that '....I don't know what the actual capacity of the section is, so its hard to identify what the real bottlenecks in the process are, apart from the more obvious ones'. The underlying problem being that the existing indicators of productivity used, which include the number of pressings made, the number of heads put on a shank, the number of hours worked and the sales value are unrelated. For example, two batches containing the same number of pressings could be made, but each batch depending on the size of the product could have a very different sales value.

The contact grinding wheels business was acquired in 1983. Described by the MD as a "niche market" the purchase has proved very successful and sales have since doubled to £250,000 per annum. The basic production process involves moulding rubber polyurethane tyres to metal hubs of different widths and then cutting out flutes in the tyre to produce the abrasive grinding profile. The company manufactures a wide range of contact wheels to suit most surface grinding applications - power grinding, polishing, blending and radiusing, the type and quality of the contact wheel being an important factor in the performance of an abrasive belt machine. At present most wheels are made to customer order, but the company is trying to improve the production economics by standardising hub sizes and reducing the thickness of the rubber on the hubs to save on material costs, but without impairing the final product. They are also looking to form the grooves on the tyre when the rubber is moulded rather than the present method of cutting the grooves by machine which is an environmentally unpleasant task in the factory.

The manufacture of steel rotary burrs and files is the original product group made by the company. The manufacturing process involves first turning a steel blank from steel bar on a CNC machine. The head is then milled to shape. A wide range of burrs and files are made in standard sizes, although the company is quite prepared to design and manufacture to special customer requirements. The level of technology used in this section of the factory, is antiquated and simple. Most of the machines are either manual or electromechanical cam operated machines which are many years old. An example of this is the machine used to cut the flutes into HSS rotary burrs, which were obtained from Germany in 1945 as part of the "spoils of war".

The fourth product group made by the company is the tungsten carbide rotary burrs, which are similar in design to steel ones but are designed for use with harder materials and have a longer life. The level of technology used is somewhat higher than the steel burr section, the process involving grinding, rather than milling of the flutes of the carbide head on the tool. The machines used in this section were developed by the company itself 30 years ago, when they represented a significant breakthrough in the technology of manufacturing carbide burrs. Many other manufacturers, especially in the US were still manufacturing mainly by manual methods. The machines are electromechanical using various configurations of cams to produce the shape and geometry of the head. Set times are considerable, up to 3.5 hours depending on the shape of the burr to be set and cycle times are typically 20-30 minutes per burr, and involve several passes in the removal of material for each flute. It is doubtful whether the company would have survived the 21 years gap of investment from 1960 to 1981 had it not been for the insight and ingenuity of its original owner in equipping it initially with effective machines.

One of the difficulties facing the company in trying to update its machinery is that the production of burrs and files is a highly specialised business and a relatively small market. Until the mid 1980's the options available for automation were very limited. There are only a few firms in the UK making burrs and so the potential market for a supplier considering making a purpose built CNC machine even taking into account the world market was relatively small and the costs of developing the associated software prohibitively expensive, given the complex geometry of many burr heads. A US grinding tool manufacturer estimated that the total world market for such machines was only between 25-30 units. This meant that although cams are slow to set up and require a good deal of manual intervention, even until the mid 1980's they were still effectively the "state of the art".

Problems of CNC Investment

While the cam operated machines have performed well for many years, their long set up times, together with increasing unreliability and inconsistency in manufacturing to required tolerances, has meant that management was faced with an increasingly difficult task in trying to produce a quality product for an increasingly demanding market, with limited scope for product differentiation. While the need for CNC technology in several of the turning operations was obvious, investment funds are limited and the firm has had to pursue a cautious purchasing policy. The idea being that the any savings from new machines would help to fund further investment in a step-by-step fashion, the key to achieving this being the rate at which the necessary cash flow can be generated. A problem in this respect is that since the market for finishing products is a mature one and relatively static, it is seen as unlikely that a major product or process innovation will occur that will change the basic customer requirements. This means that the few firms that are in the business are competing with one another on mainly a production cost basis, rather than offering some unique feature in their products. They are therefore looking to make continuous incremental improvements in their production operations, which well fits the description of "manufacturing innovation".

The first CNC machine in the turning operations purchased in 1987 was an obvious step and was a considerable success. This was soon followed by a second similar machine. In 1987, the management became aware of specialised CNC grinding machines being developed by a German and a US manufacturer. Since the company already had a very effective semi-automatic machine from the US machine tool manufacturer their machine seemed the logical choice and after a demonstration by the UK agent and a visit to the US firm an order was placed for a machine, together with a robotic load/unload facility, costing in total £150,000. The firm were able to get a regional assistance grant of £25,000 which eased the financial burden. The plan was to have the machine running in early 1989 when it would replace about 10 of the 30 year old cams making tungsten burrs. Based upon their previous successful CNC experience the management were reasonably confident that it could be introduced without significant problem. With the previous CNC investments there was little downside risk since these were standard machines widely used in industry with proven capabilities. The decision to invest in special purpose CNC burr-grinding technology was altogether more problematical. The investment cost was huge for a company of this size, £150,000 representing roughly two years investment resources which would be locked up in the purchase of a single machine which was highly specific to one product. The risk was complicated by the fact that this would be the first of its kind in the UK and only the third of its type in the world.

Although the US manufacturer could be considered to be a market leader in creep-faced grinding technology, the adaptation of this technology to burr manufacture and particularly of the operating and application software and the robotic loading and unloading feature, was highly innovative. The UK agent of the US manufacturer had no experience of the new machine and to a considerable extent MF Engineering would be acting as a "guinea-pig" for both the agent and the manufacturer. On the other hand the advantages which the machine could bring were to the company were considerable. The five main advantages were:

(1) Set times were only a fraction of the set up time for electromechanical machines, 20 minutes as opposed to 3.5 hours.

(2) Production cycle times were only about a quarter of the older machines, since the CNC machine removed all the material in a single pass per flute.

(3) Quality of the product was much higher in terms of the consistency of the geometry, surface finish of tooth, the ability to maintain helix and rake angles.

(4) The machine was programmed to both US ASA standards as well as MF Engineering standards. Hence if the company wished at a later date to enter the US market, they would have a product that met US specifications.

(5) The machine was able to produce more complicated shapes than traditional machines and this would enable them to improve the performance of some of their products which were not up to the standards of their main US and German competitors. The machine could also produce product shapes which could not be obtained on electromechanical machines.

The Managing Director commented on the decision to invest:

> '...On balance there was a degree of compulsion about our purchase of the machine. We could see that this was the way the industry was going. We could see that our competitors were going to purchase one or two machines. We felt that we really had no option but to chance our arm, and make sure that we were one of the first to lay hands on the new technology if we were not to get left behind'

The plan for the rest of the tungsten carbide section once the CNC had been introduced, was to reengineer several of the electromechanical machines to dedicate them to particular shapes and sizes of burr, which could be produced to an acceptable quality on the old machines and which would not represent a good use of the limited capacity of the new machines. Having assessed the capacity of the CNC machine on a three shift basis a "pecking" order was established to find which burrs would have the maximum value added if they were manufactured on the machine, and so make the greatest contribution to the company's profits. Apart from normal production they also decided to reserve some CNC time for experimentation with new designs. Some burr heads were also produced which were not really economical to produce on the CNC but were done so as to ensure product quality which could not be guaranteed on the cams.

Problems with CNC Burr Grinding Machine

The difficulties with the CNC machine started when the delivery period took over a year compared to the originally quoted six months. The company's engineers went to the US to inspect the equipment prior to shipment and to arrange for transportation to the UK. The contract for the machine was a contract with the US firm and their UK agent *jointly and severally* - this meant that both could be held responsible for the machine, as opposed to just the manufacturer as is the case with most contracts. The Managing Director insisted on this arrangement so that he would have easy recourse to the manufacturer in the US if any problems arose with the installation and commissioning of the machine, and in its subsequent performance. The agent was responsible for commissioning the machine and very soon afterwards, malfunctions began to become manifest.

There were early minor software deficiencies, but these were not in themselves a barrier to the effective use of the machine. What did surprise them was the straightforward mechanical unreliability of the equipment . Motor failures, encoders failed, the robot arm was "temperamental" and as the weeks went by the machine downtime became higher and higher to the point where the company was losing about a third of available production hours through breakdowns. Since the machine was still within the warranty period the management became increasingly concerned as time progressed that the company may be left after the warranty period expired with an unreliable machine, and a UK agent who charged £40 per hour for maintenance. Eventually, the US supplier (at their expense) sent over an engineer who working full time for 6 weeks at the factory, completely stripped down the machine and rebuilt it and at long last it looks as though the company has an operational machine. At one point the company was close to taking legal advice for compensation and if the US engineer had not arrived when he did, legal action would have been taken.

In financial terms the MD suggested that the machine had '.... nearly wiped out a year's profits' in terms of lost production and disruption to the business'. The company had lost business, especially a large contract because there was a deadline for the submission of samples which they had been unable to meet. The firm had been relying heavily on the machine to replace the cam machines and as the MD commented '....thank goodness we had still had the electromechanical machines to fall back on, or we would have been stuck' and suggested that one of the problems for the smaller firm using more advanced machines was that while they may replace several existing ones and be far more productive, their relatively high cost means that you can only afford one or two. In the event of a breakdown of any duration, this can leave the company very vulnerable in terms of not having sufficient machine capacity to get out existing production orders. The experience of the last twelve months has vindicated the decision to retain and reengineer the old electromechanical machines.

Wider Effects of CNC Machine

In discussing with the Managing Director the wider effects for the business that CNC technology had brought, the following were identified:

While the CNC could handle almost any of the tungsten carbide shapes produced in the factory, selecting the most appropriate work was seen as crucial in making the machine economically viable. The MD illustrated this with two tungsten burrs - one a narrow one which requires little machining and the other a wide head one with a more complex head pattern and commented

> '...The costs of the material for both burrs are almost identical at about a £1 each and labour costs are negligible on the CNC. However, I can sell the narrow burr for only £1.60 giving me 60p gross profit, while with the wide head burr I can get £7 to £8 yielding a much higher gross profit - so if the machine is going to pay for itself, its essential to run the most cost effective work on it'.

This usually meant that the more complex burr head shapes were performed on it, since it is in handling complex shapes that the machine shows the greatest improvement in productivity over existing methods. It was pointed out that an unanticipated side effect of the CNC, was that in the surrounding labour intensive machine areas using cam operated machines, labour productivity had actually gone down. The reason for this was suggested as due to the fact that the CNC had taken away many of the "good batches" of large, more geometrically complex burrs. This has left the less profitable work on the electro-mechanical machines on which the operators found it hard to "make the times" with the production mix and this had "dragged down" the labour productivity rate of the section. Although the operators were not paid on a piecework basis, the section productivity figures are displayed on the shop floor and the Managing Director thought that this had had a '...somewhat demoralising effect on the operators, especially the supervisors'...and there was now '...clearly a need to be more intelligent in our interpretation of the productivity data than before'.

One of the most significant wider effects of the CNC machine upon the business is that it showed the deficiencies in the present information systems upon which managerial decisions are made. The MD comments that the machine has:

> '....highlighted the need for a complete review of the shopfloor management information system. We have never in the past collected any data about downtime and machine productivity, largely because the critical factor in output and productivity was not so much the machine output, but the labour output; it was labour rather than machines which determined production'...'we now have the situation where a great chunk of our assets are in one machine. With so much of our production going through that machine it is critical to utilise it properly, and if it doesn't work the company could fail'.

Another significant effect of the CNC machine has been the way in which it has focussed attention on the company's scrap rate. Previously, the company did not maintain any figures on the scrap rates of its different sections. The MD comments:

> '....before you only assumed that scrap was insignificant, but what we found with the advent of the new machine is that the raw material/part machined component presented to the machine for grinding has to be to a lot tighter tolerances than with the old processes'....'this led to a critical reappraisal of our quality levels at the processes that precede grinding by the new machine. During that appraisal, at no single stage was scrap obvious, but when added together to our horror, our real scrap figure rate was well into double figures. In a way, this machine has acted as a catalyst - it has highlighted the need for, and identification of, scrap figures'.

The question has also arisen of what cost does a product go into stock if it is made on two quite different machines. This is further complicated by the fact that present accounting convention draws a very clear distinction between those fixed costs which can be included in the evaluation of stock and those which cannot. The bulk of the cost of the new CNC is financing, which is a fixed cost and for the purpose of stock valuation is not allowed to be included.

Traditionally the measurement of labour productivity, upon which the overhead recovery was based, was the number of standard hours worked. The problem now exists in the tungsten carbide section that all the jobs which go on the CNC machine have been retimed so that the standard unit of labour output is quite different from that produced in the rest of the section. The MD already had little confidence in the costing system, but found that with CNC machines this was more so, since direct labour was such a small fraction of the costs of operating the machine, the largest overhead being the financing cost.

> '...How do you cost a product which is being made, where you might have the same product part being made by two different methods, one being the new CNC method which is capital intensive and with virtually no direct labour content, the other being the traditional labour intensive method using the old electromechanical machines? How do you recover overheads on the new machine when the standard, and traditional practice in the company has been to recover fixed costs as a percentage of direct labour, and there is no direct labour on the new CNC machine?'

The company is now seeking to devise better methods of allocating costs and collecting data of machine utilisation and, most importantly, to present it in a way that the most benefit can be obtained from it. To overcome some of these difficulties the MD would like to introduce some form of costing system based on machine hours, but feels that this is only part of the wider information problem and stated that '....we need somebody to sit down and work out what our total information system needs are'. To assist in this task the local polytechnic has been approached and are planning to use this problem as the basis for postgraduate research work. The problem for this firm as with many small/medium sized firms encountered by the author during the research is that while the management are well able to identify the shortcomings of the business, they are so involved in the daily operations of ensuring that production orders are fulfilled that they seldom have the time available to "sit back" and plan for the future of the business. The MD admitted that while he was reading up on alternative production costing systems, he would never have the time himself to develop such a system and that being able to draw upon outside sources of expertise was of considerable assistance.

Training of operators was also identified as requiring change:

> '....we greatly underestimated the time it was going to take to train our people on the new machine. Because of the demands of production there is a terrible temptation to let the man who appears to have a "knack" to take "proprietary rights" over the machine, while good management practice would be to ensure that the skills and knowledge of how to use the machine is spread throughout the section and not confined to one man. At the moment we do not have enough people able to run the machine on their own'.

This has highlighted the generally low level of educational accomplishment within the company, as the MD commented '....our workforce is undertrained for what we are now trying to do'. Many in the workforce had been with the company for many years and had therefore only comparatively recently had to come to terms with working with more modern machines, where the pace of work was dictated to a greater extent by the machine rather than the operator.

The need for a different approach and the lack of an understanding of modern manufacturing techniques and equipment, was also seen as a problem with supervisors and senior managers. The MD gave the example of the production manager who had worked his way up from the shopfloor and had been with the company for many years and was extremely loyal. While his man management skills with the workforce, and on routine production matters were excellent, he had difficultly in appreciating the need to develop a wider managerial role within the business with greater emphasis on planning and analysis. It had taken the MD considerable time to convince him that time devoted to setting up a system to obtain and analyse scrap costs in the factory could have long term benefits for the business of equal value to overcoming the next immediate production problem that arose.

The MD related these problems to a wider lack of training in industry in general and the difficulty in attracting and keeping well trained people. He contrasted the situation in UK industry to that in Japan and Germany which he had visited. He commented '...in their factories you can't get a job on the shopfloor if you've not got the equivalent of five O levels. On my shopfloor I haven't got a single man with those qualifications'. To act as a source of technical input to the business the company was involved in a Teaching Company project with a local University and had two graduates working on a number of technical projects in the factory. While they had made a useful contribution to the problems under study, what the MD thought they had brought most of all was the application of "scientific method". It had come as something of a culture shock to the workforce and the supervisors to see a properly undertaken series of experiments and measurements made. The MD would like to offer a position in the business to one of them, but as is often the case in the smaller firm, has the difficulty of matching the salary and benefits that a larger firm could offer.

The MD felt that the company was not as technologically aware as it needed to be, and that in the smaller company, this was a role for the MD. However, since he was not an engineer by training, he found it difficult sometimes to identify new technological opportunities and even if he did, how they could be translated into the company. He contrasted his experiences with those of the West German companies with whom he did business and saw the engineering function as crucial to the success of adopting new technology '....in Germany no engineering company would be owned or run by someone who is not an engineer'. He thought that the quality of the engineers available to the company was not up to the standard of those he had encountered in companies in Germany, France and the US and was sometimes surprised at the lack of initiative and resourcefulness of his engineers, as he commented:

> '...British firms tend to "bumble"along from one engineering crisis to another with the emphasis on "keeping it going" without trying to harness all the engineering resources to improve the process. Engineers tend to respond to events rather than take control. This is not the case in Japan, Germany and the US'....'in the UK, people only invest because they are forced into it, but in Germany, innovation is a way of thinking and it comes down to the quality of the engineer'

The problems facing MF Engineering in adopting new technology, are similar to those of other smaller firms encountered by the author during the research, in that the size of the investment being undertaken relative to the size of the firm is a large one, and the risk correspondingly high. In the case of MF the machine being introduced was as close to the "state of the art" as it could be. The equivalent of two years investment funds were tied up in a machine which even at the time of writing, is still not functioning correctly. However, as the MD pointed out, the firm had to take the risk in order to keep up technologically with its competitors, and even with the benefit of hindsight there was little they could have done to manage the problems that arose any better.

From the author's point of view the most interesting aspect of discussing the experiences of the company with the MD was the way in which the machine had acted as a catalyst, in focussing attention on the aspects of the business which needed change, most notably the management information systems. It was agreed that the machine had been implemented in a "standalone" manner, with only limited consideration of it's wider effects on the business in terms of economic and organisational effects. The problem being that being only a small firm the management only possessed limited experience of technological change of this kind. This well demonstrated the hypothesis of the research, that sub-optimum performance is obtained when the integrated nature of the technology is not taken into account. Figure 8.4 shows a summary model of the motivations, expected benefits and problems identified in the installation of the CNC burr grinding machine. Tables 8.1 to 8.4 quantify the economic effects of the CNC problems compared to the previous production methods employed in the firm, highlighting the considerable cost to the business.

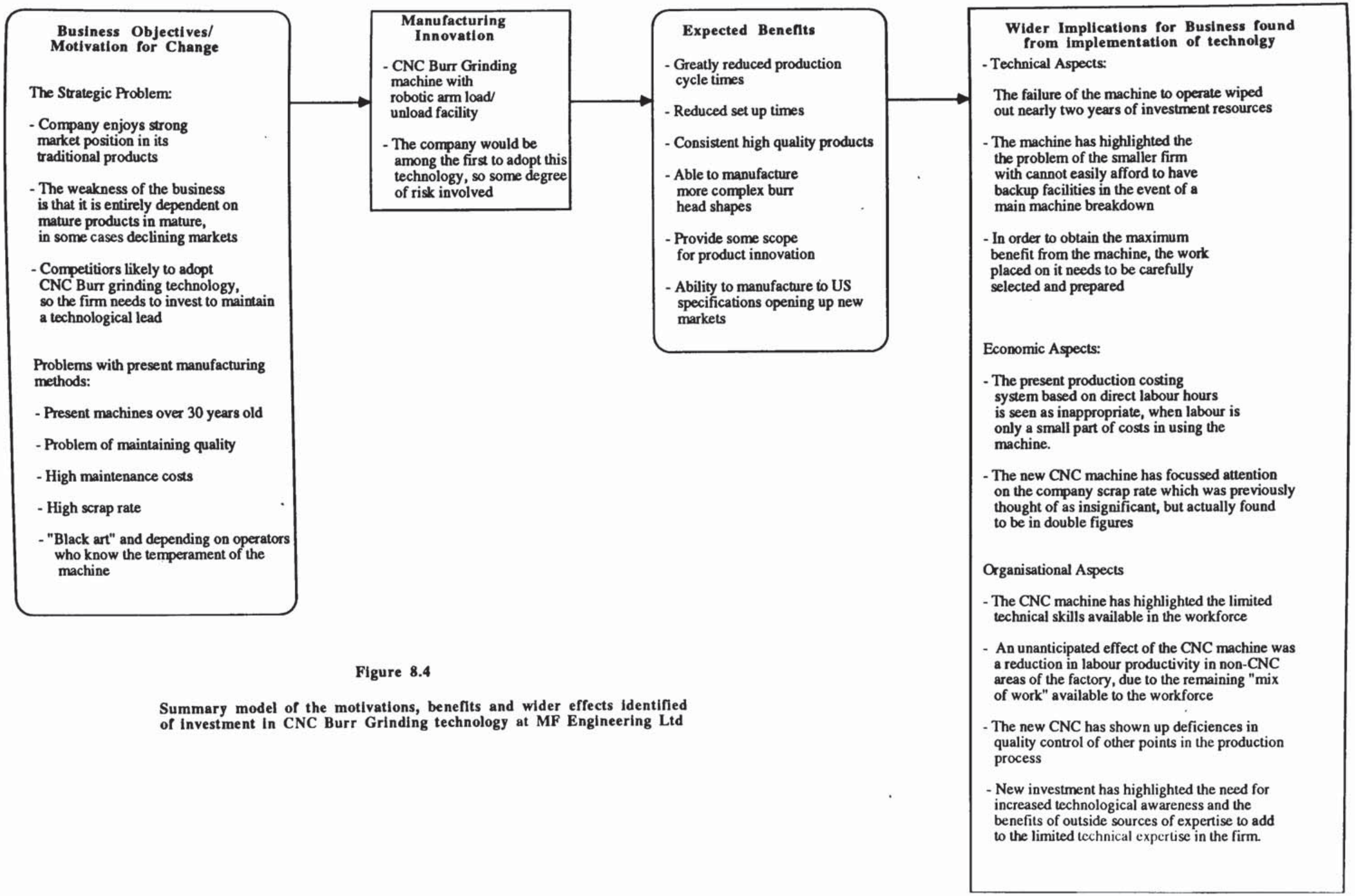

Figure 8.4

Summary model of the motivations, benefits and wider effects identified of investment in CNC Burr Grinding technology at MF Engineering Ltd

Table 8.1 Calculation of Difference in Manufacturing Costs

Calulation of the difference in manufacturing cost of producing burrs on the Tungsten Carbide machines which would normally have been made on the Unison CNC machine. Three part numbers fall into this category: M8928, M7529, & M7520.

Part No	Quantity	TC Grind	Unison Grind	Total Material	Batch Size	TC Set	Unison Set	No Sets
M892812	2348	14.01	4.00	0.29	200	120	60	12
M892812D	562	28.02	8.00	0.40	50	120	60	12
M892812K	204	14.01	4.00	0.29	50	120	60	4
M89212SC	372	21.00	5.00	0.29	50	120	60	8
M752930	514	46.50	8.54	4.203	50	120	60	11
M752930SC	44	69.75	14.20	4.203	50	120	60	1
M752930SC06	36	69.75	14.20	4.316	50	120	20	1
M752016	4345	18.12	5.12	1.35	500	120	20	9
M752016025	1550	18.12	5.12	1.35	250	120	60	6
M752016SC	1462	27.18	8.19	1.35	250	120	20	6
M752016SC08	239	27.18	8.19	1.335	100	120	60	2
M752032SC	120	35.70	12.00	1.35	50	120	20	3

Calculation Rates

T/C Labour 1.43p/min
T/C Setting 8.91p/min
Unison Labour 0.75p/min
Unison Setting 8.91p/min
Quantity = (Yr-1 x 11/12) + YTD = production since Dec 1988 to date.
Material costs being equal have been excluded from the calculations.

Cost Calculation:

Tungsten Carbide Machines

Setting = No Sets x Set-up time x Setting Rate = 801.90
Labour = Grind time x Quantity x Labour rate = 3519.62
Total Set + Labour = 4321.52

Unison CNC Machine

Setting = No Sets x Set-up time x Setting Rate = 299.38 + 33.86 =333.24
Labour = Grind time x Quantity x Labour rate = 507.32
Total Set + Labour = 840.56

Manufacturing Cost Difference = 4321.52 - 840.56 = 3480.96

Table 8.2 Calulation of Downtime between 6-12-88 and 6-7-90

The period represents 19 calender months = 82.3 weeks = 1.583 years

Unison run time allocation = 124 hours week

Lost production time (as per breakdown analysis) = 2,508 hours

Total production hours available = 1.583 x 52 x 124 = 10,207 hours

Therefore: Downtime = (2508/10207) x 100 = 24.57%

Excluding: 95% Uptime guarantee = 23.3% (2382.6 hours)

5% Routine maintenance + expected downtime = 22.2% (2263.5 hours)

Lost Opportunity Cost

Basis for calculation is on random selection of 10 part numbers

Part Number	Grind Time	Average Price	Total.Material
7570 18	5.0	6.60	1.941
7508 16	7.5	7.27	1.964
7522 18	6.5	5.20	0.961
7527 24	8.0	8.44	1.324
7528 18	4.4	6.19	0.891
7534 20	9.0	8.06	1.794
7542 18	5.0	5.81	1.641
7543 24	5.0	7.79	1.944
7544 18	6.0	4.90	1.041
7552 18	4.8	4.29	0.897

Average Grind Time = 6.12 mins
Average Average Price = 6.46
Average Total Material = 1.44

Labour rate = 0.75p/min = 0.75 x 6.12 = 4.6p/Burr

Average value added = 6.46 - 1.44 - 0.046 = £4.974/Burr

Number of Parts Lost Due to Downtime

Standard hours produced on Unison between 24-1-89 and 1-7-90 (available records)

= 70 weeks = 7423.11 hours.

Unison Downtime = 22.2%

Possible Production Time = (7425.11 x 100/78.8) = 9422.73 standard hours

Lost Opportunity = 9422.73 - 7425.11 = 1997.62 standard hours

Average standard time = 6.12 mins = (1997.62 x 60)/6.12 = 19584.5 Parts

Average value added per price = 4.974

Gross average contribution loss = 4.974 x 19584.5 = £97,413

Table 8.3 Scrap Production from Unison 8000

Part No	753924SC	754324	752218	855316
No Scrapped	80	40	80	40
Average Price	10.38	7.79	5.20	4.38
Grinding Time (mins)	11.49	5.00	6.50	4.50
Total Material	1.94	1.98	0.96	0.76
Labour	0.086	0.038	0.05	0.034
Total Prod. Time (hrs)	15.32	3.33	8.66	3.0
Contribution/Burr	8.35	5.77	4.19	3.59
Total Contribution	668.08	230.88	335.20	143.44
Total Lab + Material	162.08	80.80	80.80	31.76

Totals

Production Hours Lost	30.31 hrs
Contribution Loss	1377.84
Material + Labour	355.44
Total claim due to scrap	1733.28
Total claim due to lost opportunity	30.31 hrs
@ 6.12 Mins/piece average =	297 parts
@ 4.94 Average value added =	1468.00

TOTAL LOSS = 1468.00 + 1733.28 = 3201.23

Table 8.4 Value and Number of Contracts Lost as a Direct Result of the Non-Availability of the CNC Burr Grinding Machine

	Customer	Consequences	Value (£)
(1)	Ingersoll Rand	Failure to produce samples on time resulted in loss of existing contract for standards	£3,500
(2)	Garrett	Failure to produce samples on time resulted in loss of contract to produce	£19,800
(3)	C&H Engineering	Failure to produce samples required led to loss of contract and had detrimental effect on reputation of company	£1,800
(4)	Vickers	As above	£1,800
(5)	Lucas Aerospace	As above	£2,500
(6)	Rolls Royce	Inability to ensure repeatability resulted in considerable extra technical time and loss of face with customer	£2,400
(7)	Goldring	Had to reduce price in order to retain order after repeated late deliveries	£43,200
(8)	Various Repair projects	Repeated failure to produce samples, despite promises to customers, led to loss of initiative to competition	£10,000
(9)	Rolls Royce	Special project for customer, but unable to produce samples,with much loss of face	£5,000
(10)	Rolls Royce	Unable to deliver product on time. Value of loss of confidence and "goodwill" on the part of the customer considered by MD as incalculable.	£1,000
(11)	Kawasaki	Inability to provide samples resulted in loss of face and could endanger longer term relationship with company and large future orders	£3,000
(12)	Alpine Utensils	Inability to produce resulted in cancellation of order	£2,000
(13)	HD Pumps	Customer still awaiting samples	£1,000
(14)	Ruston Gas Turbines	As above	£1,000
		Total	**£98,000**

8.3 WM Components Limited

'My job is to drag this company out of its 19th century way of thinking'.....Manufacturing Executive

This case study discusses the technology associated problems of a small West Midlands "metal bashing" company which having survived the economic recession of the mid 1980's used the opportunity provided by the acquisition of a small automotive components supplier to enter the industry itself. Increasing demands for quality from customers, together with the industry trend towards "preferred" suppliers meant that investment in new technology was essential. However this alone was not sufficient to meet these demands and considerable organisational change in regard to quality control and existing work practices were required if full advantage of new investment were to be taken. Achieving this required the development of a new company culture and demonstrates how implementing new technology requires the development of a suitable supporting infrastructure .

Introduction

The WM Components company was established some 50 years ago to manufacture a variety of tubular metal products. The main success of the company occurred 20 years ago when it introduced mild steel tubes for use in burners in place of the cast iron tubes then in general use. This was considered quite innovatory at the time, mild steel tubes being much lighter were easier to manipulate and not as labour intensive and so had lower production costs. The company was soon followed in this step by its competitors in the gas appliance industry. The company sought also to expand further by diversifying into other product areas involving the use of plastic materials. In this task the companys' success was limited due to a lack of marketing strategy.

By 1979 the business had grown to such an extent that an operating profit of £80,000 was achieved on a turnover of around £1M from a turnover of £500,000 with £30,000 profit three years earlier. While the company was able to survive the severe recession between 1979 and 1982, by the latter year its profit was reduced to only £43,000 on a turnover of £1.32 million (3.3%) and employment was down to 58 from over 120 previously with half the factory shut down, together with the office block, in an attempt to reduce costs. At that time the company was controlled directly from the top, with the managing director and the toolroom foreman being the only technical people in the management structure. Quality control was looked after by two people, neither of whom was a calibration engineer.

Entry into Automotive Components Industry

At this point in time the opportunity arose to purchase a local tube bending firm then in receivership. This firm was one of the main component suppliers of tubular components to Austin Rover (then BL Cars) and its closure would leave them without a key supplier. The WM Chairman discussed its possible takeover with the purchasing director of Austin Rover who indicated that existing business would be continued if WM took over the company's orderbook and achieved competitive prices and quality.

With this in prospect and against the background of the recession WM thus moved into the UK automotive components industry. Until then automotive components had been only a small part of the company's business. Following the takeover, in 1983, WM made an operating profit of £68,000 on a turnover of £1.94M (3.5%) and the number of employees rose to 120. Within a year a further acquisition of another tube bending firm also in receivership and the taking over its orderbook as a supplier for Ford meant that the company now had the high volume orders it needed to try and become a main supplier. The company continued to organise its production along the lines of the companies it had acquired, in batches, with high inventories in order to buffer the irregularities of the material control schedules it received from its automotive customers. However, the problem the company faced was that during the low profitability years of the 1970's and early 1980's it had lacked investment funds, as had the firms it acquired, and much of the production equipment was antiquated. Entering an industry in which, in the words of the production director, 'quality is everything' meant that a fundamental review was needed in the operation of the company. At that time quality control was carried out by inspectors who were responsible for identifying faults in components. All too often this was occurring some time after a batch had been manufactured.

During the mid 1970's the UK motor industry had adopted the US method of Supplier Quality Assurance (SQA). This was based on the principle that a component supplier was effectively part of the production process and that responsibility for quality control did not stop at the supplier/customer interface. When WM entered the components market in 1982, SQA had become the industry standard and effectively excluded any non-approved company from supplying components. In addition, as a result of a general dissatisfaction in the relations between buyers and suppliers in the 1970's and the growing influence of Japanese ideas of manufacture, the trend was towards longer term relationships with a smaller number of "approved" suppliers. Unfortunately, WM had not acquired SQA approval from the companies it had taken over and therefore had to quickly introduce the procedures itself. In order to do this an ex-Ford quality manager was recruited in 1983 who was able to write a manual for WM, setting out the requirements and administrative measurements needed. The company hoped that with SQA approval its quality control problems would be behind it. Figure 8.5 shows a summary of SWOT analysis conducted by the management in 1983.

SWOT ANALYSIS, WM COMPONENTS 1983	
Strengths:	Responsive to Change
Weaknesses:	Financial Position Lack of "Depth" of Management
Opportunities:	Looking to Automotive Industry
Threats:	Intense Competition Difficult Economic Environment

Figure 8.5: Strengths, Weaknesses, Opportunities and Threats (SWOT), 1983

In order to improve productivity and quality, the company made its first investment in 1983 in NC technology through the purchase of a second hand machine costing £19,000. It was the first of a progressive series of investments the management planned. This represented a quite a jump in the level of technology for the company, as a manager commented:

> 'Nobody in the workforce had ever seen a machine where you could just press a button and it does the rest'

A stated objective of the Manufacturing Director for the introduction of CNC was also to deskill the existing production operations, since it was difficult to get skilled operatives. Also, the existing machinery often required a degree of 'black art' on the part of the operator in order to keep it running, which meant that the management often relied on particular individuals with 'a knack' on particular machines. When CNC machines had been installed it had taken some time to get across to operatives, that when a problem occurs, they must inform the maintenance personnel, rather than trying to fix it themselves, which can (and has) resulted in further problems. In 1984, Ford introduced a requirement that all suppliers must adopt statistical Process Control (SPC) procedures, and Failure Mode and Effects Analysis (FMEA) in order to comply with its new quality control standard, referred to as Q101. The quality control manager had had experience of this system during its development at Ford and assured the WM management that the company would gain acceptance, and issued guidance instructions on complying with the system. However, in practice meeting the new higher standards was found to be a far more difficult task than envisaged, and it soon became apparent to the WM management, that the heart of their problem was not simply a question of incorrect procedures, but a deeper one of poor internal communication, and the need to develop the company culture in respect to quality control and technical change. This was the first indication to management of the considerable education and training task ahead of the company.

When Ford representatives visited WM early in 1986, they were unimpressed with procedures and Q101 approval was not given, as a result of which the quality manager left. While Ford custom represented only 20% of turnover, in contrast to the 50% of Austin Rover, the management realised that Ford was leading the field in this area and that its other customers would eventually follow suit. With the benefit of hindsight the WM management believe that the failure of the company to get Q101 approval worked to their advantage, since it set them thinking about what to do. While in order to get SQA approval the company had been able to effectively "buy in" the expertise it required, the disciplines of SPC required a more fundamental change in company culture which had not been recognised. The senior management had assumed that the method of buying in expertise which had worked with SQA would again work with SPC and had no reason to believe otherwise, and the quality control manager had not brought to their attention sufficiently the implications of the new procedures. Failure was the result of not realising that SPC required a major initiative in terms of resource planning.

Company Response to Quality Problems

This setback proved a major shock to the company, and the option of leaving the industry altogether was considered. This was quickly rejected as unrealistic, and so the management set to the task of implementing SPC in a more systematic manner. A new quality manager and quality engineer were appointed with suitable qualifications to overcome the problems at the operational level. Although Ford was still not a major customer in terms of volume, this time their help was sought together with assistance from a quality training consultancy, and most importantly these initiatives had senior management commitment.

A key part of the plan was the training of employees. Every shopfloor operator, setter and supervisor received 50 hours off-the-job training over a period of eight months. The training was supported by a local training grant for employers provided by the Manpower Services Commission. The roles of the Quality manager and engineer were vital in this task and much of the training was carried out by them. The main problem was getting employees to change their traditional thinking and to assume responsibility for the quality of the parts they were making. This involved explaining to employees how to use SPC charts. Many operators had only limited mathematical skills and were unhappy at the idea of being responsible for their own calculations. Initially it was envisaged that each operator would require 5 to 6 hours of quality training, but in practice. using external lecturers, it took 28 hours to teach basic graphs. It was a case of finding out the skills which each employee needed and providing teaching in them. The time available for training was short, since it was necessary to implement the new procedures almost immediately.

Another area which had to change was the wage payment system. The company operated a piecework system, which was standard among many "Black Country" manufacturing firms, which meant that employees were paid according to their output. Thus, there was considerable pressure on operators to maintain output, regardless of quality. In addition, time taken by the operator filling in the SPC charts was seen as taking time in which money could be earned. The management therefore decided to pay the operator for the time taken to fill in the chart. If it was a simple "go-no go" attribute chart, the operator would be paid an extra 3% on top of the earnings for the batch. If the chart required the calculation of averages, then the figure was 4%. If the full SPC chart was used then the operator received 5%. The effect upon company direct labour costs was a rise of 3.7% in 1985/86. While this policy was helpful in getting the operators to accept some responsibility for quality it was only a partial solution, and did not resolve the fundamental incompatibility between payment by volume and the new ways of working the company was seeking to implement. The attitudinal problem of operators still existed, since it still benefited the operator to work as fast as possible and ignore bad quality. A manager commented:

> 'If they found they'd made a few bad ones, then they could always hide them under the rest - it's be some time before they were discovered, by which time nobody would know who was responsible and what's more - the bloke who did it would've been paid'.

Convincing operators that stopping the machine when a problem arose and to look for the cause and solution of the problem was a very difficult task, most found it difficult to believe that management really meant it. This well supported the literature on technological change, for example Child (1982) which shows that resistance is a common phenomenon to all activities where people feel their interests are threatened in some way.

To facilitate further change it was realised that continuous retraining for all members of the company would be needed, and a budget was set aside of four to five hours off-the-job training for all operatives every two months. The quality control staff were able to attend evening classes at the local technical college in order to become computer literate, funded by the company. The value added system has since been modified again to a far more simple one, where the whole workforce (including the management, for whom this meant a reduction) all gain exactly the same bonus. A large indicator board with a monetary scale and an arrow prominently displayed on the shop floor shows the workforce the level of their bonus as the month progresses. This is considered to be working well and complementing the team culture the company is trying to foster. Figure 8.6 shows the percentage of technical managers as a percentage of staff, reflecting the increase in technical staff between 1982 and 1988.

Success however, brought its own problems, since with Q101 approval the company acquired more business. This extra load meant that the company had to take on over 30 extra operatives in a matter of six months in 1988. The in-house training program had not been designed to cope with such an increase in demand in employee induction. The result was that many of the new operators went to work not fully appreciative of what the company was trying to achieve and as a result the scrap rate again rose. This problem was made worse by the need to introduce an evening shift where operators worked with little supervision. It was somewhat ironic that at the same time as scrap rose so reducing profitability, the quality control procedures ensured that the quality of parts delivered to customers was not affected, and the company actually won the Rover Sterling award for quality. Regaining control of quality has taken time, but this time response came from within the company through its greater technical expertise, rather than relying on expertise to be brought in from outside. The increase in the number of technical staff has assisted in this task as shown figures 8.6. An interesting innovation was to start sending operators to the factories of their customers to actually see their components being used. Thus operators were able to see at first hand the problems that faulty parts created for customers.

A manager commented:

> 'We had to change the culture of the company and the resistance to change was far greater than anyone anticipated, the labour force was basically frightened'.....'The wage payment systems was an ongoing saga, they (the operators) wanted to do it the way it had been done for the last 20 years'.

To overcome these problems the management decided to introduce a form of value added payments scheme, based upon a flat rate of pay, with new grades across the entire company, and a percentage bonus linked to output of good parts. 60% of the grading was based upon quality factors, including understanding the objectives of quality control, timekeeping, and flexibility.

However, this scheme was also not without its problems, since for operators it held no immediate benefit, (although most received an increase in pay), but it did mean that shutting down a machine to search for the source of a problem would not mean loss of pay, and also that no one would get paid for producing scrap. The fundamental challenge that these changes meant to long established attitudes cannot be overstated and "selling" the idea to the workforce proved a difficult task.

In 1987, Ford staff came to reassess WM for Q101 approval. This involved looking not only at their own components, but also those of other customers and the general procedures of the company. By this time WM had made considerable progress, not only in respect of its procedures, but also of changing its culture to one where employees had greater responsibility for their own quality, and in consequence Q101 approval was given. Achieving this had taken just under a year, and was now seen as paving the way for further improvements.

However, the workforce still mistrusted the added value payment scheme, particularly when the bonus varied between 4% and 12%. The problem was that the system was a complex one having been adapted from a system normally used at larger firms. The operators found it difficult to understand the calculations and mathematical formulas involved and so were skeptical as to the results it produced. While the quality control procedures were successful at preventing bad parts from passing through, the concept of scrap being related to added value had yet to be fully appreciated and the scrap bin was still collecting such faulty parts. The management decided to try out the idea of quality circles, but the initial attempt failed, turning into a "slagging off" session. It was felt that the vital preparation work needed for this had not been given. These problems highlighted to the management that they were involved in a continuous process of introducing change, and that gaining Ford approval was only an initial step.

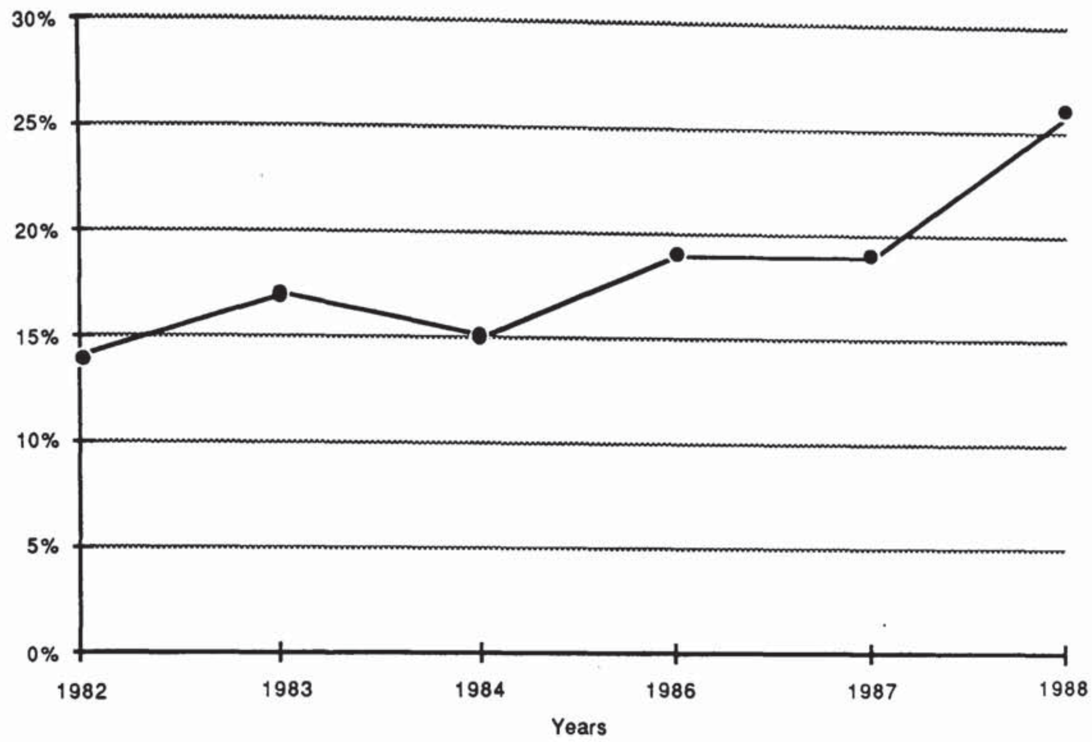

Figure 8.6 - Technical Managers as a Proportion of Staff

Since 1983, the company has continued to invest in CNC technology and now has several CNC tube benders. Whilst previously setting the old manual machines took over a day, the new machines can be set by the setters (operators do not perform their own setting) within in a matter of minutes, and are able to keep within manufacturing tolerances to a far greater extent. The company was able to innovate itself through the development of a digital readout/sample mean and range calculating machine which is now on the market. However, being privately owned, the company has found it a struggle to raise the necessary investment funds over this time, requiring up to £0.5M per year. This has not been helped by the generally low profitability of the automotive components industry.

A particular development in the company is to reorganise products into families, and production into group technology cells. For this company this represents a considerable organisational innovation. Previously the layout of the factory was a traditional functional one, where machines were placed into groups of the same type, this often resulted in the inefficient transport of components needing work at different machines around the shop floor. The use of group technology techniques has meant that the production is now organised on a cell basis, with each one making a family of parts.

This resulted in a considerable improvement in productivity, but alongside it was the need to introduce the workforce on a similar group working basis, with multi-skilled operatives. With many in the workforce coming from a traditional manufacturing environment with rigid skill demarcations this has been quite a "culture shock". Many of the unskilled workers had never previously considered acquiring skills to any large extent, and skilled workers were naturally somewhat apprehensive about others encroaching onto what they have long thought was their own territory. Nevertheless, despite initial problems, the management has persisted in its objective of establishing group working and over half the production of the firm is now carried out it this way. A group typically has five to eight workers, equipped with the machinery needed to complete a particular family of components. All workers are multi-skilled, rotating between jobs and teaching others who join the group. While there is no single person within each group responsible for supervision it is hoped that, with time, "group leaders" will emerge.

Another aspect of gaining Q101 approval is that it has enabled the firm to become an "early involvement" supplier which is asked to enter into design discussion with vehicle assemblers early in the development process. This is typically two years with Rover and three years with Ford. The trend in this area is eventually to push much of the design work down to suppliers and WM is preparing for this with the introduction of a CAD system. While this does provide the opportunity to consider quality at a very early stage in a components life and to use FMEA techniques properly it does result in other problems. In particular, for the smaller company, the design lead time can often be long and vehicle assemblers are often reluctant to pay for the design work as it progresses, expecting the supplier to recoup their investment when the component goes into large scale production. Clearly, for a smaller company waiting for this to happen can have severe cashflow implications. WM had recently invested the equivalent of £100,000 in work on the design of components for Rover, and were forced to ask Rover accountants to come in and look at the books relating to the project to demonstrate that without some financial support in advance of production it would be difficult to find the resources to keep up with design schedule required. Figure 8.7 shows a SWOT analysis summary conducted by management in 1988.

SWOT ANALYSIS, WM COMPONENTS 1988	
Strengths:	Responsive to Change "Preferred" Supplier
Weaknesses:	Financial Position Investment Capability
Opportunities:	Broader Presence in Automotive Industry
Threats:	Intense Competition

Figure 8.7 - Strengths, Weaknesses, Opportunities and Threats: 1988

Honda Contract

The next step in the development of the company has arisen through the link-up with the Japanese company, Honda, who are in the process of building a factory at Swindon in Wiltshire. As is the practice with Japanese vehicle assemblers the company is seeking to have a smaller number of "preferred suppliers" and WM are keen to become such a firm. This prospect has provided the company with the opportunity to rethink their business strategy and consider longer term investments. An important development has been the appointment of a operations director with a "systems" background who has spearheaded the implementation of a Materials Resource Planning system (MRP II) in the company for production and inventory control. When considering the appointment of a new operations director the senior management sensing that the business would need to develop its computer systems in the long term took the deliberate decision to appoint someone with systems expertise as opposed to someone with just a strong engineering background, as had been the case with previous occupants of the position. This did cause some initial resentment within the company among its longer serving engineers, who tended to place less importance on the development of computers within the business.

The Honda contract is likely to require considerable investment on the part of the company and will require the introduction of robotic cells to make the components. The problem is that from the initial design lead time to full scale production will take in the region of four years. Honda however, will not allow companies to produce prototypes on the existing machines, but insist that companies install the equipment that will actually be used in practice. This clearly requires a supplier to make a considerable initial investment and although some financial assistance is provided, payback periods are significantly extended to 4 to 5 years. For this company as with many others, 2 years is the commonly required payback period. It is assumed that the benefit of a longer term relationship will outweigh the disadvantage of a longer payback period. In discussing the problems facing the company in introducing robotics with the robotics consultant brought in to design and implement the system, it was suggested that getting the management to realise their need to break away from the existing focus on short term payback, to one where the longer term competitive and strategic aspects of using the technology are emphasised has been one of the most difficult. This supports the conclusion by Van Blois (1983):

> 'robot justification (is) radically different from the traditional financial justification methodology...which is based on the short-term question of "what will it do for me over the next six months to three years?". When dealing with robots, however, the question ought to be, "What should be the strategic direction for the organisation"'.

In order to assist in the development of a closer relationship, the Manufacturing Executive was able to visit Japan to view the Honda factory producing a similar component to the one WM will have to manufacture. This was being carried out in a highly advanced robotic cell, specially designed for tube manipulation. While one option would have been to copy the cell in Japan, this was not practical, since the cell had a production rate of five times that envisaged for WM and so would not be economically viable. The company is therefore developing its own robotic cell, with the assistance of the outside robotics consultant, at a much reduced cost. A key issue in selecting new machines is that because of the considerable expense involved in new technology, the machines purchased must be sufficiently flexible so that they can be used for the manufacture of other components, so outlasting the product life.

Summary

This case study has been developed at some length because it clearly demonstrates one of the major factors associated with apparent sub-optimal performance after the installation of more advanced manufacturing systems, be they embodied within higher technology plant or machinery or essentially expressed in changed forms of work organisation. That factor is the ability of the workforce - including the management as well as the shopfloor - to understand and implement the new processes. "Custom and practice" is a strong characteristic of behaviour at all levels in manufacturing operations and the cost of changing this (as well as that of *not* doing so) has often been omitted from estimates of the benefits of investment in higher technology. The consequence has frequently been disappointment with the rate of return on that investment - a situation that has only been remedied when the basic "holistic" nature of technological progress within the business has been realised and allowed for. Very similar circumstances to those encountered at WM Components were experienced by a much larger engineering company, which must remain anonymous here, which found that its very considerable investment in machining centres failed to pay off in the anticipated period because of both the intractability of worker custom and practice - particularly in relation to machine setting times - and the lack of balance between the level of technology inherent in the machining centres and that available from the support services within the company - including even the computer systems, which had been assumed, being themselves relatively recent innovations, could cope with the operational requirement of the advanced manufacturing technology.

In the longer term WM faces several problems, in particular the threat from new materials technologies, eg. plastic petrol tanks in cars, pipeless gas appliances. While the company has managed to maintain investment levels it has been a struggle and profit margins have remained low. With the ever increasing cost of new investment, it is unlikely in the long term that the company will be able to remain privately owned, and it probably will become part of a larger industrial group, in order to have access to the necessary capital to fund a higher level of investment. Further challenges also lie ahead, in order to obtain the British Standard (BS 5750) approval from one of the five validating bodies in the UK, the company introduced a computerised batch control system (MRP) in 1989, and is still very much on the learning curve of its use. Likewise, with the introduction of CAD, also in 1989, which is vital to the company if it is truly to become involved in research and development for its customers.

To illustrate the changes in the company since 1983, figure 8.8 shows a breakdown of employment between 1982 to 1988. Figure 8.9 shows the Sales Turnover and profit between 1982 to 1988 and figure 8.10 the profit as a percentage of turnover. These figures show the strides the company has made in improving profitability, but due to the higher demands for new investment in the foreseeable future, it is unlikely that higher profitability as a percentage of sales can be achieved.

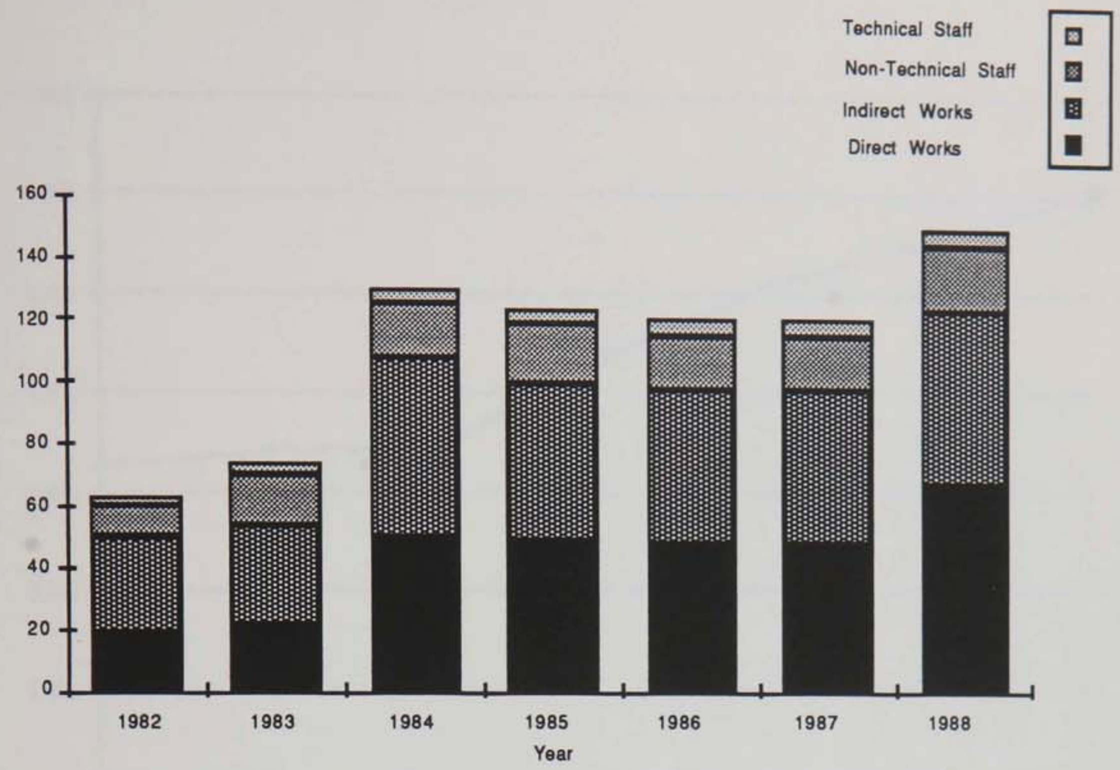

Figure 8.8 - Employment at WM Components 1982 to 1988

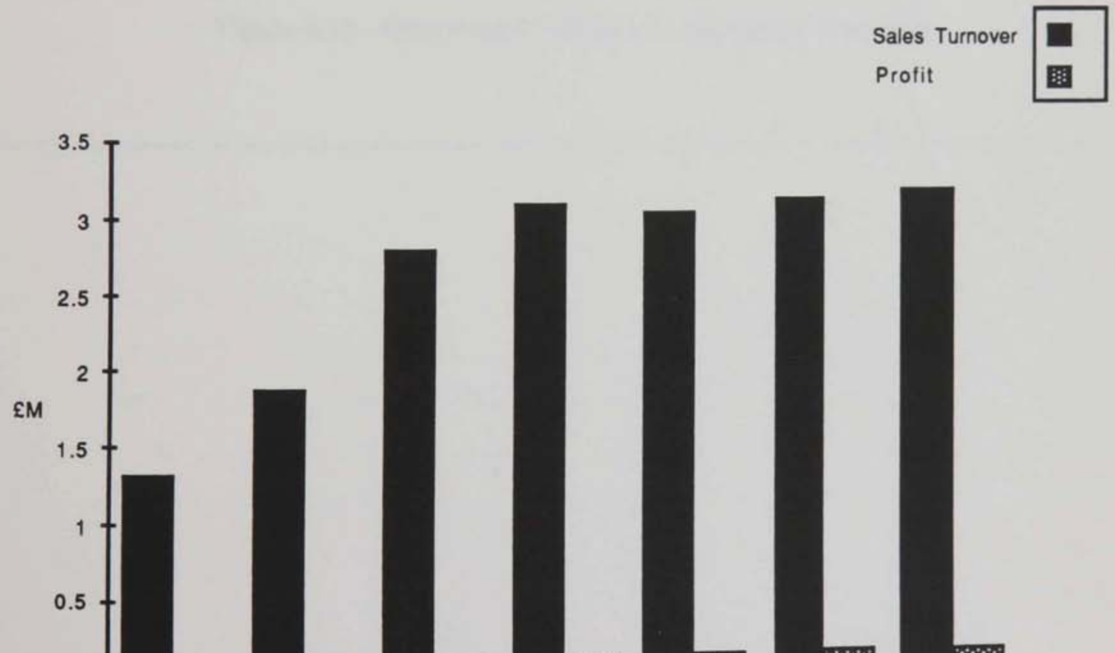

Figure 8.9 - Sales Turnover and Profit

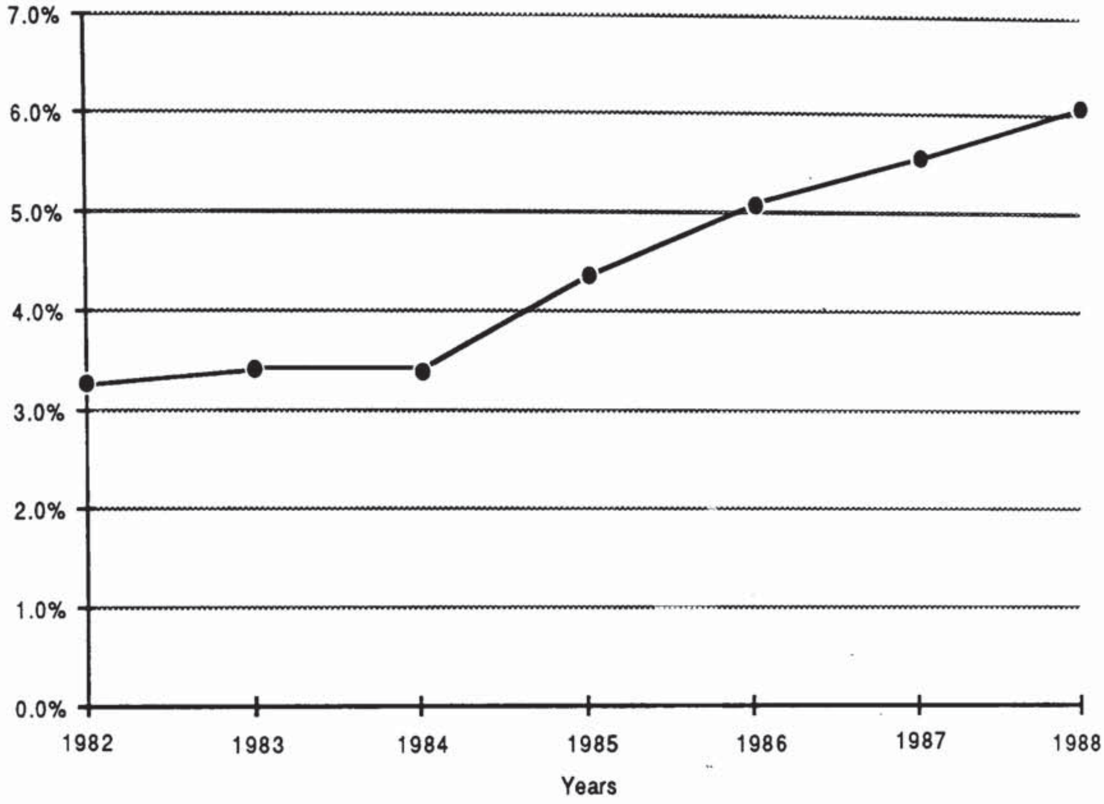

Figure 8.10 - Operating Profit as a Percentage of Turnover

8.7 CM Machine Tool Company

'Whatever shape the factory of the future may take, there is no question that the key to making it work successfully will be people, not technology'.......Project Director

During the research the author was fortunate to be able to draw upon the experiences of the project director of the UK subsidiary of one of the world's largest manufacturers of machine tools. This provided a unique opportunity through a series of interviews at periodic intervals during the research to monitor the technological trends in the machine tool industry and compare the experiences of the case study companies using new technologies with those of a major supplier (who in several cases was one of their suppliers).

Introduction

The US parent company is a multi-national company over 100 years old and has fourteen plants throughout the world manufacturing a wide range of products including, machine tools, coolants, grinding wheels, plastic moulding and extrusion machines, CNC control systems and robotic systems. The company has traditionally sought to keep pace with changing technology (indeed its motto is "find a better way") and has made substantial investment in its UK plant totalling some £5 million during the last five years. This investment was seen as the principal reason for the firms's survival when many other machine tool companies closed as a result of contracting markets and overseas competition. Two of the most interesting trends in the company during the 1980's have been firstly the change in emphasis of its product strategy from concentrating its efforts primarily on developing highly engineered manufacturing systems, often on a one-off basis, to its development of *smaller* systems and secondly, the introduction of a small mass produced machining centre. This change in emphasis is best illustrated by the example of the company's development and subsequent modification of a flexible manufacturing system.

Development of FMS

In May 1983 the company decided to install within their UK factory customer training and demonstration area, one of their latest high technology machine tools. This was a US built prototype, (referred to as a T10) horizontal machining centre with an automatic work changer (AWC) which had been designed and built for the 1983 Paris machine tool show. As company policy is not to sell prototypes on to customers this was not an unusual decision. However, the production management considered that far more benefit for the company could be derived by installing this equipment in the production environment and using it to produce piece parts more efficiently for its own use. Customers would thus be able to see the latest technology being used within the company and not just in show conditions.

Before the equipment was installed during August 1983, the manufacturing engineers and computer systems departments had been discussing the merits and limitations of a single T10 machine with AWC. It became clear that while such a setup would provide useful benefits, in relation to the company's overall objectives regarding factory modernisation and sales image it was not the complete answer. At that time in the machine tool industry considerable interest was being expressed in the potential of flexible manufacturing systems, and indeed the US parent company was in the process of developing and installing several such systems.

The UK subsidiary had traditionally been associated with expensive heavily engineered, high quality machines and identified the flexible manufacturing concept as one in which it needed to acquire more experience. After further investigation the existence of Government grants for FMS installations was pursued. From this a plan was developed using a prototype T10 machine as the basis to design a FMS for the production shop that would serve as manufacturing facility, sales tool and training equipment for the production and software personnel. By the end of July discussion with the Department of Trade and Industry (DTI) were completed and a system design was ready for phasing and financial justification. A Discounted Cash Flow analysis for the entire three phases of the project was carried out and expenditure from the US parent was authorised totalling £743,775 of which the DTI were prepared to make a grant of £247,677. The final cost to the company of £496,098 was seen as very attractive. The financial justification of the FMS is shown in appendix 8.1.

In addition to the production unit of the company, the electronics division had also applied for an innovation grant to develop a Flexible Manufacturing Cell Controller (FMCC) which was approved in November 1983. This development made it possible for the company to consider a previous idea, this being to exhibit an FMS controlled by a FMCC at the 1984 UK Machine Tool Show. To achieve this objective required the acceleration of the FMS project, a task at which the company was successful. In March 1984 the decision was taken to reinstall the show system as displayed, into the production facilities of the factory. This required modifications to the overall system and extended agreement with outside equipment suppliers, who in the event were pleased with the opportunity to keep the show system operational, thus displaying their equipment under production conditions.

The company envisaged that the system would also help in furthering its own understanding of the flexible manufacturing concept .and show customers the advantages of a "building brick" approach to achieving automated systems. Figure 8.11 shows the"ideal" steps a customer might take in moving towards a more automated

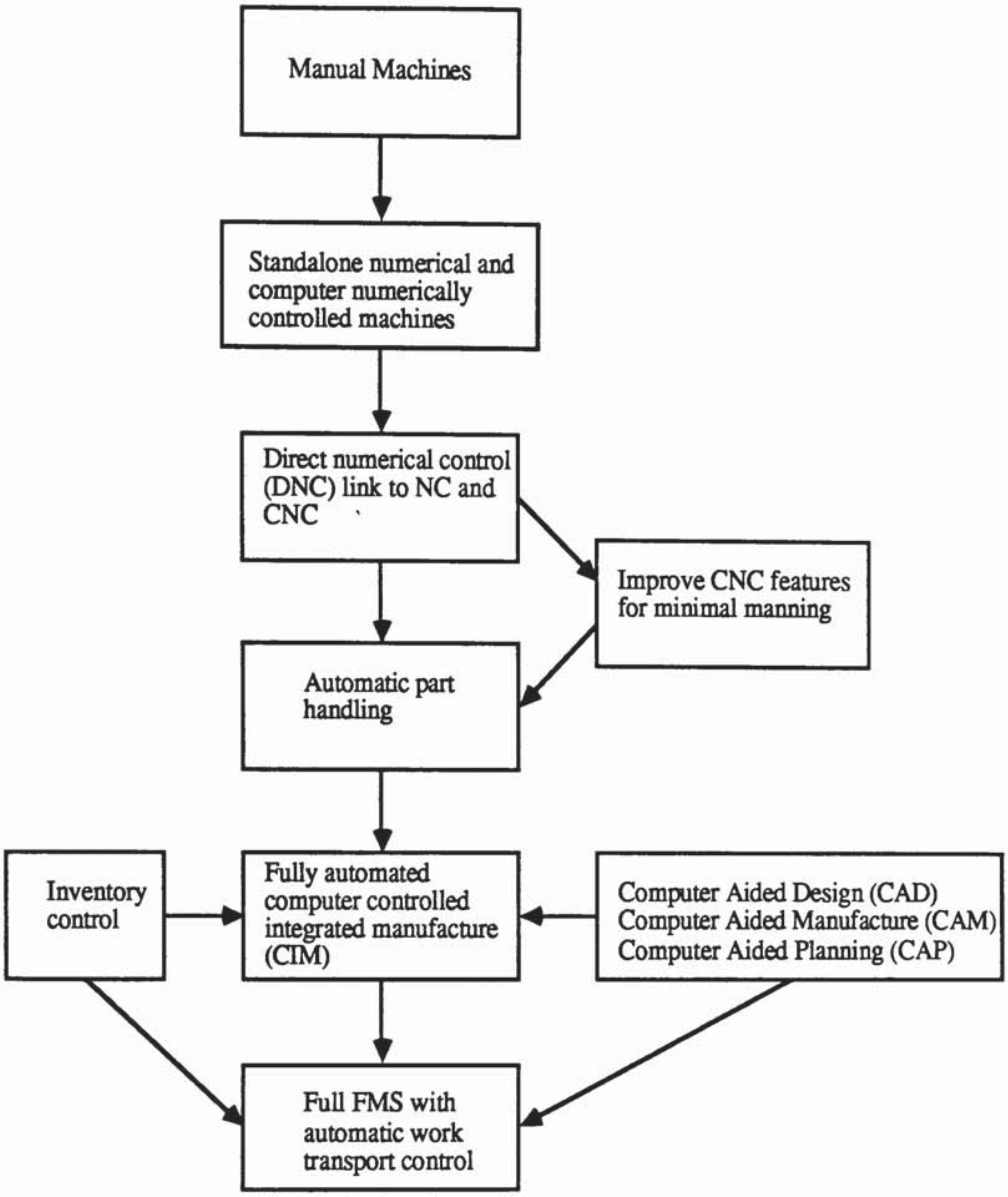

Figure 8.11 Ideal Logical Steps to FMS and the Automated Factory

system of manufacture, enabling a firm to acquire the experience and skills needed as it progresses. In discussing the criteria for successfully implementing AMT, a manager commented:

> '....there must be evolution not revolution, and since the solutions are not all at hand today, there must be a progressive build up of knowledge and features with some stable period of consolidation to provide the necessary confirmation of performance'...'it is almost impossible to provide an optimum system at the outset since the problems involved are so complex that the solutions must be developed systematically'....'progressive build up makes the financial outlay more acceptable and achievable, although is may be influenced by the availability of government grants which can define the minimum steps which can be introduced'.

The company formulated its own model of automation at four levels as shown in figure 8.12. Level 1 is represented by standalone machines and from the point of view of FMS is the starting point of the engineering process.

Level 2 involves a slightly more complex control system together with some form of work storage. In the case of a machining centre, a pallet loop is the work storage device feeding work to the machine. The control of the pallet loop located in front of the machine is derived from the machine control. At this level many of the problems and requirements for minimally manned operation are similar to the ones associated with higher automation levels, since once the operator is taken out of the loop, the same requirements for dealing with damaged tools and swarf removal are necessary.

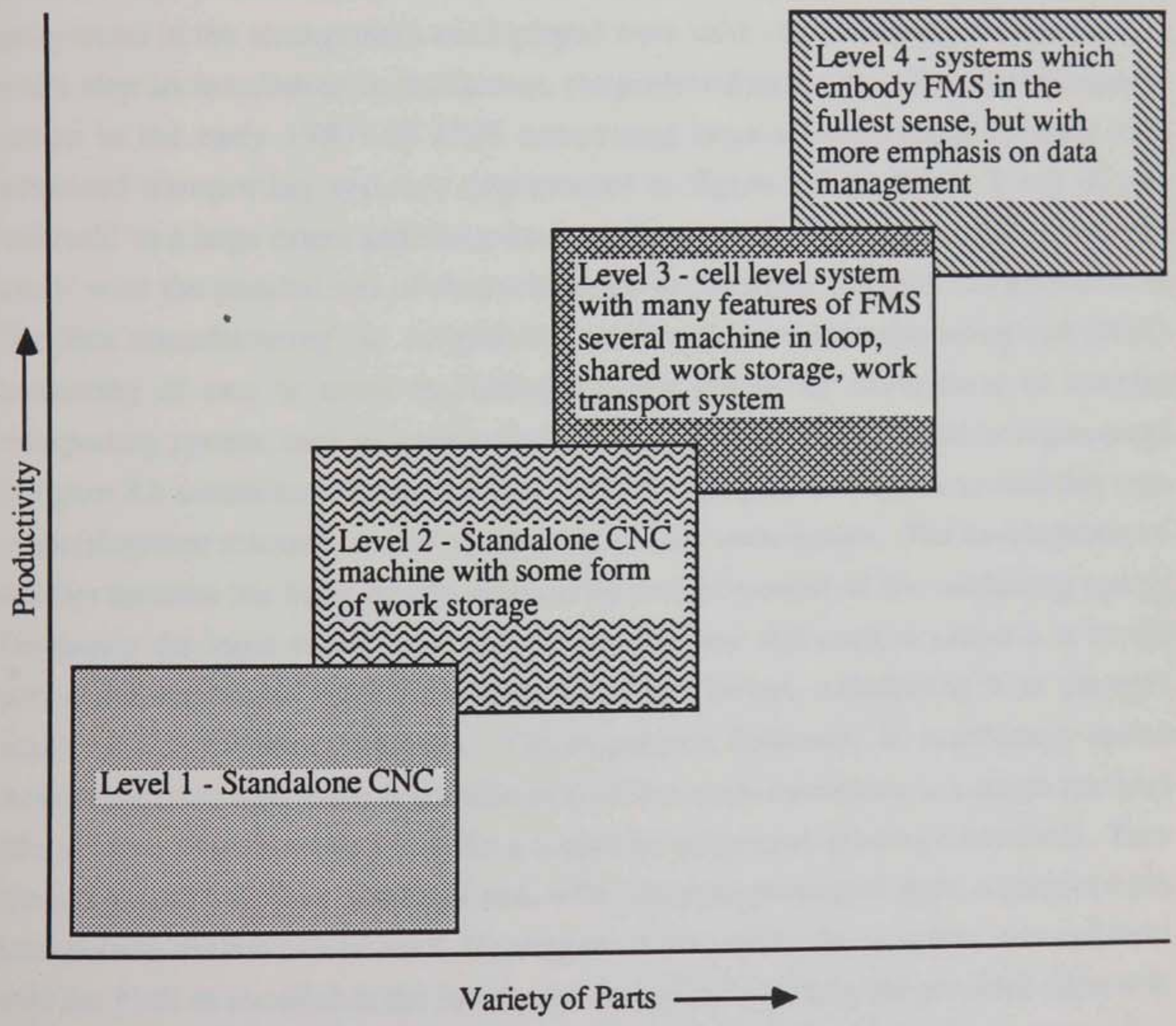

Figure 8.12 Company Model of Levels of Automation

Level 3 corresponds with what is termed the cell level and several of the features of advanced systems are demonstrated such as; several machines in a pallet loop, shared work storage between machines, probably to some extent shared tools. At the cell level the work transportation method can be one of several machines, robots, conveyors, rail vehicle or automatic guided vehicle (AGV); Level 4 would include all of the features which characterise FMS. To some extent it is a question of degree in moving from level 3 to level 4 since many of the same features are common to both systems. The significant difference lies in the emphasis at this level on data management and reporting capabilities. At this level the need for flexibility would probably involve the use an AGV. In these terms, the system the company had developed lay somewhere between levels 3 and 4.

While the Mach'84 exhibition stand was felt by the company to be very successful and at the time generated a lot of interest in its ability in trade journals to produce a FMS, no systems in the arrangement as displayed were sold. In discussing the system five years after its installation in the factory, the project director considers that the media image in the early 1980's of FMS comprising large all-embracing systems with advanced transporting systems, (represented in figure 8.6 on levels 3 and 4) was 'oversold' to a large extent and that even manufacturers like themselves, did get 'carried away' with the possibilities of the technology at the time. Instead, the emphasis in "flexible manufacturing" is towards the smaller flexible manufacturing cell (FCC) consisting of two or more machining centres linked by some form of simpler transporting system, such as a rail conveyor. This type of system would be represented in figure 8.6 somewhere between levels 2 and 3. The project director termed this type of development towards simpler systems as *smaller automation*. The development of smaller systems has been greatly assisted by the refinement of the machining centre. Originally the logic of the large transfer system was that each machine in it would perform a number of operations on a piece part before transferring it to the next machine for further operations. Developments however, in machining centre technology have now made it possible to combine more operations at a single machine (the ultimate objective being to make a complete component at a single machine). Thus there is a need for fewer machines and, with less transporting of parts, a simpler work transporting system can be used. He suggested that while the company may not have sold the FMS as installed in the factory, its design and building has provided them with invaluable experience which had been applied in producing the smaller cell systems. Also by running the FMS themselves, it had forced the company to prepare for future technological change and had given them an insight into the kinds of problems their customers face in using advanced systems.

The FMS also highlighted the problems of conventional overhead recovery systems when using advanced machining methods. Like most engineering firms, the company allocates its overheads based on direct labour hours. The FMS operates on a 24 hour (3 shift) five day week with maintenance being carried out at weekends. The company expects around 70% efficiency on the the FMS which gives roughly 20 hours of saleable production per day. However, since only two of the shifts are manned (16 hours) the question arises of how to allocate overheads for the extra 4 hours of production. The project manager admitted that costing is one area of the company's activities where the they were still behind the technology they were using, and put this down to organisational inertia. The finance department were reluctant to change from widely accepted industrial practices, although there were now moves to introduce a new system allocating costs based on machine hours.

An interesting problem that arose when planning the FMS, and one where the manufacturing director considers that there are still many areas of uncertainty, is how to allow for depreciation with advanced manufacturing systems. Traditionally most firms use either a straight line or reducing balance method over a set time period to write down the asset value of their machines to zero. However, if a machine spindle is running for 18 hours per day on a FMS compared to approximately 4 hours on a conventional machine, should depreciation be the traditional 10 years or half of this? The value selected will have a substantial effect on running costs. In addition should software be depreciated over a shorter time period than hardware to allow for obsolescence? Very little is also known about the life expectancy of advanced transport systems. These kind of problems, despite considerable discussion within the company, have still not been adequately resolved. It may well be that as experience grows, different elements of a manufacturing system will be depreciated at varying rates. Whatever the case, if a company is to be soundly based, it must maintain its asset value. The project manager suggested that to achieve this a depreciation fund should be set up to enable the purchase of replaceable equipment at any time. Yearly deposits to this fund equivalent to current depreciation values should be company policy.

The need to link manufacturing investment to an overall business strategy was particularly stressed:

> '....Companies cannot afford to launch into AMT without first determining which technologies are appropriate to their situation. There are already enough examples where systems have failed because management has not developed a strategy, selected the appropriate technology or applied it effectively'....'AMT's philosophical implications, their impact on the way we approach our manufacturing businesses are just as profound as those of the first industrial revolution'

In discussing what were the main criteria for successfully using AMT, it was commented:

> '....Whatever shape the factory of the future may take, there is no question that the key to making it work successfully will be people, not technology. The technology is largely available and ready to use, but we have some way to go before organisations can use it properly. What is badly needed is *organisational adaptiveness* and that is not something that a machine or a piece of software can provide. It has to come from the people in the organisation, which means investing as much in them as in the new technology'....'Successful users of advanced systems are those who have spent time and trouble trying to get the best fit between the technology and their organisation's skills, experience and needs'....'There are ways of helping this process along through top-level commitment to change, consultation and involvement, and a strong emphasis on training, not just for the specific skills needed to support the new technology, but to develop individuals'.

The project director considered that in terms of the use of more advanced technologies in smaller companies the market had matured considerably and that such companies were now purchasing quite sophisticated machines. He saw the machine tool market (particularly in the automotive industry) as dividing into three general categories:

(i) Large engineering firms: as one would expect, it is in this sector that the market for more advanced technologies is most developed. Firms may require specialised systems to be designed and built for a specific application, or the modification of standard range machines, often with some form of linking. This sector has traditionally been where the company has concentrated considerable effort. Most customers have considerable experience of advanced technologies.

(ii) Large subcontractors: It is in this sector in recent years, that the greatest advances in terms of the level of technology employed have occurred. Many such firms faced with increased market competition and the demands for higher product quality from their large customers, have responded by purchasing *small* systems to try to move towards a high volume/low cost manufacturing environment. For example, two turning centres linked with a robot load/unload facility to form a manufacturing cell type arrangement would today cost in the region of £250,000. Several years ago such firms would be reluctant to commit themselves to this level of investment and would also be concerned whether they have the in-house skills needed to run them successfully. Increasingly however, from their experience of standalone CNC machines, they now realise that they do have the expertise to adopt more advanced systems, a process that has been considerably aided by advances in CNC control technology which reduce the learning curves involved The key aspect of their justification is that, in order to obtain the two year payback on the investment (most customers still think in terms of simple payback), the machines must be used intensively so that the full benefits of their greater productivity can be obtained. This usually involves adopting a multi-shift operating pattern, and "gearing" the firm up for a higher rate of throughput.

(iii) Small subcontractors: this market is also showing considerable expansion as customers become interested in cost effective, usually standalone machines that still offer high performance. Firms in this sector are willing to pay around £45,000 to £60,000 and want a machine that can just be "plugged in" and which requires only minimum training in order to use it. It is for this segment of the market that CM have developed a small machining centre.

Development of the Small Machining Centre

CM has traditionally had a reputation for expensive, heavily engineering, high quality machines, so the decision to produce a low cost machining centre (the Sabre) aimed at taking on Far Eastern and European manufacturers, represents quite a significant new development and was described as being "quite a culture shock" to the company. The Sabre is offered at £45,000 but with a catalogue specification that exceeds most of the competition selling machines under £60,000. The machine's development originated from a change in corporate strategy. Until the mid 1980's the company's UK design input was mainly limited to Europeanising US designed machines. Since the mid 1980's the development and manufacture of particular products have been decentralised from the US headquarters to individual factories, to try and achieve a *focussed factory* concept allowing the design and manufacturing functions to become more integrated. The UK plant is the *focus factory* for vertical machining centre development.

The reason for developing the "Sabre" was stated thus: 'CM wanted a product that would provide a stable source of revenue from the steady production of a well defined machine with predictable sales volumes and which could be sold from a catalogue'. While the company would continue to produce specialised systems, a problem with one-off designs is that much of the development work cannot be applied elsewhere. Since CM had been used to this one-off production environment with a substantial engineering input, producing the Sabre on a large scale has required major changes in existing practices. The Sabre now has its own assembly line and suppliers were involved at an early stage, together with the setting up of bonded stores to create a Just-in-time production system.

The predecessor to "Sabre" had been the "7VC" machine which was a well engineered machine with no real competitor in terms of spindle power-to-work envelope ratio. However, it was disadvantaged in price terms compared to its competitors. The aim in developing the Sabre was to incorporate as much of the "7VC"s specification as possible, but at a much more competitive price. A senior engineer commented 'Sabre was designed around a minimum annual production volume of 100, compared with 50 for its predecessor, so we could take economies of scale into the equation. We've attempted to develop a machine for a wider market than that satisfied by our traditional CM machine, and we designed the machine to be manufactured, rather than try to manufacture the machine we'd designed'.

An innovative organisational aspect of developing the "Sabre" was the use of a "project team" which enabled concept, design, development and launch to be compressed into 12 months. This approach had been tried successfully for an earlier machine and involved bringing together marketing, engineering, manufacturing, finance and purchasing from the very start of the project. To facilitate this approach, the engineering department established the position of "Project Director" who would have overall responsibility for specific long term projects in the company such as the "Sabre" and who would coordinate between functions in the company and outside suppliers, acting as a "project champion".

The initial brief was to design a machine with the same work envelope and tooling capacity as the older machine, but selling at around half the price. The machine was also intended to be a universal design suitable for both European and US markets. To achieve this, the engineers analysed other machines in the class which gave an indication of which features were required and how the maximum performance could be obtained within the cost constraints. The objective being to maximise reliability through the use of a minimal number of components to be assembled in a closely controlled environment. The technical features of the Sabre include a 15 metre/minute rapid axis transverse speed, a six second metal to metal tool change, a 11kW 60 to 8000 rev/min spindle and a 760 by 381 by 508mm work envelope. These features compare favourably with similar machines of that class. Being a lightweight machine, computer based finite element analysis was used to develop a machine frame of sufficient dynamic stiffness. A number of innovative methods were also used to keep the parts list/direct labour content of the machine down to a minimum, but which at the same did not result in any major compromises in terms of performance. These included the elimination of hydraulics (the z axis counterbalance, spindle drawbar and tool magazine are all pneumatic), using the spindle to pick and place tools from the magazine and the use of a direct drive spindle system with no gears and an electrics cabinet and control console integral with the machine frame. As a result of the cost benefit/savings analysis, the company believes it has produced a machining centre which is "engineered" rather than "over-engineered".

To ensure economic manufacture and maintain quality, the company decided to divide the parts list into critical and non-critical parts. The critical parts like the spindle are made in-house. The advantage of this approach being that it enables the company to concentrate its efforts on design, test and assembly of a smaller range of parts. The non-critical parts which make up some 80 per cent of the machine are bought in, so the company has obtained bonded stores agreements with main suppliers. This enables just-in-time operation without the risk of of a lorry not turning up at the allotted time. Involving their suppliers at an early stage in the design process, reinforced their commitment to the project, and their design input assisted with the 12 month timescale from design to manufacture. A senior manager commented '...The first job our purchasing department had to do, was to convince suppliers we were going to make this machine in volume, so that we could agree component pricing in line with our target works cost. We also had to have straight -to-line quality certification, traditional step by step goods inwards, inspection, stores, works order and issuing procedures that would not waste too much time'.

To facilitate the manufacture of the Sabre, the company has effectively created a "factory within a factory" dedicated solely to its production. The main element in this new arrangement was the modification of the flexible manufacturing system previously discussed, to become part of a cell arrangement with three other conventional machines to make components for the Sabre. In this new arrangement it would make only a narrow range of some 30 parts and so its ability for "flexibility" as originally envisaged in its design was largely redundant. The new arrangement, is dedicated to components on a random call-off, initiated by emptying of bins of components located by the assembly line on a just-in-time basis. Other machine tools can also be dedicated to the product if the number of required machine hours justifies this move. A significant change is the introduction of flow line build, which combined with the use of pre-painted components, provides a production capability of one machine per shift from the assembly area. In the early stages of assembly, the bed and saddle are assembled on air pallets, then transferred through to be joined with the column/spindle carrier and electrical cabinets. Lineside stores holding a month of low cost components were introduced to save time and smooth the assembly process. The machine is then craned to the final assembly and test area before shipment. Every fully assembled machine undergoes three cutting tests and laser calibration, together with a 24 hour reliability run. An automated test facility is being developed, which will enable a number of geometrical and laser positioning tests to be conducted without the need for direct operator intervention. In terms of manufacturing lead times, its predecessor, the "7VC" which a five week build cycle, and the Sabre spend a week in build and a week on test.

In economic terms the machine has undoubtedly been a major success for the company, with over 400 units sold in 1989. With each unit retailing at £45,000 this suggests a gross revenue of around £18 million through a combination of agency and direct sales. The company plans to sell over 450 units in 1990 and if the markets predictions are fulfilled, the Sabre may well be the precursor of an entire range of competitively priced machines.

Summary

The experience of the CM company is interesting in that it reflects a number of technological trends over the past decade. Figure 8.13 shows the author's interpretation of the pattern of key technological, market and organisational changes in the company during this period. Initially it was envisaged that the need for flexibility in manufacturing would be met by large complex systems, which would be very flexible but at a high cost. In practice this market has not materialised in the way envisaged, instead the emphasis the demand has been for smaller "cell" and "soft automation systems" which, although not offering the level of flexibility of the larger systems, are more cost effective. Developments in machining centre technology have also facilitated in this trend by combining several machining operations so reducing the need for complex work transport systems. As is the case with most technologies, what has occurred is a progressive refining and cost reduction process whereby a feature that was previously expensive, in this case "flexibility", is now made available to a wider market through new models which offer the essential aspects of the larger systems but at a fraction of the cost.

Within the market for machining centres itself, the Sabre repeats the process by offering on a cost effective basis many of the features of more expensive machining centres. Such manufacturing innovation clearly has important business implications for smaller firms. In some respects there is an element of irony in the fact that the FMS designed and built by the company to meet an anticipated demand for flexible systems should now be reorganised to produce a limited range of parts for high volume production of a small machine. Coping with such technological developments has also led to the company adjusting its organisational structure with the adoption of "project team" approach combining many of the different functions within the organisation at an early stage and also to the introduction of a JIT environment to build the Sabre machine.

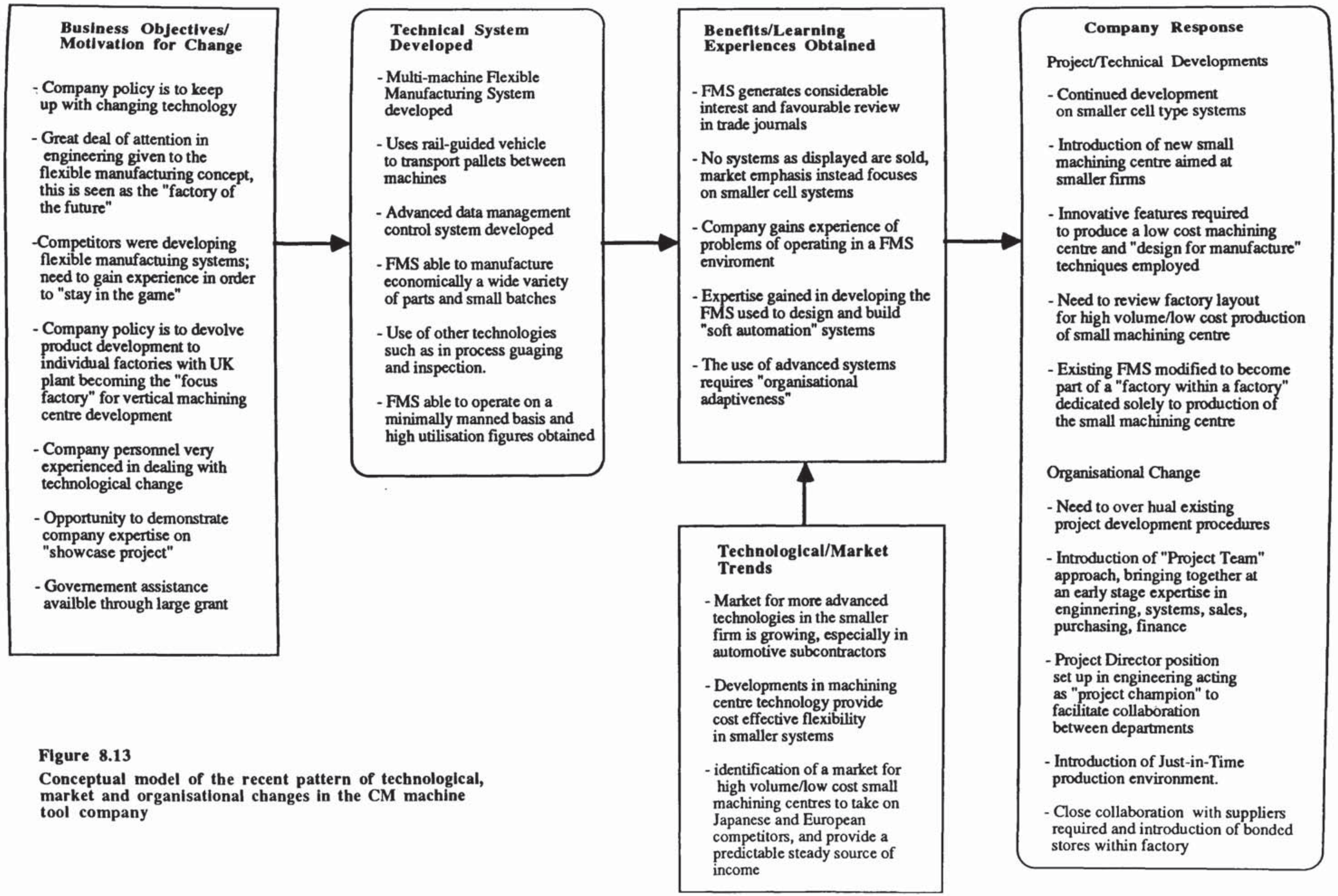

Figure 8.13

Conceptual model of the recent pattern of technological, market and organisational changes in the CM machine tool company

8.4 PE-Inbucon Group (Manufacturing Division)

'Integrated Technology requires a similarly integrated organisation to run it effectively'.
Senior Consultant

During the research the author was fortunate to have the assistance of the PE-Inbucon group, a leading management consultancy firm with a specialised manufacturing division based in Solihull. The group's consultants have in recent years been involved in a wide range of projects using advanced manufacturing technologies in companies of different sizes and levels of technical expertise. From interviews with consultants and access to company documents the author was able to draw upon their considerable experience to obtain an account of the problems their clients face in adopting AMT, and outline the kind of approach that is used to develop a manufacturing strategy for a client company.

The use of consultants in manufacturing industry is undoubtedly a growing trend, for instance the list of consultants in the Department of Trade and Industry's (DTI 1985) *AMT Awareness Program* contains over 400 organisations (42 in the West Midlands alone) claiming to have some expertise in an aspect of AMT. From the point of view of the PE group they see that many firms faced with the growing complexity and competitiveness of the manufacturing environment find it uneconomic to employ on a full time basis all the specialist skills they may need. Instead they are increasingly choosing to use consultants who have the specialist knowledge and most importantly practical experience of how to use it in a real-life situation derived from the management of technological change in other organisations. Ideally, the consultant being from outside the client's organisation should be able to bring a fresh, detached and objective approach to a problem. Often the consultant will be required to facilitate the process of change in an organisation, by setting up a management team to handle the agreed programme. The objective being to provide a cost-effective professional source of expertise and solution(s) to a particular company's problem(s).

The Changing Perspective of AMT in Industry

In discussing how the perception of AMT has involved in industry over the 1980's a senior consultant commented that '...in the early 1980's FMS, Robotics and the CIM concept were all oversold' He considered that many companies had justified such technologies because they '...felt that they ought to be doing it' rather than basing such decisions on well thought out business reasons. The introduction of computer based manufacturing equipment on a large scale had also highlighted the differences in priorities that can exist within a firm between functions such as computing and engineering, where one wants a more "elegant solution" than another and it is 'difficult to get agreement on a overall coherent approach'. Further encouragement to adopt advanced technologies had also come from government through the AMT grants available at that time. A problem with these grants was that they may have sometimes encouraged firms to consider purchasing more sophisticated systems than perhaps they really needed, simply because they did not have to pay the full cost themselves. The result had sometimes been that '...companies had caught a "cold" and were not able to able to cope with the technical side'...'often the implementation time in practice was

twice that originally allowed for'. Another key problem identified at that time was that, '...you could not find people willing to do a *turnkey* system, suppliers tended to offer "packets" of expertise which led to problems allocating project management responsibilities'. He suggested that with the benefit of hindsight, many companies had made '...the best guess at that time, but the scale of the systems involved had got out of control'...'Experience from the rapid growth of the "CIM" industry highlights the potential for moving into a solution that has yet to find the problem'.

While it cannot be said that the problems outlined have been overcome, indeed it was agreed that the technology available is still ahead of the knowledge to manage it, in terms of the current use of AMT it was commented that '...management today is much more pragmatic'. Many firms are seen as having realised that a more gradual step-by-step approach in adopting such technologies is often more appropriate to their needs giving them the opportunity to acquire experience as they progress. Technologies such as CNC were now seen as commonplace in small and medium sized firms, a trend which had been greatly facilitated by the advent of simpler CNC control systems which have greatly reduced the learning curve involved in using them. This enables the operator to be given an outline programme which they could then tailor to produce a specific component, thereby dispensing with the need to have a large centralised programming function in a firm. Another significant technological trend is seen as trying to 'complete a component in one visit to a machine'. A key element in achieving this has been the rapid developments in machining centre technology which enable several different operations to be combined. For some applications machining centres were described as being 'an FMS in its own right' with the great advantage that they do not require complex pallet transporting systems. This fitted in with a perceived pattern in industry where firms having adopted CNC and CAD technologies with some form of computer based production and stock control system, were now progressing to using CNC technology in some form of cell arrangement, ie. two linked machining centres with an automatic load/unload system such as a robot. Such an arrangement would often provide many of the benefits of more advanced "flexible systems" but at a fraction of the cost. Only a relatively few large firms were seen as progressing towards the "CIM" concept. This confirmed similar comments by the project manager of the CM machine tool company.

Adopting technical change has usually required clients to consider wider organisational changes in terms of the management structure, communications and training. The "Japanese influence" was identified as having implications for many firms in relation to the need for high product quality and *just-in-time* type production and delivery. In particular, the large savings that can be obtained through reducing inventory, thereby removing 'dead capital'. However, JIT requires a rethinking of the underlying practices upon which an organisation is run which is often difficult for many clients. Experience of handling this type of change rather than technical change is something which few firms were seen as having. In terms of financial justification, the PE group found that most firms still relied on simple payback measures over 2/3 years often because their market was changing so much it was difficult to plan much further ahead with any conviction. The consultant in this respect was often able to bring a new perspective through a more rigorous DCF calculation linked with risk analysis, and in certain cases apply some form of corporate planning modelling technique.

The Introduction of New Technologies in Client Companies

In outlining the approach a consultant might take in assisting a client company in the adoption of new technology, the author would like to stress that the following discussion is in general terms and should not be taken as stated company policy.

Given the complexity of the contemporary manufacturing environment and the problems that consultants are often faced with in client firms, experience shows that a structured approach is essential in this task. While the eventual outcome of a study will usually be a detailed *Action Plan* unique to a particular company, a key aspect in formulating this is the development of a *Manufacturing strategy* for the company. Figure 8.14 shows a "Manufacturing Strategy Model" which has been tested in client companies and found to provide a useful analytical framework against which to work. The emphasis within the approach can be said to fit in with the "total system view put forward by Parnaby (1984) who states the need when organising for innovation of 'combining manufacturing design skills within a framework of business strategy appreciation'.

Stage 1 - The Business Strategy

The objective at this stage is to gain a deeper understating of the "purpose of the business" by defining the business strategy in terms of the financial requirements, market needs, company philosophy and key attributes so that all subsequent effort can be concentrated more effectively. The financial requirements will seek to clarify how the company measures success or failure, this need not always be in very complex

Manufacturing Strategy Model

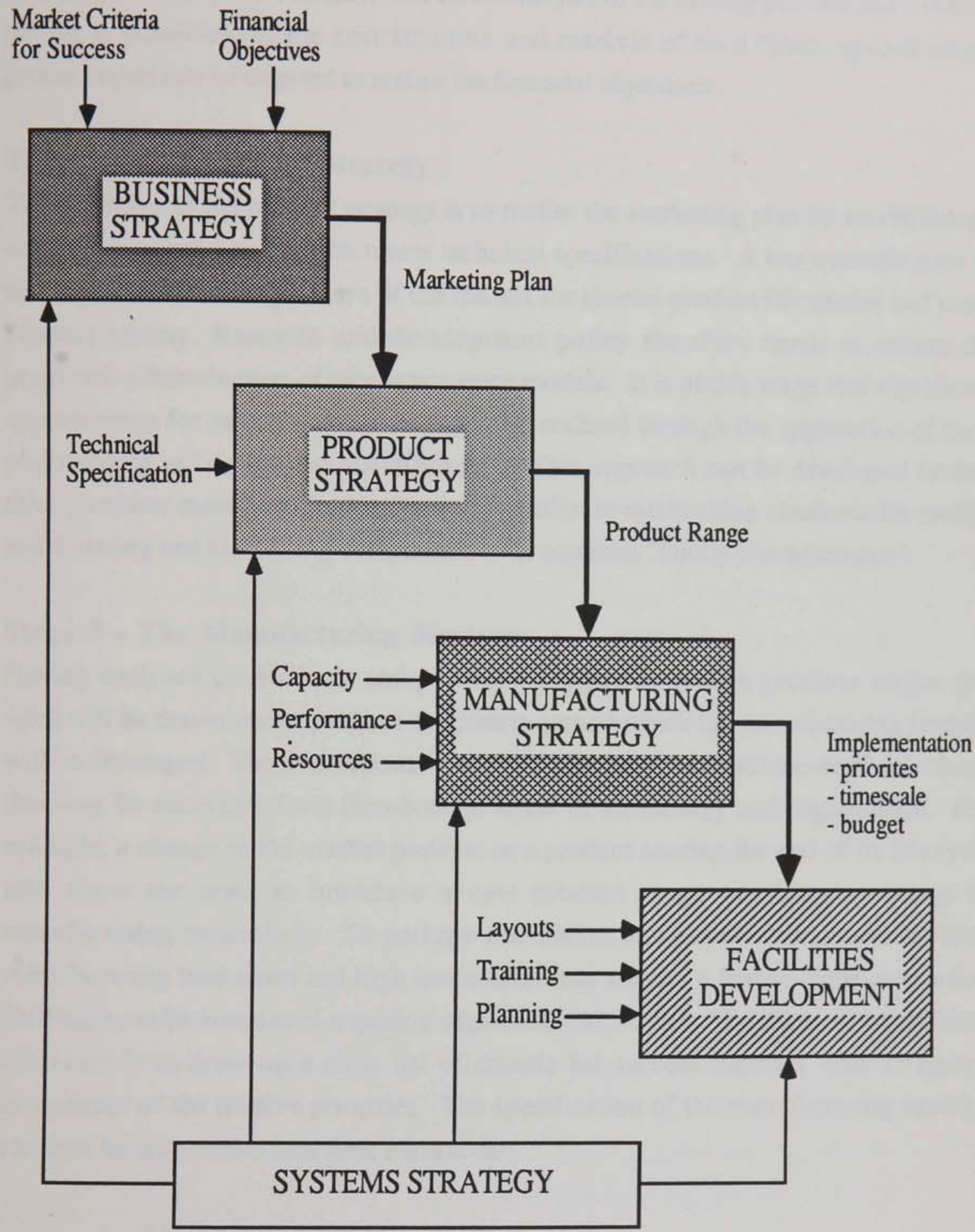

Figure 8.14 - Manufacturing Strategy Model

terms, ie a certain return on capital invested. The marketing plan is the foundation on which many of the subsequent strategic decisions are made. Such a plan would normally be expected to analyse the market segments, define product ranges and estimate volumes and the timescale needed to reach an identified position in the market. Included in the volume forecasts will be an analysis of the pricing policies and a outline (as far is possible) of the cost structure and markets of rival firms, against which product costs can be targeted to realise the financial objectives.

Stage 2 - The Product Strategy

The objective of the product strategy is to realise the marketing plan by establishing a coherent product range which meets technical specifications. A key consideration in this is the competitive pressure of the market for shorter product life cycles and more product variety. Research and development policy therefore needs to ensure the progressive introduction of new innovatory models. It is at this stage that significant opportunities for product cost savings can be realised through the application of such philosophies as "design for manufacture ". This approach can be developed further through closer manufacturing/design collaboration in establishing standards for tooling and fixturing and identifying components with common "family characteristics".

Stage 3 - The Manufacturing Strategy

Having analysed the business and product strategies in the two previous stages, this work will be drawn upon to set out the criteria around which the manufacturing strategy will be developed. The conclusions from the preliminary work set the depth of change that may be necessary for a firm both in terms of technology and organisation. For example, a change in the market position or a product nearing the end of its life cycle may show the need to introduce a new product range requiring a change in manufacturing technology. Or perhaps the market and financial pressures on long manufacturing lead times and high inventories may require a Just-in-Time production philosophy to be introduced requiring organisational change. The eventual objective at this stage is to draw up a clear list of criteria for success together with an agreed assessment of the relative priorities. The specification of the manufacturing strategy can then be rationalised into three main areas:

- Manufacturing Capacity Review

- Manufacturing Performance Audit

- Manufacturing Resource Appraisal

Manufacturing Capacity Review

The aim of the capacity review is to determine the suitability of the existing plant and equipment in achieving the objectives set out in the business, market and product reviews. Usually some form of capital investment will be required and it is at this stage that the consultant's role is pivotal by drawing upon their own experience and those of the client to appraise the technical options available. A consideration in this task is the fact that the life cycle of the manufacturing plant is likely to exceed the life cycle of the products and therefore more than one product generation may have to be produced from the proposed investments. In selecting new plant such as a machine tool, a methodical approach is again employed using the following steps:

(i) Identify "core components" determined by product performance, commercial security and make/buy evaluation. Consider the "family characteristics" of the components features and their potential for completion with minimum handling. The aim is to complete the component from raw material, to finished part, in one visit to a machine or manufacturing cell.

(ii) In order to decide upon the level of flexibility required of the machine to be purchased, its likely utilisation is determined together with a review of the "family characteristics" of 'non-core components' to obtain increased loading needs.

(iii) Typical components are selected from across the range upon which to base the machine tool analysis. The essential features of each machine are listed together with other desirable features. Decisions are then taken regarding other supporting equipment, ie. tooling, fixturing and gauging.

(iv) A supplier enquiry list is drawn up and the response assessed to determine a shortlist. Drawings are sent out for detailed time estimates and tooling/fixturing quotations, these components forming the basis of the machine acceptance and pass-off trials.

(v) Quotations are analysed to select a preferred supplier and negotiate the final package. The capital and revenue expenditure justification document is prepared for executive approval.

The financial justification is another area where the consultant can provide a client with a useful input of new expertise. While the direct benefits of advanced production technologies in terms of increased output and labour savings may be obvious, others such as those resulting from the faster throughput of material giving lower inventories are often less easy to quantify, and may be outside the experience of client firms. In carrying out this task, the consultant may be able to offer a more enlightened approach to financial justification requiring a reappraisal of the clients existing approach to capital investment.

Manufacturing Performance Audit

The basic criteria of the performance audit is to assess the company's current overall performance in terms of cost, quality and delivery and highlight where improvements are needed. The experience of PE is that a methodical high profile cost reduction drive drawing upon the expertise of the clients manufacturing, design and application engineering functions can often bring surprising results. This approach has been found to be particularly useful to a company with a long product life that is nearly exhausted before the replacement is available.

The growing market demands for product quality is leading to the situation where many companies are having to review their philosophy towards quality. The trend is now to change the conventional practice in many firms where the responsibility for quality is regarded as solely resting with the quality control function. Instead to develop a "zero defects" environment where the emphasis is upon everyone being responsible for the quality of their own work. The introduction of new manufacturing technology with its greater accuracy and repeatability and availability of on-line data collection systems provides a unique opportunity for a client to review current quality control procedures.

The delivery performance will be determined by the competitive position in the market. The responsibility of manufacturing is to meet the required lead times and maintain them. To achieve acceptable lead times without resorting to safety stocks requires an analysis of the reliability, risks and exposure not only of the firms capacity, but also those of their suppliers.

Manufacturing Resource Appraisal

Fundamental to the overall success of strategic project development in a company is the human element. In the same way that plant and equipment becomes gradually obsolete, so does the organisation structure and skills of its employees. The resource appraisal sets out the changes in organisation structure required to cope with technological change. This will normally involve training for operators, supervisors and shop floor managers. Traditional demarcations and working practices will often need to be revised affecting industrial relations. Organisational change also inevitably calls for an overhaul of the (often nonexistent) policy of communications and briefing within an organisation. Motivation of the workforce and existing methods of payment and incentives are also issues which feature prominently. Since the programme of change a firm faces will often be long in duration, the sustained support and effort of staff at all levels is a great facilitator in this task.

Stage 4 - Facilities Development

Realising the development of the manufacturing facilities identified for change in the specification of the manufacturing strategy requires a sustained effort in terms of project planning and control. While generating ideas, rationalising options and setting out final specifications for technological and organisational changes are major tasks in themselves, actually implementing the agreed programme of change within a demanding timescale and to a set budget remains a major challenge for most clients. In discussing the approach required in this task a senior consultant commented, 'The management of reorganisation will require a blend of skills depending on the scope of the changes, but the primary requirement will be for a high profile, committed, communicative style that is independent of any vested interest group. For major changes a full-time project coordination will be a prerequisite for success'.

All the proposed changes in the client company will be set out in a detailed *Action Plan*. This will provide a prioritisation of the work to be done in the form of a detailed work analysis with timescales and budget costs. A network plan is included which allocates responsibility for completion of the different aspects of the project, against which and from whom progress can be monitored.

Systems Strategy

An important consideration arising from the identification of the technical and organisational changes that a client may need to make is the realisation of a complementary *systems strategy*. While in previous years, simpler technologies were introduced without much regard for their wider effects on a business, the complexity and inter-relatedness of modern manufacturing methods requires companies to adopt a "systems based approach", which many lack experience of. The need for change in an organisation may involve developing manufacturing systems which range through materials management, shop floor control, operating cost control, as well as the more technical requirements for machine tool monitoring and control as part of CNC, FMS and robotics installations. The technicalities of the systems and their interfacing is a complex task and one in which the consultant will often be expected to provide the required specialist knowledge which will be needed at an early stage in the development of the manufacturing strategy.

Comment

Several of the experiences of the PE-Group were confirmed by the companies with which the author has collaborated. In particular the advantages that a methodical structured approach can provide in evaluating technical and organisational change. While the role of consultants is not without its difficulties at times, as both PE and the case study firms admitted, their use as source of outside expertise can be beneficial in providing a different perspective on a business problem, and all the case study companies, had used outside sources of expertise at one time or another. While only a few years ago, the very idea of a firm needing to have a *systems strategy* could be said to apply to only a relatively few, mainly large firms, the growing complexity and interrelated nature of modern technologies and markets means that smaller firms will increasingly need to consider thinking about the implications of "systems" within their own organisations.

8.5 Yorkshire Valve Company Limited

'The managment were reluntant to break from their piecemeal approach to investment'...PE Consultant

This section discusses a long established valve manufacturing company which, faced with outdated machinery and a diminishing market share, brought in PE-Consulting Services to review the existing business strategy and develop a new one. The conclusions reached focussed upon a programme of factory rationalisation and the introduction of CNC technology. However, the firm's management decided not to pursue these recommendations and to continue with existing procedures. The firm is now in the hands of the receiver. Based upon discussion with PE consultants and company documents the author tries to show the interrelated nature of the changes required when introducing new technology and the advantages of the structured analytical framework discussed in 8.4.

Yorkshire Valve Company Background

The Yorkshire Valve company, established over 100 years ago, was for many years a major UK supplier of water and control valves, having built up a good reputation for quality based on traditional engineering techniques and innovation in valve design. Indeed, 50 years ago it had developed the "Meehanite" process in its foundry which is used to increase the consistency and strength of cast iron. However, the traditional techniques of manufacture and engineering which had held it in good stead throughout its long history were increasingly found wanting as the years went by. Despite periodic efforts on the part of its management to update the manufacturing facilities, it was gradually slipping behind its rivals and losing its share of the UK market. This was made worst by the fact that its management had neglected to cultivate any really sizable export sales. Hit badly by the effects of the recession in 1983/84 the company had struggled from a loss making position to being just in profit in 1986 mainly on the basis of cost cutting. Sales were static at £12M and it was still losing its share of the market to competitors. Faced with these problems, the management decided to bring in outside expertise to review existing procedures and develop a new business plan. The manufacturing consultancy division of PE-Inbucon was approached for this task. Using the analytical framework and structured approach described in 8.2 and the manufacturing strategy model shown in figure 8.3 as a basis upon which to work, PE were able to prepare a detailed business plan which would involve a fundamental rationalisation of the business and the introduction of modern manufacturing techniques.

Business Strategy

The first task facing PE was to conduct a thorough review of the existing business and to set the corporate and financial objectives to develop a new business plan. The company at that time was split on two locations with one site producing steel valves and the other cast iron valves with a foundry on the same site. A sister company producing control valves was also to be involved in the rationalisation process.

The proposed overall business strategy focussed on two main elements:

- the rationalisation of the business to achieve a streamlined product range and reduce company overheads

- the creation of a competitive price and delivery performance by the modernisation of manufacturing methods through investment in CNC machine tools, to reduce lead times and inventories, thereby obtaining further reductions in operating overheads.

The financial objectives for the new rationalised business were, to achieve and maintain an overall profit performance in excess of 10 per cent return on sales and a return on average capital employed of at least 20 per cent. The plan called for the reorganisation of the business into three manufacturing divisions located on two sites:

(1) Steel products Division - The production of all steel products and valve products above 1000mm bore size would be located on the present site of the sister company,thus enabling the other existing site of the business to be disposed of. The company headquarters and controlling administration, together with design, sales and finance would also be located on this site.

(2) Cast Iron Products Division - This would continue on the existing site and concentrate on producing cast iron products below 1000mm bore size.

(3) Foundry Division - This would remain in its present location alongside the cast iron products division, but would also seek to expand its sales to outside customers.

To ascertain better the characteristics of the valve market and the scope for innovation PE intended to conduct an in-depth market survey. However, the company was unwilling to accept the costs of such a survey and decided to carry out its own review of the size of the market and where potential lay for innovation. With the benefit of hindsight, this was a mistake but PE had no choice but to accept their figures and base their plan on these. The figures suggested that significant market opportunities existed to provide for a sales growth of over 30 per cent, to give a turnover equivalent to about £20 million by 1992. The market for valves was divided into small valves below 1000mm bore size, medium/large valves above 1000mm bore size and control valves.

Small Valves - The company's share of the home market was based on budgeted sales in 1987 of £2.5m, this was estimated at 26 per cent of a then static home market total of £9.5m pa, mainly supplying regional water authorities. The company had two main rivals in this market which had become very price sensitive. The main business opportunities were assessed as occurring when the contract tenders were required to be submitted to the regional water authorities. PE believed that it was essential having restructured the company for them to pursue an aggressive marketing policy to try and increase their market share. Given that the market was static at the time the only way to do this was by reducing prices, even though this meant accepting reduced margins. If significant gains in market share were attempted (ie. in excess of 40 per cent of the total) it was expected that the two main rival firms would respond with a similar price reduction campaign. The intention was that the company as a result of reorganising and investing in new technology, would be in a much better position to manufacture at lower cost. Opportunities for further market development were seen as lying in other industrial sectors, although since this market is mainly supplied through distributors it was thought that this would take some time to establish. In terms of export sales, although these were small at a budgeted annual sales figure in 1987 of £1m, they made up 30 per cent of total company sales in this category and so only a modest increase in their market share would make a significant impact on annual turnover. The main problem was that most viable export markets already had a local manufacturer. Scope for innovation was seen in the development of skills to develop valves in alloys and more sophisticated materials for applications in the petro-chemical and process industries.

Medium/Large Valves - The share of the home market with budgeted sales in 1987 of £2m was estimated at 20 per cent of a total home market of £10m pa. As with the small valves, it was intended that the company would try and use its improved competitiveness to increase its market share by cutting prices. The refurbishment market in the UK power generation industry for large butterfly and gate valves was seen as having a potential of £1m pa and a 10 percent penetration was seen as realistic target. Again product innovation for this market was seen as needing the acquisition of skills in advanced materials, to develop coating and lining protection for large valves, together with valves made from structural composites. Export sales were small with budgeted annual sales in 1987 of £1.5m and the competitiveness of the market meant that there was limited potential for growth.

Control Valves - The home market share with budgeted sales in 1987 of £1.4m was estimated at 7 percent of a £20m home market. Historically, the company had a much larger share of the market particularly for power generation applications. This had been lost through poor delivery performance and a product development programme that had not kept pace with the competition. The opportunities in this market were seen as considerable, but the competition was very strong. The main priority was seen as rebuilding customer confidence by ensuring that prompt delivery dates were maintained and reduced manufacturing lead times. In the longer term, product development was the only way to regain the initiative from competitors. Export sales were small with budgeted sales of £0.4m in 1987, but with a total market in excess of £60m the potential for growth existed if delivery and product development could be improved.

Product Strategy

In following the analytical framework in figure 8.10 attention was next focussed on developing a product strategy that would realise the objectives outlined in the business strategy. In previous years, the company had enjoyed a good reputation for its engineering and innovative capabilities. However, when PE began work they found that the management had allowed the product range to "stagnate" and in a review of company policies it was commented:

> 'In recent years the business has suffered from a deteriorating delivery performance which has sapped customer confidence and a lack of innovation which has lost the company its market edge'.

In the past both companies had been very strong technically and the product development had therefore originated from technical rather than market leadership. This had resulted in a mismatch between the valve designs then produced and what was actually needed to satisfy market demands. Lack of integration within the business had also led to some overlapping of product ranges. In terms of innovation, the problem faced by the company was that while its products were traditional mature engineering designs (with the exception of control valves) whose operating principles have not changed, a wide ranging "web" of new standards and specifications from customers and regulatory bodies had enmeshed the design criteria. This was inevitably perceived as a severe restraint on product development, with the consequential abandonment of any determined approach to achieving a technical breakthrough that would be exciting to its customers. PE saw that the impetus for research and development as needing to be rekindled, by creating an organisational structure that facilitated innovation and encouraged collaboration with key customers and the regulatory bodies. Based upon the review of market opportunities the formulation of a clear product strategy required the addressing of two key issues:

(1) The rationalisation of the current product ranges of both companies into one integrated range.

(2) The identification and specification of priorities for future product development.

This required renewed attention being focussed on the marketing function of the business which had previously been neglected. To achieve this, it was proposed that a small product development team be set up bringing together personnel in the Marketing, Technical and Manufacturing functions to look at the issues of cost control, design for manufacture, technical specification and product performance. The appointment of a Marketing manager to spearhead the identification of the potential growth areas was seen as of crucial importance. Another important change involved exploring the possibilities for "design for manufacture". The considerable scope that then existed for cost reduction was well recognised at all levels of management and supervision and a number of ideas had already been put forward. The problem at the time was, that there was nobody with the responsibility for bringing together these ideas in a defined and structured manner so that they could be refined down to the most cost effective proposals and to establish priorities from both a cost reduction and a market point of view. It was the therefore proposed that a "cost-reduction coordinator" be appointed who possessed a knowledge of the products from both a technical and manufacturing standpoint, and who should conduct a high profile cost reduction campaign throughout the company over a two year period. While these proposals may not seem very profound, trying to develop a more collaborative approach between its departments represented a substantial change from previous procedures, but which was essential if the full benefits of modern methods of manufacture were to be obtained.

Manufacturing Strategy and Specification of Facilities

Having set out the business and product strategies, attention now focussed on the manufacturing strategy and the facilities required. In a review of current manufacturing methods, a senior PE Consultant stated:

> 'The lack of investment in the past is obvious, and this puts the company at a serious disadvantage in respect of both cost and quality. The dramatic advances in the last decade in computer technology as related to machine tools and processes have largely been ignored. Manufacturing methods are still based on old fashioned Production Engineering skills, together with a traditional, skilled/semi-skilled, Setter/Operator, approach to shop-floor operations. Multi-machine routing with a single operation per machine creates major progressing and work prioritisation problems, with attempts to highlight and eliminate bottlenecks only marginally successful.

Commenting further on quality control and maintenance procedures:

> 'The low profile of quality control in the machine shops, in which the capability of the machine process is highly questionable and has not been checked or monitored for years, inevitably leads to an excess requirement for 'fitting' at the assembly stage. The burden of queries and concession requests to the technical department contributes to the lack of achievement in more productive cost reduction activities. The fire-fighting approach to maintenance over the past years has produced a situation of some machines in working order, others in partial commission and the majority highly suspect on capability and reliability'.

A new manufacturing strategy was therefore proposed based on the introduction of modern CNC technology. In order to do this, a thorough analysis of current manufacturing methods was carried out, before developing a future workload based on the sales forecast. Table 8.5 shows such an analysis of one of the company sites highlighting the fact that the average age of the machines then used by the company was over 25 years.

In selecting future machining methods the objectives of the manufacturing strategy were:

(i) Reduced unit cost at low output
(ii) Shortened lead times
(iii) Flexibility to accept change in design and product mix
(iv) Improved stockturn through minimum stock and WIP
(v) Maximum utilisation of capacity

The principles by which these objectives were to be realised included:

(1) Exploiting to the full, the flexibility in the range of operations a CNC could perform
(2) The completion of a component from raw material to finished part in one visit to a machine
(3) The operation of the machines on a multi-shift basis
(4) Reduced direct and indirect manual involvement in operation, loading, setting, inspection and maintenance
(5) Minimising the materials handling requirement by optimising the flow path of manufacture
(6) Improved monitoring of the capability of the process, to reduce the dependence on traditional inspection methods
(7) The creation and regular updating of a company manufacturing plan which establishes through the company computer system, the priorities for each stage of the manufacturing activity

The structured approach (discussed in 8.4) was used to determine which machine features were essential to meet the specification of a new machine tool and which were desirable, but dependent on enhanced cost justification. This involved assembling a portfolio of the full range of components to be machined and from these selecting typical components on which to base machine tool analysis and determine specifications. Having done this suppliers were then approached for quotations.

The future workload analysis for conventional machines, as shown in tables 8.6 and 8.7 was used to estimate the available load for transfer to CNC machines. A CNC improvement factor was applied to estimate a potential CNC with an assessment of the type of machine (lathe or machining centre). This showed the considerable improvement that could be expected as a result of CNC technology.

In terms of the capital expenditure involved, detailed quotations were obtained and analysed and a capital expenditure justification prepared as follows:

3 off Yamazaki Slant Turn 25/30 ATC Mill Centres	£ 350,000
2 off Niigata HN50B Horizontal Machining Centres	£ 510,000
2 off Frenco Presetters	£ 20,000
1 0ff Applicon 'CAM" Program Package	£ 20,000
Tooling and Fixturing	£ 174,000
Installation	£ 30,000
Total	**£1,104,000**

In terms of savings relating to machine shop operations obtained from the investment, these were estimated at:

Manpower saving - 36 weekly paid	£ 300,600 pa
- 3 works staff	£ 27,600 pa
Inventory saving - (working capital £900,000)	
- carrying costs	£ 135,000 pa
Operating cost saving - energy	£ 27,800 pa
Total annual savings	**£ 491,000**

This gave a capital recovery of 26.9 months (ROR of 44.6 per cent) and a once off saving in working capital of £900,000 as the inventory was gradually reduced.

Table 8.5
Yorkshire Valve Company, Cast Iron Products Division, Machine Tool Analysis Summary

Machine Type	Work Load on Standard Hours per Week		Number of Machines			Condition Comment	Average Age
	General Valves	Control Valves	Current	Retain	Dispose		
Lathes:							
- Chuck	51.7	0.0	4.0	3.0	1.0	Worn	33
- Capstan	80.9	55.4	10.0	4.0	6.0	Worn	24
- Turret	77.4	123.4	20.0	8.0	12.0	Worn	22
- Screw	58.3	0.7	3.0	2.0	1.0	Worn	22
- Auto	39.9	25.8	4.0	2.0	2.0	Serviceable	21
- Centre	15.0	31.6	9.0	2.0	7.0	Serviceable	N/A
Borers:							
- Vertical	137.5	121.9	12.0	4.0	8.0	Worn	31
- Horizontal	59.3	79.9	8.0	4.0	4.0	Worn	26
Drills:							
- Radial	64.1	75.2	10.0	3.0	7.0	Worn	33
- Vert/Mult	77.1	0.0	6.0	1.0	5.0	worn	19
Mills:							
- Vert/Horiz	47.3	29.5	7.0	4.0	3.0	Worn	25
CNC/NC	158.6	101.4	5.0	4.0	1.0	Requires Reconditioning	10
Special Purpose	229.0	0.0	12.0	9.0	3.0	Seviceable	N/A
Miscellaneous	245.3	23.4	15.0	12.0	3.0	Serviceable	N/A
Total	1341.4	668.2	125.0	62.0	63.0		25

Table 8.6
Cast Iron Products Division, Load Transfer From Conventional To CNC Machines

Machine Type	Conventional Machines				CNC Improvement Factor	CNC Machines			
	Available Load		Transfer Load			Transfer Load			
						Lathe		Machining Centre	
	General Valves	Control Valves	General Valves	Control Valves		General Valves	Control Valves	General Valves	Control Valves
Chuck Lathe	51.7	0.0	37.3	0.0	50%	0.0	0.0	18.6	0.0
Centre Lathe	15.0	31.6	15.0	31.6	60%	0.0	0.0	6.0	12.6
Turret Lathe	77.4	123.4	73.1	90.7	50%	36.5	45.4	0.0	0.0
Auto Lathe	39.9	25.8	39.9	25.8	0%	39.9	25.8	0.0	0.0
Screw Lathe	58.3	0.7	55.7	0.7	70%	16.7	0.0	0.0	0.0
Capstan Lathe	80.9	55.4	74.9	46.1	50%	37.5	23.0	0.0	0.0
Horiz.Boring	59.3	79.9	23.7	38.2	50%	0.0	0.0	11.9	19.1
Vertical Boring	137.5	121.9	40.8	47.7	50%	0.0	0.0	20.4	23.9
Radial Drilling	64.1	75.2	16.0	23.2	50%	1.6	2.9	2.4	2.9
Milling	47.3	29.5	47.3	29.5	75%	0.0	0.0	47.3	29.5
Drilling	35.9	0.0	35.9	0.0	0%	14.4	0.0	21.5	0.0
Total	667.3	543.4	459.6	333.5		146.6	97.1	128.1	88.0

Table 8.7
Load Transfer from Conventional to CNC Machines, Steel Products Divsion

Machine Type	Conventional Machines		CNC Machines	
	Available Load	Transfer Load	CNC Improvement Factor	Transfer Load Lathe
Turret Lathe	276.8	215.2	50%	107.6
Centre Lathe	116.0	92.8	60%	37.1
Milling	39.0	10.0	0%	10.0
Drilling	100.0	25.0	0%	25.0
Total	531.8	343.0		179.7

Development of Assembly and Test Methods

While new machine tools may cut metal at a faster rate, the full benefits of their use will not be obtained if the surrounding factory is not organised towards their use. Thus PE undertook an analysis of the layout of the factories, the flow of work within them, the assembly methods, quality control procedure and storage facilities.

The method of assembly then employed had been conditioned by the practicalities of weight, size and complexity of the product range, with the small valve range using an effective flow line approach, building up a valve in different stages. It was suggested that this idea could be extended to medium and large valves to develop specific stages and improve the flow of work, by providing the operators with a production engineering work station. The principles for the work station would be developed around the introduction of a height adjustable rotating table and powered tools. Testing was another area which the company had tended to neglect, with the result that the technical department was continually dealing with customer problems. If customer confidence was to be rebuilt, then along with improving the manufacturing and delivery performance, the problems of quality control had to be overcome by the development of improved test procedures which were able to ensure a consistent high quality product. This was especially so in the case of control valves whose operating specifications are very high. The specification and development of test procedures was seen as requiring the joint input of the technical engineering and production engineering departments. Eventually such test procedures would also provide a data bank of information for research and development purposes.

Reorganisation Planning and Common Systems Development

In rationalising the two existing businesses, the setting up an effective organisational structure to manage the changes taking place was a prime consideration. The suggested "planning structure" is shown in figure 8.11. It was recommended that each aspect of the business, sales, engineering, etc would take responsibility for implementing the part of the reorganisation plan which related to them, by assigning staff to carry it out with no other operational responsibilities. The key appointment was to be the planning coordinator, who would provide a focus for planning, co-ordination and problem solving. One of the first tasks identified for tackling this problem was the drawing up of a network list to ensure that all necessary tasks were planned in the correct sequence.

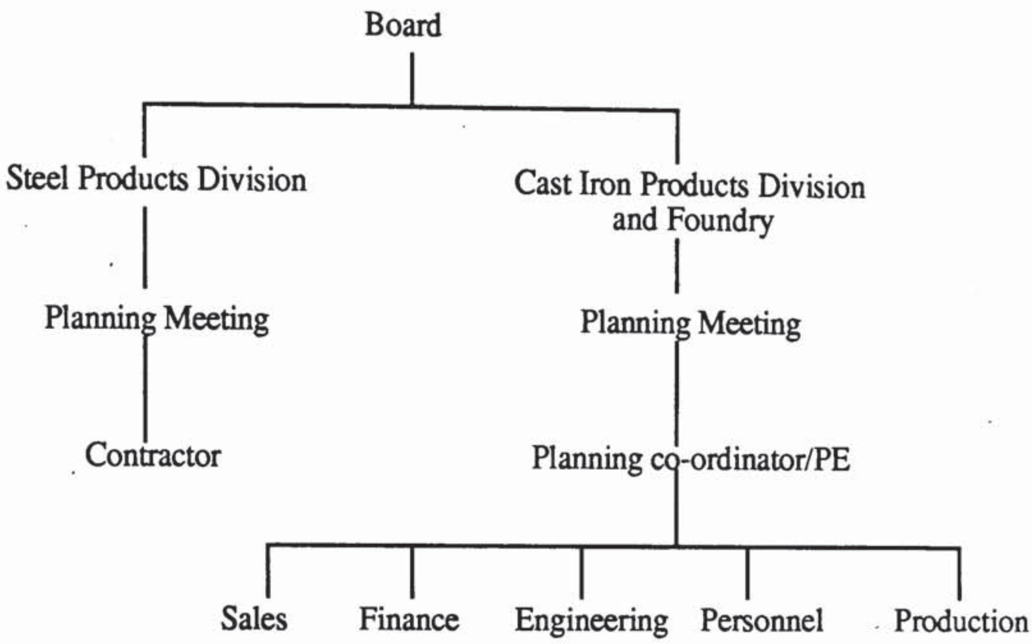

Figure 8.15 Reorganisation Planning Structure

The issues identified included:

Sales	-	public relations
	-	new company style
	-	information to customers, new contract details
Finance	-	computer installation and links between product divisions
	-	telecommunications
	-	wage payment system
Engineering	-	drawing reproduction and availability at both sites
	-	standards and procedures
	-	bill of material structure
	-	classification and coding
Production	-	machine tool installation and refurbishment
	-	new layout of factory
	-	site clearance
	-	changes in manning levels
	-	production engineering and production control support
Personnel	-	harmonisation of conditions/employment hours
	-	relocation of selected employees
	-	new contracts of employment

A key emphasis of the approach taken by PE is to make its client companies aware of the need for an underlying *systems strategy*. In working with small/medium sized companies to introduce new technologies, PE tend to find that few such firms have considered their need for developing common systems, (in may many cases firms were not actually aware that they had a problem). This is largely a result of the fact that previous manual technology operated on a largely "standalone" basis and could be implemented more easily without consideration of its wider effects. With the interrelated nature of modern manufacturing technology, there is a need to adopt a *systems* based thinking approach, a vital part of which is concerned with the interfacing of different systems within a business. In concluding a report on existing company systems, a PE consultant stated:

> 'We would again emphasise the scale and extent of the work needed to bring the company's plans to create a low cost, high efficiency, and profitable manufacturing organisation. During our work over the last six months, many of the systems fundamental to the successful operation of any manufacturing company have found to be wanting'.

A major feature of the proposed new business organisation was a study by PE with grant support from DTI's advanced manufacturing technology scheme to define its manufacturing control requirements. This work was aimed at establishing an effective computer aided production management system covering both sites. At that time the steel products division operated a manual system and the iron products division had a computerised one (this was ineffective due to incomplete and poor implementation). The study was also intended to provide an outline plan for further developments, covering a new computerised job time estimating system, shop floor data collection and the eventual introduction of CAD into the engineering function with links to manufacturing. However, the need for a "systems strategy" was not confined just to manufacturing. Common systems were also identified as needing to be developed in areas including accounting, sales order processing, purchasing, payment systems, management information and reporting and in quality assurance.

The need to achieve better integration was also reflected in the proposed organisational structure. While previously the business had been split on three sites with considerable integration problems, the company would now have three distinct manufacturing divisions based on two sites, with a centralised controlling administration based on the steel product division site, along with the sales, engineering and finance functions. A major advantage of this was that the firm would have a single marketing function for all three manufacturing divisions selling a coherent product range. Also closer contact between the engineering and marketing functions would help to ensure, that future research and development work was more "market led" rather than technically led, as had tended to be the case in the past.

Reorganisation Budget

Steel Products Division Site	- Refurbish building and machine move	£500,000
Iron Products & Foundry Divisions Site	- Refurbish building	£250,000
	- Site development	£ 70,000
	- Plant relocation	£ 80,000
	- Stores relocation	£ 74,000
	- Paint Booth reorganisation	£ 21,000
Total Reorganisation Budget		£995,000

Operating Cost Savings (Before Investment in CNC Machine Tools)

Iron Products & Foundry Divisions Site - Estimated savings

(1) Rates	£ 60,000
(2) Energy (heating, boilers)	£ 57,000
(3) Maintenance	£ 30,000
(4) Employee costs - hourly paid	£493,000
- staff	£ 83,000
Total estimated savings	£723,000 pa.

Notes: (1) Rates apportioned on basis of area; 1987 budget = £175,000: area saving = 35%, so saving = £ 60,000

(2) Energy costs, apportioned 15% foundry, 85% 'others'; 1987 budget = £192,000: Therefore 85% 'others' with 35% area saving = 30% saving, gives energy saving of £57,000 pa.

(3) Maintenance costs apportioned 75% foundry, 25% 'others' 1987 budget = £300,000: Therefore 25% 'others' with 40% saving = 10% saving, gives maintenance saving = £30,000 pa.

(4) Employee Costs:	Current number	- hourly paid	339
		- staff	184
	Proposed number	- hourly paid	280
		- staff	175
Calculated payroll costs of employees:		hourly paid	£8,350 pa.
		staff	£9,100 pa.

Therefore hourly paid saving: 59 x £8,350 = £492,650 pa.
staff saving: 9 x £9,200 = £ 82,800 pa.

Steel Products Division: modifications to existing buildings and site would add £26,000 to rates cost and £130,000 to energy costs, giving additional total costs of £156,000 pa.

Combined operating cost savings (excluding benefits obtained from investment in CNC)

Iron Products & Foundry Divisions site savings -	£723,000 pa.
Steel Products Division site additional costs -	£156,000 pa.
Net operating cost savings :-	£567,000 pa.

Financial Justification: Budgeted reorganisation costs = £995,000 pa.
Estimated operating cost savings = £567,000 pa.

Therefore payback = 1.75 years

Financial Analysis

Based on the savings from the introduction of CNC technology and reorganisation of the company, a trading forecast was prepared for the first year of trading.

Estimated Operating Statement	Total year ending Jan 89 (£,000)
Sales	15,000
Materials	(5,035)
Foundry supplies	(538)
Direct Labour	(1,420)
Gross Profit	8,007
Percent gross profit	53.4%
Works overheads	1,921
Wages and salaries	296
National insurance	65
Contract expenses	78
Patterns	575
Energy	135
Tools	90
Consumable stores	100
Repairs & renewals	100
Product development	50
Depreciation	325
Others	90
Admin/Selling overheads	531
Salaries inc NI	120
Pensions	165
Rates	80
Insurance	80
Telephones, telex, postage	60
Stationary	140
Data processing	110
Travelling, entertaining	175
Management charge	100
Advertising, publicity	75
Despatch, carriage	320
Agents' commission	70
Others	40

Total Overheads	5,901
Trading Profit (Loss)	2,106
Bank Interest	(240)
Non Trading Items	60
Profit (Loss) Before Tax	1,926

Trading Forecast Year Ending January 1989
(after investment in CNC machine tools)

	Steel Products Division (£,000)	Iron Products Division (£,000)	Foundry Division (£,000)	Combined (£,000)	Percent (%)
Sales	7,500	5,500	2,000	15,000	100
Direct Cost of Sales	3,408	2,889	796	6,993	47
Gross Profit	4,092	2,611	1,204	8,007	53
Total Overhead	-	-	-	5,901	39
Trading Profit	-	-	-	2,106	14
Non Trading Items	-	-	-	60	-
Bank Interest	-	-	-	(240)	-
Profit Before Tax	-	-	-	1,926	13

Financial Statistics:

Profit before tax as a percentage of sales	13%
Capital employed	£7,000,000
Profit before tax as a percentage of capital employed	27%
Profit before tax per employee	£4,233
Sales per employee	£32,967
Stock	£3,000,000
Sales as multiple of stock	5.0

Discussion

Although the review of the present state of the company and the recommendations by PE consultants on how the company might overcome its problems were fully accepted by management, they were never implemented. In January 1989 the managing director announced the closure of the firm with the loss of 430 jobs. Commenting on this in a local newspaper he stated that the company had '....been losing money for five years in spite of cost cutting and new sales initiatives' and blamed its closure on '....overcapacity among water industry suppliers'. Asked if the firm could be saved it was said '....talks had been had with half a dozen interested parties about the site, but it was of considerable size and the plant was *archaic'*.

In many respects the Yorkshire Valve company well fits the pattern of gradual industrial decline in several small/medium sized firms encountered by the author during the course of the research. These were often old,well established firms, many of whom had built up good reputations based on mature, well tried and tested products, using traditional engineering and manufacturing techniques with their sales primarily coming from the domestic market. The problem for many such companies is that they have been too slow to change and have allowed competitors (often overseas) to pass them by. Realising usually too late that they needed to change, the task facing them is now that much greater, since in contrast to previous technological change, where it was a case of "plugging" in a new machine, the interrelated nature of modern technologies and its wider business implications, are difficult for them to grasp.

Asked why the firm had the not carried out the plan, the senior consultant responsible felt the its senior management were somewhat reluctant to face up to the considerable efforts required to reorganise the business and break the pattern of "piecemeal" change that had persisted in the company until that time. One of the key information requirements upon which PE base any business reorganisation is a detailed market survey to identify areas for future sales growth and product development. PE had intended to carry out such a survey themselves to ensure objectivity, but the company management insisted in conducting its own survey so PE had no alternative but to rely on the figures provided to them. With the benefit of hindsight, these figures were thought by the senior PE consultant working on the project to be "optimistic" and may have given the management the mistaken impression that they did not after all need such extensive reorganisation, but that by introducing some new machines themselves they could obtain most of the benefits of the plan, but at a much smaller cost. In many respects this links back to one of the original problems of the business, that the management were unable to appreciate that in order to obtain the benefits of new manufacturing methods, it is not simply a case of "putting in few new machines and turning on a switch" as they had done previously. But that it was necessary to look at the investment in new machines in relation to the *total* business and the other systems operating within it.

While it can obviously be said that since the plan by PE was never implemented. it will never be known if it was right, the main point arising from discussion of the Yorkshire valve company plan is that it well illustrates the interrelated nature of modern production technologies, the need to use a structured analytical approach to understand the relationships involved, and the extent of the consquential changes needed. Figure 8.12 shows a summary of the development of the manufacturing strategy of the company.

The planned adoption of CNC technology in this company falls well within what can be termed as manufacturing innovation. But even at this level of innovation, in order to use the technology effectively, considerable change was required in the wider organisational structure and the development of complementary common systems. For example, rationalising the product range and making product development more "market led" required collaboration between the sales, technical, manufacturing and finance functions in a way that had not occurred previously. Such concepts as "design for ease of manufacture and assembly" if properly used, can have as great an impact as new production equipment. While this may all sound obvious, the experience of the Yorkshire valve and others, show that the tendency is still to divide and apportion responsibility within a business in discrete "little packages" without ensuring adequate communication between functions. Interrelated technology requires that companies adopt organisational structures that are equally able to interrelate, even in small/medium sized firms.

Development of Manufacturing Strategy

Information Inputs

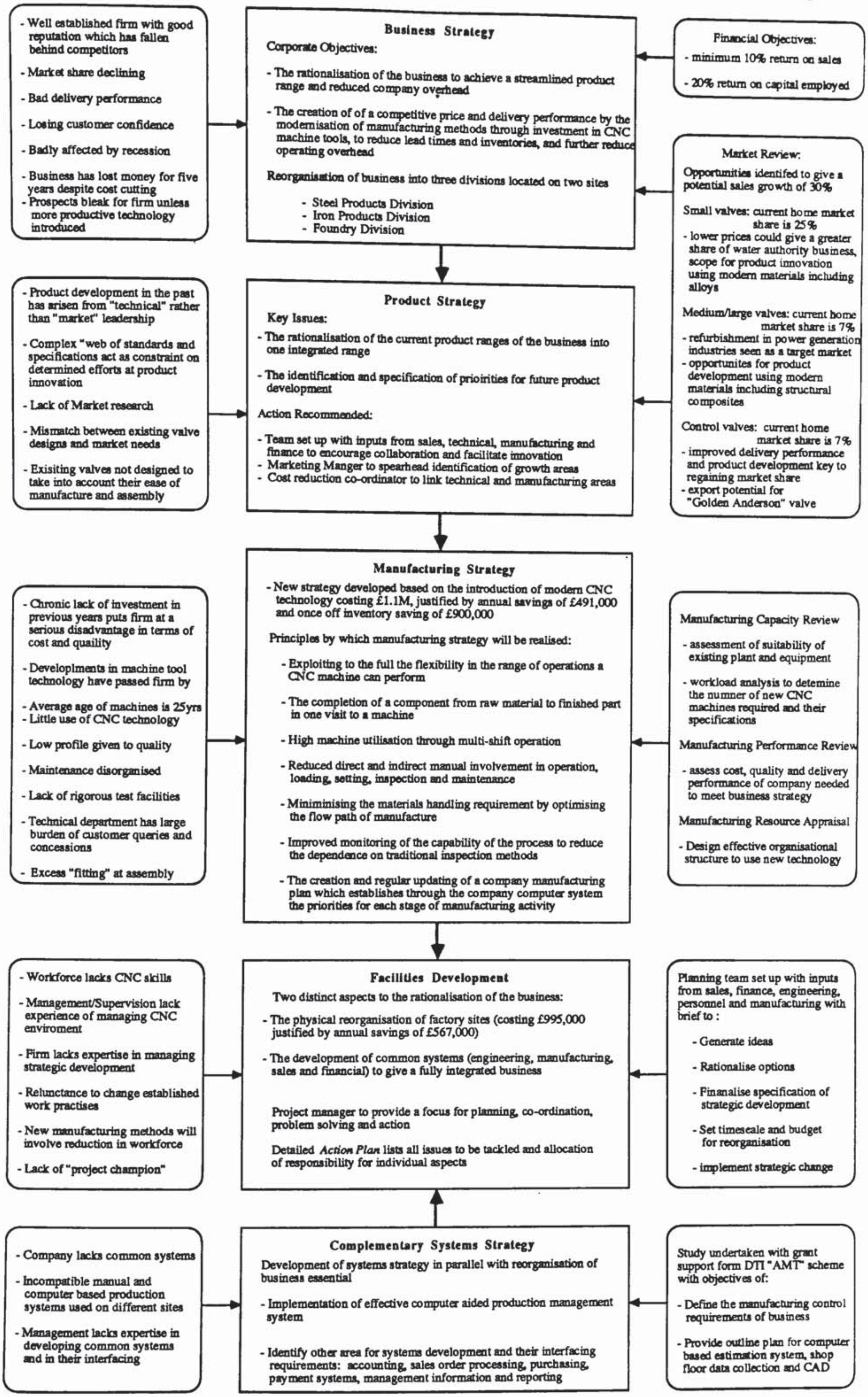

Figure 8.16 Development of Manufacturing Strategy of Yorkshire Valve Company

Chapter 8 References

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Chapter Nine

Discussion and Conclusions

...Rule XI
If, after gaining intuitive knowledge of several simple propositions, we are to draw some further inference from them, it is useful for us to run through them in a continuous and uninterrupted movement of thought, to reflect on their interrelations and to form, so far as we can, distinct conceptions of several at once. For this adds much to the certainty of our knowledge, and it greatly increases the scope of our mind'.

Descartes (1596-1650)

Preamble

This chapter brings together the main conclusions reached and reviews the methodology used. The research identifies the wider effects of modern manufacturing technology in the case study companies and relates this to the integrated nature of the technology. The approach taken by the managers in implementing new technology is discussed together with the problems associated with its economic evaluation. The discussion goes on further to assess the insights gained from the individual case study companies. The conclusion summarises the research findings, and the advantages and limitations of a modelling approach with guidelines for good modelling practice.

9.0 Introduction and Restatement of Research Propositions

While in the 1970's many of what are today referred to as *advanced manufacturing technologies* were available in some form, their prohibitive cost effectively confined their use to larger manufacturing firms. However, during the 1980's the decline in relative cost terms of computing power made possible by developments in microprocessor technology, enabled such technologies to come within the expenditure range of small and medium sized enterprises, thereby enabling their diffusion on a wider scale. The starting point of the research was the observation by BL Technology that, in several of the smaller client firms with whom they had worked to implement AMT, the expected benefits of the technology in operation had not been fully realised in terms of improving overall business performance. Several accounts in the literature also report instances where the results of new manufacturing technologies have been disappointing, (eg.Currie,1989a; Boddy & Buchanan,1987; Ingersoll Engineers, 1986, New & Myers, 1986). While many of the problems facing smaller firms will be similar to those of larger ones, since the size of the investment relative to the size of the firm will often be large and the financial and technical resources more limited, it can be expected that the problems and ways in which smaller firms adopt new technology will display certain unique characteristics which merit further investigation.

In searching for a description of the type of innovation taking place in the companies discussed in the research, the concept of *manufacturing innovation* described by Bessant (1982) and Braun (1985) was found to be a useful one. This refers to changes in the method of manufacture of goods which although radical does not change either the product or the basic process.

The original propositions of the thesis given in the introduction were:

- *That advanced manufacturing technologies have frequently not fulfilled their original expectations in improving overall corporate performance*

- *That the main reason for such unfulfillment has been the integrated nature and effects of AMT on those aspects of the business not immediately associated with the innovation.*

The research explored these propositions using a case study approach involving several small/medium sized businesses, complimented by the insights of a major manufacturer of machine tools and a large management consultancy firm. Given the complex nature of manufacturing innovation and the production environment, no one single method of investigation was thought to be suitable on its own and so a combination of methods were used. These included:

- Models developed using microcomputer based spreadsheets
- Interviews with managers in case study companies
- Documentary sources
- Projective interviews and diagrams
- Observation

A key aspect of the methodology was the development of a series of spreadsheet models. Whereas the use of company models has tended even in the quite recent past to be restricted to large firms as a result of the high cost of computing, the availability of relatively cheap micro computers places in the hands of the management of the smaller business a powerful analytical tool. The spreadsheets proved to be an effective means of assisting in quantifying in economic terms the effect of new technology upon overall business performance. Gold (1983) discusses how the integrated nature of AMT can make it difficult to quantify the benefits using localised discrete cashflow calculations which look at a particular project in isolation from the rest of the enterprise, and that methods need to be devised which look at the potential advantages of AMT in terms of the performance of the whole enterprise. Since the basic motivation behind the acquisition of new technology is either directly or indirectly to enhance profitability, which is reflected in the operating budget and cashflow of a business, the development of a series of spreadsheet models was found to be a relatively straightforward method of measuring the overall effects resulting from the introduction of new technology. The essential feature of the models is the capability to vary key financial parameters to test their relative effects upon profitability. The information obtained in the three case study companies permitted the simulation of the profitability of the companies under a series of scenarios. The worth of the spreadsheet software developed is shown by the fact that all three modelled companies have requested copies (together with the management consultancy firm PE-Inbucon), and two have already purchased the *Excel* spreadsheet package upon which to run it.

Of perhaps equal value to the actual results obtained, was that the very act of obtaining the data to develop the models forced managers to go through a systematic process for explaining an investment decision. The managers were made to quantify economically the expected benefits of new investment, but were also made to try and quantify the effects upon other aspects of the business not apparently related directly to the initial investment. In particular, how the overhead costs of a firm can change as it progresses in terms of automation, which is often the "hidden cost of technical change. This was found to be in marked contrast to the often much less rigorous methods usually employed. Obtaining accurate data for the models also highlighted the deficiencies in the information systems available to the managers upon which their decisions were based and made them aware of the extra information they needed to assess the full impact of technology on the business.

Review of the current financial appraisal procedures and discussions with management indicated that the use of spreadsheets was about the maximum level of sophistication to which smaller/medium sized firms were willing to go in analysing new investments. Interviewing management in different functions also highlighted the different perspectives and values held towards technological investment. For example, production engineers preferred to have the have the best equipment for a particular job, but sometimes lacked a full appreciation of the cost implications of the investment; correspondingly financial managers lacking technological expertise can underestimate the benefits that new investment may bring. This was certainly the case in the VHME case study. An important aspect of the models is that their development showed their potential in assisting in the bridging of this gap. Although the outline framework of a model would probably be put in place by a manager on the financial side, attempts to quantify much of the detail, for example many of the "wider effects", necessitate communication with those people charged with the operation of the new technology. It was also found that spreadsheet-type models could be easily understood by such people who usually lacked complex financial skills. The ideas and insights gained from the modelled case study firms were further discussed and explored in chapter 8 with reference to those other case study firms not used for modelling purposes.

Discussion of the method of financial appraisal used in a business was found to be a good indicator of the perspective taken by a company towards investment in AMT, ie. a 2 year payback calculation can indicate a different perspective from that of a company willing to accept a longer payback period based on the gaining of longer term strategic advantage. The difficulty of the modelling approach was that many of the characteristics and problems of implementing AMT are difficult to quantify in economic terms. In such instances the author tried to identify them using the other methods employed in the research. In addition, a key factor in the accuracy of the models was the quality of the data used. Since many of the models were predicting hypothetical situations, the author had to rely on the experience of the managers in question, backed up by documentary material, to validate the accuracy of the models. The models were then run on the assumptions of managers, and could be rerun with different assumptions to test their relative sensitivity.

9.1 Discussion of Main Research Findings

One of the common characteristics of the case study companies is that until the 1980's, they had generally enjoyed a relatively stable environment, making mature products for mature markets using well established engineering principles. Their relationships with their customers had been well established and one of the main objectives of the firms was to try and achieve long production runs in order to realise economies of scale. However, one of the distinct impressions obtained was that over the decade of the 1980's, all had found their environment more turbulent. All had suffered to some extent in the recession of the early 1980's (some quite badly) and had emerged with a greater awareness of the need for new investment to ensure their long term futures. Competition was now seen as being generally more intense and they were facing increasing demands from customers for higher product quality, more variety and tighter delivery deadlines.

These pressures were reflected in the motives that managers gave for their investment decisions which are listed in figure 9.1. In this respect the research confirms the work of others, Braun (1985), Bessant (1982), Gold (1983), that there are usually several motives behind manufacturing innovation. In several of the case studies, flow diagram techniques were used to show the links between the motivations, resources, objectives and "learning experiences" of the firm. This was found to be an effective way of assisting in understanding the innovation process within the business, since the diagram could be discussed with managers to see how well it represented the experiences of their business. It was found that managers usually had a conceptual "ideal" model of the production facilities towards which they aspired, and to which they compared the existing facilities of the company. The justification and priority afforded to a particular investment often depended on the extent to which it moved the production facilities towards that ideal. In chapters 5 to 7 the author tried to represent these existing/ideal models.

Initially, when asked why a firm had adopted a particular technology, managers often cited one or two of the more common motivations listed in figure 9.1 eg. increased productivity, reduced direct labour cost etc, together with a number of subsidiary ones. Further questioning however, usually revealed how these motivations linked together into a coherent pattern, forming distinct strategies for improving the overall performance of the business to meet the competitive and customer pressures they were facing. This fitted in with what Carter and Williams (1957) describe as the 'opportunity to invest' where they point out in their discussion of the process of investment in new technology, that such decisions are motivated by a variety of business and technical factors. Another point they make relevant to the case study firms, is that where competition is intense, as is usually the case in mature industries, and the margin of profit is often low, the motive to invest in order to maximise profit tends not to be so dominant. Since the case study firms were making products for well established, (in some cases declining), markets, they were competing essentially on a price basis and had limited opportunity to develop significant product differentiation. Most badly needed new products and to acquire new technology to assist them in producing a higher quality product with more variety, and to increase the scope for product differentiation, and innovation. This also emphasised the need to link investment in AMT to the business strategy of the firm. Whilst it may be said that this should be the case with any investment, with previous generations of manual technology, the gains in productivity between one generation and the next, of say, machine tools were often marginal. In contrast, the difference in performance and new opportunities opened up by AMT represent a considerable discontinuity from the previous experience of managers in long established firms, which needs to be appreciated. An example of this was in the VHME company where the innovative opportunities opened up by new technology and collaboration between other group firms is still being actively explored.

In order to give an indication as to whether the expected motivations behind an investment had been fulfilled, managers were asked to quantify the benefits that they believed their firms had obtained, and this is summarised in figure 9.1. This was not always a simple task, since none of the firms had thought it worth attempting any systematic post-implementation audit of their investments, and in two of the case study companies the proposed investments did not reach the implementation stage. It was therefore necessary to rely on the judgement of managers, backed up where possible by such company information as productivity figures, scrap rates, etc. Overall, when dealing with a well proven technology such as CNC, firms were able to realise considerable improvements, with productivity gains in terms of reduced cycle times of a typical factor of 2 to 3, with CAD showing a similar factor of improvement in design lead time over manual methods.

Figure 9.1 - Summary of motivations for manufacturing innovation in case study companies and "wider" effects observed

Company	Technology	Main Motivations for Manufacturing Innovation	Were Expectations Fulfilled	"Wider" Effects Upon Business/ Observations/Problems Identifed
VHME	CNC	- High quality components - Economic at small batch sizes - Able to operate on a minimally manned basis - Reduced cycle times - Reduced outwork - Able to subcontract spare hours - Reduced scrap - Reduced setting/downtime	- Considerable benefits have been realised: - Cycle times reduced by 20 to 40% - Quality improvements have resulted in fitting times reduced by 5 to 10% - Scrap rate greatly reduced - The company has been able to subcontract some spare hours, but most hours are required for its own work	***Technical Effects*** - Acquiring operators with the necessary CNC skills has proven more difficult than expected - Many in the workforce are from a traditional manufacturing environment where the general pace was slower, and are having to adapt to the more intensive CNC environment the company is creating - this takes time - Since CNC downtime is very expensive in terms of lost production, the management is trying to move towards a more systematic maintenance programme, rather than just responding when a machine breaksdown ***Economic Effects*** - As the firm moves towards an all CNC environment the existing absorption costing system is seen as becoming less appropriate - The evaluation of new machine investments needs to take into account wider stategic planning and cost implications than is shown by payback and DCF calculations
	CAD	- Shorten design leadtimes - Act as database of designs	- CAD technology has been very successful at reducing manufacturing lead times, Productivity improvements estimated at between 2:1 to 3.5:1 - A library of designs is now being steadily built up and is a key element in improving overall design and responding rapidly to customer enquires	- The company has found that more emphasis on the management aspects of CAD needs to be given than originally thought - in particular given limited facilities, which designs are most cost effective to be drawn using CAD and which ones manually. - The need to better co-ordinate the use of CAD between the design and production engineering functions - Several of the benefits of CAD found difficult to quantify in economic terms - ie. value of improved design - Need to improve communication between group companies to establish common design practices - In installing CAD throughout group companies, need to ensure hard/software compatibility - "systems strategy" ***Organisational Effects*** - Central sales unit set up to coordinate between group companies in order to become more "market led" - Development of "Total Engineering"concept where group companies can each contribute to a product, giving potential for product innovation

Company	Technology	Main Motivations for Manufacturing Innovation	Were Expectations Fulfilled	"Wider" Effects Upon Business/ Observations/Problems Identifed
Midland Ballscrew Company	FMS	- Increased productivity - Consistency of high quality product output - Able to operate on minimally manned basis - Reduced work in progress - Production flexibility - "Showcase" state-of-the-art installation - Government funding available - Improve production flow	- Since the system was not implemented it is difficult to say to what extent the expected benefits would have been achieved, but the system was expected to increase output by between 2.5 to 3 times, with scope for further future increases.	***Possible Problems with FMS Identified*** - Problem of considerable production disruption in the event of a breakdown to the system - The development of the FMS would require considerable new skills in the business, both technical and managerial - Further investment required to balance production in other production areas, most notably assembly greater than anticipated - Problem of integrating "greyhound" FMS output with slower "Donkey" machines - Increased expenditure on overheads, particularly sales
	CAD	- Shorten Design leadtimes - Easy to recall and modify previous designs	- Productivity improvement varies according to complexity and type of work, but the design manager thought that an overall general figure of around 3:1 as been achieved	- Design leadtimes not reduced by as much as anticipated - Learning curves longer than expected - Key advantage of system has been improved quality of design work, which has facilitated product innovation - Difficult to quantify economic benefits
	Computer based production control Shopfloor data collection	- Better control of Stocks and WIP	- Intend to reduce stocks & WIP by 25%	- The development of further computer systems within the business is making the management consider its needs for an overall "systems strategy" to ensure hard/software compatibility
PP Print Company	Computer Controlled Printing Press	- Increased productivity - New print features - Need to gain experience with this technology - High quality print output - Reduced setting time - Improve production flow	- The expected gains of £146,000 in reduced outwork and £150,000 in extra sales were not achieved in 1989. However now operational the press is proving successful and is maintaining company competitiveness during a downturn in demand in the print industry	***Technical Effects*** Initial technical problems with machine turned out to be much worse than originally anticipated and show how with fewer, more automated machines, in the event of non-operation, considerable disruption can be caused to the business, since there are fewer options to reroute production - Careful consideration needs to be given to ensuring that the most cost effective work is run on the more advanced press
	Small Specialist Press	- Need to enter a specific market	- The company has been quite successful at obtaining work in this market and paper plate methods used on machine transferred to other printing presses used in company	***Organisational Effects*** - Problems with the 3B press have highlighted the need for greater technical expertise within business - Better integration needed between sales and production needed
	Desktop Publishing	- Shorten publishing leadtime and keep up with competitors adopting similar technology	- Technology has proven to be very successful and further purchases of more equipment is being considered.	

Company	Technology	Main Motivations for Manufacturing Innovation	Were Expectations Fulfilled	"Wider" Effects Upon Business/ Observations/Problems Identifed
IHW Engineering	Specialist Assembly Equipment Online	- Reduction in cycle time - High quality finished products - To assist "work flow" in factory - Overcome existing production "bottlenecks" - Meet customer technical specifications - Reduced stocks and WIP	- The equipment is in the process of being installed. Previous specialised assembly equipment would indicate productivity improvements of at least 3:1 over manual methods - Intend to reduce inventory holdings by 80%	- The whole task of setting up the JIT system has proven much more difficult than originally thought, especially convincing managment and the workforce of the importance of the underlying philosophy and getting operators to take responsibility for the quality of their own work. The considerable organisational change involved goes against many years of established work practices - effective communication needed to over resistance to change at all levels in company
	Computer Link to Customer	- Regular updating of production schedule	- System working satisfactorily	- Need to develop "systems plan" within the business and to prepare for the eventual direct linking of production schedule to customer's computer system
	CAD	- Shorten design leadtimes - Maintain records of previous designs	- Productivity improvements of around 2:1 achieved in terms of design man-hours required	- Has improved the product innovation capabilities of firm
MF Engineering	CNC Burr-Grinding Technology	- Expand capacity - To prepare for the eventual introduction of further automation - To ensure consistent quality - Meet higher customer technical specifications - Reduce scrap - Reduced maintenance costs - Allows the production of more complex designs	- Production cycle times of 25% of previous machines have been achieved - Set up times on average between 20 to 30 mins compared to previous set up times of 3.5 hours - Scrap rate of machine is insignificant	***Technical Effects*** - Unanticipated technical problems with system resulted in considerable financial losses - Relatively high cost of equipment means that business can only afford one or two machines - in the event of problems the company can be very vulnerable - Skill limitations in company more of a problem than initially anticipated - More care than previously thought needs to be given to the selection of work to run on the CNC machine - Reduced productivity in non-CNC areas due to loss of moral - need to rethink display of information to workforce ***Economic Effects*** - Existing costing systems inappropriate - main overhead cost of machine is finance payments, direct labour only a small percentage of overheads

Company	Technology	Main Motivations for Manufacturing Innovation	Were Expectations Fulfilled	"Wider" Effects Upon Business/ Observations/Problems Identifed
Yorkshire Valve Company	CNC	- Reduced unit cost at low volumes of output - Reduced cycle times - High product quality	- Since the system was not implemented it is difficult to estimate if expected benefits would have been achieved, but PE-Inbucon estimated that new invesment in the machine shop alone would realise £300,000 in labour savings, reduce inventory (working capital) by £900,000 so reducing annual carying costs by £135,000	- The development of a manufacturing strategy for the business as part of a long term business plan would represent a considerable departure from the "piecemeal" investment pattern in the company in previous years - A key aspect of the new business plan was to make the company more "market led" by improving communication between technical and sales functions, this would be a difficult task in this company
	Specialised assembly amd test equipment	- Maximum utilisation of capacity - Reduced material handling - Ensure high quality product - Improve "work flow"	- The minimum estimated CNC productivity improvement in production cycle times over existing manual methods was 50%	- Considerable change to existing organisational practices would be needed to realise an efficient manufacturing organisation.
	Computer Installation	- Develop computer links between sites - Development of common engineering database		- As more computer systems are installed there is a need to develop a "systems strategy" for the business
CM Machine Tool Company	FMS	- "Showcase" state-of-the-art installation - Production of high quality parts - To gain experience with this type of technology - Government funding available - High productivity - Reduced scrap	- While the system has been a technical success, and has provided the company with considerable experience of the technolgy, in commerical terms it has not been a success and no system as developed and displayed has been sold. - The benefits of the FMS need to be seen as part of the overall improvement to the machine shop where labour productivity has risen by 50% over the last five years	- The system has highlighted the need for smaller systems, which do not use such costly transporting systems such as AGV's. - The economic costing system has been found to be increasingly inappropriate - Increasing use of design for ease of manufacture principles - Developing the FMS has highlighted the importance of better integrating the R&D, sales, technical, and production functions within the business, and a "project team" approach is being used to develop future systems
WM Components Limited	CNC Tube benders	- Higher production - Consistant quality of parts - Reduced Scrap - Remove 'black art' element of existing machines - Deskill production operations - Reduced direct labour	- CNC setting times greatly reduced (mins instead of hrs) - Greatly reduced downtime - CNC machines a factor of 3 to 4 times more productive, depending on individual operations	- Need to implement new technology in a more systematic manner aimmed at fulfilling long term business plan - Considerable organisational change required in terms of developing a new company "culture" in which operators are responsible for ensuring product quality. New wage payment system required to assist this
	Robotics	- Introduce greater machine flexibility into cells - Need to acquire experience of the technology to prepare for further investments	- Still in the process of implementing technology, but preliminarly trials with simpler robots show encouraging performance	- The introduction of new technology and new quality control procedures highlightened the considerable training and education required by the workforce to use machines effectivitly and in order to overcome resistance to change within workforce - Need for greater technical expertise within company management - Introduction of group technology and workforce being gradually changed to workgroup system oforganisation - Robotic technology emphasised the need for AMT investment to be seen in a longer term perspective, linked to the business needs of the firm
	CAD	- Reduce Design Leadtime - Research and Development work for Automotive customers	- CAD installed only recently, so only on the early learning stages, but productivity gains of 2 to 3 estimated over previous manual drawing methods	- Importance stressed on ensuring that CAD is used in its most cost effective manner

However, even relatively well tried technology can have problems as shown by the PP Print company, the economic cost of which can be considerable. In the final column of figure 9.1 are summarised the "wider effects" discussed in the main text identified within each firm as arising from the introduction of new technology, and which assists in testing the propostions of this research. This highlighted a wide range of technical, economic and organisational issues. A common theme that arose in discussing these issues with managers was how the introduction of new technology was seen as acting as a "catalyst", forcing attention to weaknesses in existing practices. This supports Munson's (1985) conclusion:

> '(Automation) will cure only a limited number of factory-floor ills. In fact, it will reveal more ills than it will cure. For all its versatility, (automation) is a disciplined creature and it requires a disciplined environment. It is unforgiving and it is a past master at revealing inefficient, ill-conceived, and outmoded processes'.

Many of the problems encountered by firms were related to what might to be termed an imbalance between the level of technology being introduced, and the existing technical and organisational infrastructure of the firms. In particular, the importance of the non-technical issues, especially, the attitudes and skills background of the workforce, were significant factors in determining how successful firms were in implementing new technology. The effect of technological change on the organisational structure of firms was often quite subtle, for example in the MF case study, an unexpected "wider" effect of the introduction of CNC technology had been that in the non-CNC areas of the factory, labour productivity had gone down due to "the mix of work" remaining on manual machines causing a loss of morale among the operators and supervisors.

In regard to the financial justification of new investment and the costing of production, one of the most revealing aspects of AMT encountered was the marked contrast between the rigorous highly structured methodologies advocated in the literature and the ill defined, unstructured nature of the problem in practice; in fact there often seemed to be little in common between them. The inadequacies of conventional accounting methods - such as payback and return on investment (ROI) - were well recognised in the companies, but since it was quick to do and fitted in with their short term productive pressures, it was still the favoured method of evaluation. Aside from the financial appraisal, management's considered judgement as to whether an investment was 'right for the company' played a large part in the decision making process, often being the dominant factor. DCF calculations were usually performed in a secondary supporting role, and where it was required for Government grant applications. This suggests that 15 years on, Nabseth and Ray's (1974) finding is still valid:

> 'Calculating the profitability of a new process is more difficult than is usually acknowledged in studies on the subject...This does not mean that firms do not try to estimate the relative advantage of a new process, but rather that their calculations are very subjective...It follows that profitability calculations for new processes are very much linked with management attitudes, especially when experience of the technology is scarce and perhaps contradictory'

There was however, a growing realisation among management of the long term necessity to invest in AMT, even though the payback period may be extended. Examples of this were the printing press at PP and the introduction of robotics at WM Components, where the payback on the investments were longer than the companies normal two year repayment period, but where a decision to invest had been made on the basis of a perceived longer term "strategic" requirement, and the need to gain experience of the technology involved. The magnitude of such a change in emphasis for many traditional manufacturing companies should not be underestimated, coming after many years of where the practice was only to invest when the existing machines became unserviceable.

The research would suggest that the economic evaluation of new technology is not simply a question of which is the most appropriate accountancy method, the most important aspect within a business is the overall financial decision making process: its priorities and time horizons. With regard to the allocation of overhead costs, all the case study companies used direct labour-based absorption systems, even the CM machine tool company who are technological leaders employed this method. While there was a general recognition among managers that their costing systems and other management information systems were often inadequate, it was often admitted that improving this aspect of the business tended to be subordinate to optimising production efficiency in terms of investment in machines. This fitted in with a general trend encountered within the case study firms that the value of effective computer based managerial information systems and production control systems tended to be undervalued. The problem in the firms was that there often tended to be "gap" of relevant expertise in the management structure. Senior managers tended to come from either a finance or technical background, while at the production operations level, managers were strong on engineering and man management but again lacked systems expertise. The result was that there was often no person in an organisation with responsibility for championing the cause of computer systems. This was confirmed by PE consultants, who commented how few smaller firms have considered their need for an overall systems strategy to ensure hard/software compatibility which had the capacity for further expansion.

An issue raised in the literature on AMT (Currie, 1989c; Gerwin, 1982) is that because of the difficulty in assessing the economic benefits of AMT there is a temptation for engineers to "overstate the figures" in their proposals in order to gain funding, in which case the financial justification proposal becomes more of a "political" document. While this does occur in larger firms, in firms the size of those in the case studies this was not evident to such an extent, since having fewer layers of management, there were fewer people to convince.

The problem of "intangible" benefits associated with particular investments was also encountered, the best example being that associated with the introduction of CAD technology as discussed in chapter 6. The initial motivation to introduce this technology was to shorten manufacturing leadtimes and to compile a database of designs which could easily be recalled and modified. In practice, while leadtimes were reduced, this was not to the extent anticipated. Instead, designers tended to use more time experimenting with new ideas, which could however, result in an overall better designed product, but was difficult to quantify economically. DCF calculations used in CAD justifications were not believed to really state the full benefits, and it was suggested that there is a need to see this technology in terms of its longer term strategic value to the company. Similar findings are reported in the literature ie. (Currie 1989c: Senker, 1984). While authors such as Primrose and Leonard (1985) argue that the benefits of all investments of AMT can be quantified, the research findings suggest that few managers have the time or inclination to use elaborate methodologies to perform such evaluations.

The research highlighted an interesting paradox, that while managers were often aware of how the literature tells them of the "theoretical methods" that they ought to be following in the implementation of new technology, ie. formal long term business strategy, planning for integrated systems, evaluation of "intangible" benefits, DCF calculations, etc, the reality of the short term pressures in their productive environment often meant that few actually had the time to give to these matters the full attention they would ideally like to. This problem was however, mitigated to some extent by the fact that being small companies, the managers were aware of the shortcomings of the business, and had an idea of how they wanted to overcome them. A theme which emerged from discussion was the way in which the managers believed their ideas had changed with regard to AMT over the decade of the 1980's, both through their own experience and the knowledge of problems encountered by other firms. In particular, AMT was not seen as providing a "neat technical" solution to all their problems. While managers were aware of the need to improve the organisational links between marketing, design and production, in order to take full advantage of new technology, the problem they faced is that being small they often lacked the necessary in-house skills to improve the situation. As the research has shown the adoption and successful implementation of new technology is a complex and difficult problem, which is usually the job of engineers. However, for the traditionally "technically" orientated engineer, particularly in a "black country" type firm, this represents quite a challenge, since they often lack an appreciation of the "wider" non-technical economic and organisational issues or downplay their importance, as 'not real engineering'. The research would suggest that those people charged with the responsibility for managing new technology need to take a broader perspective in order to take account of these issues.

What particularly impressed the author in the case study firms was the way in which though lacking R&D facilities, (with the exception of the CM company) and with limited technical skills, they were still able to make effective use of new technology. Certainly in realising the potential of new technology for a business, having a member(s) of staff who maintained a high degree of awareness of current technological developments, acting as a kind of "technological gatekeeper" was found to be of considerable benefit. This was shown in the Midland ballscrew and MF engineering case studies. The research therefore confirms previous innovation findings. The characteristics of Carter & Williams (1957, pp.177-192) idea of a "technically progressive firm" could certainly be applied to the VHME and Midland ballscrew companies, that is a constant searching for new opportunities and willingness to take in new ideas from the outside. Indeed, a revealing aspect of the research arose when discussing with managers their objectives for the future of the firms, such as occurred when the author was drawing up the "present/optimal" models of the company was the way in which they linked the problems they faced to the opportunities available to them. This bears out the comments by Freeman (1982)

> 'Innovation is a coupling process and the coupling takes place in the minds of imaginative people. An idea 'gels' or 'clicks' somewhere at the ever changing interfaces of science, technology and the market'

In terms of assisting the companies to implement new technologies, the bringing in of outside sources of expertise, for example, from academic institutions was found to be of considerable assistance. Since in all the firms studied technical expertise was limited and the management were used to working in well established patterns, what was provided, as described by the Managing Director in the MF case study, was the application of "scientific method" to long standing problems and the fresh perspective it provided. Both the VHME and Midland ballscrew companies also had collaborative projects with academic institutions. This is not to say that outside assistance is not without its problems, but well managed it can be an effective way of helping the smaller firm to develop and implement new technology and deal with some of the problems that can arise.

At this stage it is appropriate to look in turn at each of the case study companies and discuss what was shown by the development and application of the models.

The chapter 5 case study illustrated how obtaining the benefit from new investment is not simply a question of how much is spent, but also the importance of the way a business is organised to take advantage of the investment. In this this case several declining traditional manufacturing firms have been brought together and transformed by making them more market led and export orientated by integrating them with a central sales unit. The business strategy being to realise a *Total Engineering* concept through the development of *synergy* between group companies. A key aspect is to use new technology, most notably CNC and CAD, to realise this strategy. A "wider" effect of the implementation of more advanced CNC technologies, including a large machining centre, was that the existing absorption system, based on labour hours worked, was seen by management as becoming increasingly less appropriate as direct labour declined in relative terms as a proportion of costs. Using the *Excel* spreadsheet package a pilot machine based model absorption system was developed to explore this problem. The company's existing labour absorption system was run on several unlinked simple spreadsheets and involved several manual transfers of data. This disadvantage was overcome by incorporating all of the variables in a modular designed model with subspreadsheets linked to one another. This was found to save a considerable amount of time, especially when the model is being used under varying assumptions. The model has now been implemented within the company and is being developed further. The sensitivity analysis capabilities provided enable its use for forward planning and can be fed with data inputs from sales, both quantities and unit prices and absorption data - burden rates, material cost of sales, production lead time and machine hours per production, to show the economic benefits of reducing outwork and increasing subcontract work. The model is intended to be used as a flexible managerial decision aid as a "total company model" to assess future machine tool investments, with the potential benefit being shown on the profit and loss account. Previous to this, most capital investments had been evaluated using payback calculations. An important insight gained from developing the model was that it made the management consider how they may have to change their existing management information systems in order to supply the necessary data inputs.

In chapter 6, the author reassessed the financial viability of introducing a flexible manufacturing system which the company had considered several years earlier, but rejected as involving too high a degree of risk. The companys' motivation behind the original FMS proposal arose from growing competition from foreign suppliers, especially Japanese, who enjoy home markets which require high volumes of ballscrews providing them with the cost benefits associated with large scale production. In contrast, the British market demands high variety and low volumes, with the result that it had been difficult to automate for longer production runs. The FMS was seen as a means of changing its manufacturing strategy towards low cost, higher volume production in order to compete more effectively with overseas manufacturers. A key aspect of modelling the economic effect of the FMS was the ability to take into account the "learning experiences" of the management gained from using AMT since the time of the original FMS study. The model was able to analyse the effect of several shortcomings which had been identified in the original FMS study. These included the need for additional equipment to balance production, the cost of technical delays and higher overheads, particularly sales expenses. The models demonstrated that the FMS would have been financially viable if it had become operational within the planned two year development timescale, within budget, and achieved expected sales and cost benefits. However, had problems occurred the company cashflow could have been under prolonged strain. Since the FMS involved a considerable degree of technological innovation, such problems would have been very likely, and in the authors opinion, the management were correct in rejecting the proposal. Indeed, what was surprising was the large of unknowns associated with the project. Since the FMS proposal, the focus is in using new technologies to obtain improvements across a broader spread of functions within the business. In particular, the emphasis in the company's manufacturing strategy is now directed towards developing production cells using advanced CNC technology with multi-operation capabilities. The company has requested a copy of the models developed with a view to using it in a supporting role for capital investment decisions.

The chapter 7 case study provided a useful contrast between the problems of introducing new technology in the print industry and the other engineering case studies. The PP Print company had for several years been struggling to make a profit in a very price sensitive market. Realising that they needed new investment in more modern presses if they were to remain competitive, the decision was taken to introduce an advanced computer controlled printing press. This represented a considerable investment for a company of this size with small profits and was the first major investment for several years. However, following installation the press was unable to operate for nearly a year due to technical problems and the company incurred considerable financial losses through its nonavailability. Although only a limited amount of data was available the author was able to provide a detailed simulation of the planned operating budget in the year in which the press was introduced and the cash flow of the business, and to try and to model a further press investment the company are now considering. The company has now purchased the *Excel* spreadsheet software and are developing several of the ideas inherent in the models to further suit their own business needs. An important aspect of the problems of the new press is that it highlighted the low level of technical expertise in new technology within the company. To overcome this problem the company are now reorganising their production management structure to take on staff having experience of managing such technology. The company are also now seeking to try and achieve better integration between the sales and production functions within the business to take full advantage of new investment. The model could have anticipated the vulnerability of the company's cashflow to the problems discussed in this chapter. Had this information been available to management in advance the investment might have been delayed or remedial action taken sooner. As the loss of cash due to the delay in achieving specified output levels was £200,000 the potential value of a model that can perform sensitivity tests to reveal vulnerability is demonstrated.

Looking now at the companies not modelled with spreadsheets:

The IHW case study was an example of how competitive pressures are forcing companies not only to consider manufacturing innovation, but what might be termed "organisational innovation" in order to use AMT. Here, the requirement for ever higher product quality had made the company invest in specialist assembly equipment. For several years the firm had been adopting technology on an incremental basis to improve various aspects of its productive processes. The gaining, however, of a major contract from a large Japanese car manufacturer required not only manufacturing innovation to set up the new production line through the adoption of further specialist assembly equipment, but also organisational innovation by adapting Just-in-time principles to its own needs as the basis upon which to run the new production line. The interesting point is how organisational concepts such as JIT are diffusing down the chain of suppliers. The case study supports Whiston (1989, p.590) who in discussing the need for managerial and organisational integration in response to technical change, suggests that such ideas are just as relevant to the smaller firm as the larger one:

> '....accountants trained in discounted cash flow procedures and thinking need to understand the strategic logic and value of, say, FMS systems: non-technical management must become technically literate; technologists must take greater responsibility for strategic thinking in a financial framework'.....'One might consider that these arguments pertain only to large organisations. This is not so. Increasingly, smaller organisations which have habitually been concerned with batch manufacture, one-off style etc., are caught up in this spiral'....'consider a smaller Lucas Plant which is a supplier to Austin or another major automobile manufacturer. If the major manufacturer moves (say) to an FMS-type system of production or a CIM-system, or if it begins to demand the a just-in-time form of delivery, all of this is carried over to the subcontractor in a variety of ways. The managerial and organisational demands'..'are then carried over to the smaller contractor or sub-supply industry'

Adapting JIT to their needs and getting their own suppliers to deliver on a regular basis and adapting a Kanban type system in their factory has required a total rethink of the existing practices of the firm. The major change is that the new production system will require the management to run the firm on the basis of a new "philosophy" which involves operators taking responsibility for the quality of their own work. A key figure in the realisation of the plan was the production manager who through his knowledge of the problems facing the company and his awareness of Just-in-Time principles was able to act as a project champion for the project.

In the CM machine tool case study, two of the main insights gained were the "perceived" overselling of the "FMS" concept in the early 1980's and the growth in technological sophistication among smaller companies. Anticipating a large potential market for FMS technology the company sought to develop its expertise in this area by the development of an FMS for a machine tool exhibition, which was later installed in its factory to demonstrate a working system. The company envisaged that its customers would progress to an FMS in a series of steps and formulated its own model of automation at four distinct levels. However, the eventual system, despite being a technical success, was not a commercial one. The management now believe, with the benefit of hindsight that the FMS concept was"oversold" to a large extent, both by themselves and the engineering media. Instead, the market has developed for *smaller systems*, which can be built up in a step by step manner, using advanced CNC machines with considerable multi-operation capabilities, linking together to form "cells", typically two or more machining centres, linked by some form of rail conveyor. The FMS however, had provided them with valuable expertise in the use of the technology, and encouraged them to prepare for future technological change, and gave an insight into the problems their customers would face in its use. In discussing the main criteria for successful use of AMT, the management suggested that the key to making AMT work will be 'people not technology' and stressed the importance of *organisational adaptiveness*. Successful users were seen as those who tried to get the *best fit* between the technology and an organisation's skill, experience and requirements. This was seen as needing senior management commitment to change, consultation and involvement, with a strong emphasis on training.

CM considered that the understanding of more advanced manufacturing technologies in smaller companies had grown considerably in recent years. Many smaller companies, faced with increased competition, demands for higher product quality and tighter delivery deadlines were responding with the purchase of more advanced systems. The key to their financial success being the management's ability to organise their intensive use so as to obtain a payback within an acceptable time scale. The recognition of the growing sophistication in the small company market was in part the motivation for CM to develop a small machining centre at a price that gives it a mass market. An organisational innovation for CM in developing the new machine was the use of a "project team" approach, which enabled concept, design, development, and launch to be compressed within twelve months by the bringing together of marketing, engineering, manufacturing and finance. This is part of the development of a *focus factory* concept aimed at the integration of functions within the business. The new machine was also designed with ease of manufacture in mind and CM have created a *factory-within-a-factory arrangement* and adapted principles of Just-in-Time to produce it.

In the MF Engineering case study, the main motivations for the introduction of CNC burr grinding technology were to expand capacity and ensure high product quality. The strength of the company had been its large share of the UK market for steel and tungsten burrs, but the weakness was that these were mature products in mature markets. The strategy of the company had been to try and overcome this disadvantage by acquiring two new businesses, making complementary products, but using different technologies. This strategy however, presented its own problems since it involved managing four distinct technologies in a single factory. Given that the opportunities for product innovation were small, and that firms were competing on the basis of production costs, the company adopted a similar strategy to other smaller firms in mature industries and tried to move towards a higher value-added product. The MD saw investment in CNC burr grinding technology for the manufacture of tungsten burrs as a way to improve the quality of their products and so achieve a measure of product differentiation. The case study also highlighted the problem for smaller firms in that as automated technology increasingly concentrates the productive capability in fewer machines, the firm can be very vulnerable in the event of disruption to the production system. The non-operation of the machine had wiped out the equivalent of two years investment funds. The CNC machine has also acted as a "catalyst" forcing attention onto other areas of the business, most notably the costing side. Whereas with the existing technology used in the company, direct labour had been a large part of production costs, on the CNC machine it was relatively insignificant, finance charges being the main cost. The question was also raised of how to cost similar products made on conventional and CNC machines. The case study also showed the importance of a technological "gatekeeper", in this case the managing director who having become aware of the availability of the technology and its adoption by competitors was able to link this with the resources available to the company.

The WM Components case study demonstrated how in order to use new technology to best advantage, there is a need to create the organisational infrastructure that will facilitate its use. In this case the decision to enter the automotive components industry forced the company to reconsider its ability to produce high quality products. Considerable organisational change was required to breakaway from long established "blackcountry" custom and practice and overcome resistance to change from the workforce. Much emphasis was placed upon the training and education of the workforce, to enable them to cope with the new information and technological systems being introduced, and the need to take individual responsibility for the quality of their own work. The development of workgroups, with multiskilled workers was a considerable organisational innovation for the firm. The development of closer, long term relationships, with their customers, has led to the management to move away from investing when a machine is no longer serviceable, to one where the investment is part of a long term strategy, for example, in the introduction of robotic technology. This highlights the importance of manufacturing as a competitive weapon. With the introduction of robotic cell technology, it was also found necessary to take a longer term view of the financial implications necessitating a longer payback period.

The case study based on the conversations with management consultants at PE-Inbucon, reinforced many of the findings and observations of the author in the earlier case studies on the need to use AMT as one part of an integrated strategy aimed at improving overall business performance. It was felt that to a certain extent in the early 1980's such concepts as FMS, CIM had been "oversold". Many of the earlier users of large AMT systems were seen as having justified the technologies on the basis that 'they felt that they ought to be doing it', rather than for well thought-through business reasons and that in terms of overall business performance the results had sometimes been disappointing. The technology had often highlighted the differences in priority between the different parts of a business and many firms lacked the skills to use them to best advantage. It was felt that there was now a general greater awareness of the problems associated with AMT in client firms, in particular the wider organisational changes that may be needed to the management structure, communications and training. The "Japanese" influence was identified as having implications for many firms in relation to the need for high product quality, and using Just-in-Time principles in production and delivery. Few firms had experience of implementing technical change of a very profound nature, and most lacked staff with the necessary skills which is where a management consultant could be of considerable assistance as a *facilitator of change*. In terms of financial justification, PE found that most firms still relied on simple payback measures over 2/3 years. The consultant was often able to bring a fresh perspective in this area through combining economic evaluations with the longer term strategic needs of the firm.

A key aspect of the approach taken by PE in introducing new technology, was the development of an effective integrated plan for a client which can be structured into a series of logical steps to form a framework in which the manufacturing strategy translates the business and product strategies into a plan for developing existing facilities and justifying new investment to obtain competitive unit costs. Complementing each stage of the strategic development of a firm is the need to develop a computer systems strategy, to ensure hard/software compatibility which must be developed in tandem if the introduction of other new technologies is to achieve the maximum potential for improvement in the business performance. PE find that many client firms have not considered their need for develop such a strategy.

The Yorkshire valve case study provided an example of how the methodology put forward by PE would ideally be realised in practice, although in this case the plan was not actually implemented. The major insight being the way the methodology first reviews the overall business plan in terms of corporate and financial objectives and then proceeds to develop integrated product and manufacturing strategies. In this company the strategic problem was that the engineering techniques and products that had held the company in good stead for over 100 years were found to be wanting as the years went by and despite periodic efforts on the part of the management to update the manufacturing facilities it was gradually slipping behind its competitors. The planned development called for the overall rationalisation of the business to achieve a streamlined product range and reduce company overheads, and the creation of a competitive price and delivery performance through the modernisation of manufacturing methods by investment in CNC machine tools to reduce lead times and inventories, thereby obtaining further reductions in operating overheads. A key aspect of the Yorkshire Valve plan was the development of a *systems strategy* which is able to integrate the various functions within the business by the development of common databases.

In summary, the research has shown that the holistic effect of AMT often presents the smaller/medium sized firm with considerable problems to come to terms with. It is often outside of the immediate experience of their managers, especially so in long established firms. Developing an appreciation of its overall effects can take a considerable period of time, and a commitment to change is necessary at all levels within an organisation. If there is a common characteristic among the firms visited by the author, (others have been visited than just those described in the text) between those that were successful and those less so, in their use of technology, it is the ability of management, usually senior, to be able to take time to stand back from the day to day pressures and to review the direction of their organisations and acquire knowledge on subjects which may be of longer term value to the future of the company. While this might sound relatively simple, in practice the business environment of the smaller firms encountered in this research is an intense one, and it is easy to become completely enmeshed in short term problems.

9.2 Technical Evaluation of Modelling Methodology

From a technical perspective, the selection of spreadsheets as the method of modelling proved to have many advantages, one of the key ones being effective cognitive coupling. All three case study companies had simple spreadsheet packages available on microcomputers, but their use was confined to financial management, and were only used on a small scale. The database potential of spreadsheets in all three firms had not been considered, indeed, what surprised the author was the general lack of awareness among management of the full information processing capabilities of the packages available to them. In view of this, the author believes that the use of spreadsheets is about the limit of sophistication that managers in small firms are willing to go in financial evaluation. The more elaborate modelling methodologies discussed in chapter 4, using high level computer languages or specialist packages are too far outside the experience and skills of those in the smaller business to be of practical value. The great advantage of spreadsheets is that while they may appear simple, they are in fact a powerful tool of analysis which all too often is underrated.

Looking now at the *Investment Analysis Sheet* and the *Financial Impact Analysis* models described in chapter 4. The *Investment Analysis Sheet* used to calculate DCF has an interface which guides the user through the programme prompting at appropriate points for the input of data. This was found to be of use in demonstrating how a series of programmed financial routines can be used to enable persons with non-financial training to perform DCF calculations for themselves. Likewise the *Financial Impact Analysis* model based on the work of Earnest (1987) was found to be a useful demonstration model, but since this model worked on the basis of a company having only a small number of products, each selling at a discrete price and none of the companies fitted this description, it was not possible to use it other than for demonstration purposes.

In developing the models, the use of a structured methodology was found to be of considerable assistance. The initial specification of the model was found to be a critical stage, at which the problem is analysed in detail and the logical relationships established. The use of flow diagrams to represent information flows within the model proved to be an effective means of communication in explaining how the models worked to managers. The decision to use the *Excel* spreadsheet for modelling due to its ease of use was found to be well vindicated. None of the companies had previous experience of using such an advanced spreadsheet and all expressed surprise at the ease of use of *Excel* compared to their existing packages, and its enhanced ability to act as a powerful communication tool in financial evaluation, especially graphical functions. Two of the companies have already made replaced their existing spreadsheets with *Excel*.

The main limitation to the effectiveness of using a modelling approach is that many of the business variables affected by the adoption of new technology identified in the companies, are not very suitable for quantifying in economic terms. The effects of many technologies are often incremental and diffuse, and operate on a very subtle level within a business. The use of a modelling approach is more suitable when the effects of adoption of a new technology are large enough so that they have some meaningful economic result. The quality of data available for analysis can also present problems, since although the management may have a good idea of the expected benefits that a particular technology may bring, it is often hard for them to predict if those benefits will be realised to the same extent in their own business. Based upon the experience of the author, the following "good" modelling points were identified:

(1) In specifying the model, work as closely as possible with those who will use the model - It is often at this stage that that the author was able to obtain several of the main insights into how the management justified their investments. In the opinion of the author the most useful models of the three case studies is the VHME company case study (chapter 5), for the simple reason that it was designed in close collaboration with the financial director to overcome a specific problem.

(2) Keep the level of detail as simple as possible - In all the models, the author tried to tailor the level of detail to suit the nature of the problem in question. With spreadsheets as with other computer packages the number of features offered to the user usually far exceeds what is actually required to produce meaningful results. The nature of the problem in chapter 5 meant that a complex model was required, while in chapter 6 a simpler model was used, since the financial information available was more limited. In chapter 7, given the limited nature of data available the model employed was perhaps, over complex for the depth of the problem under consideration.

(3) Document the model fully and list assumptions - Although this is a standard recommendation in any work with computers, there is still a considerable temptation when developing any model to proceed without fully documenting the model as one goes along. Problems typically arise when, having completed a model and moved on to other work, there is a need at a later date to go back and use the model. Unless, it has been documented properly, considerable time can be spent retracing logic relationships to relearn how the model works. Information flow diagrams were found to be of considerable assistance in overcoming this problem.

A disadvantage of the modelling approach is the amount of time required to specify, develop and validate the models. The individual manager is presented with a cost/benefit analysis type question. Do the potential insights offered by using a modelling approach justify the time that would need to be invested in its development? A crucial aspect of getting managers to use any financial decision aid is that it needs to relate to their everyday work. One of the problems with the more advanced methodologies described in chapter 4 is that they are not usually the type of techniques used in the daily routines of those financial managers who would probably do the modelling and so a lengthy learning period is involved. In contrast, most are familiar with spreadsheets, and by basing the models on the profit and loss accounts of the business, they are able to relate to them more easily. Since with spreadsheets the logic is not "hidden" from the user in the same way as with high level computer programming languages and financial packages, the relationships within the spreadsheets can be more easily traced and understood. The user is also able to quickly set up a simple model and obtain results; initial success is always a good reinforcement in the early stages of modelling.

In terms of the context in which a modelling approach would be most useful the author believes that given the length of time required to develop them, models should be used in a flexible manner in conjunction with the wider evaluation process taking place within a business. Figure 9.2 illustrates what might be termed an "ideal" situation. Assuming that a business is under pressure to invest in new technology, the management would first gather information about the options available. From an initial appraisal based on empirical judgement, the management would reject those obviously not suitable to the business. The management would then carry out an appraisal of the investment using payback and DCF calculations on the remaining options. Spreadsheet models would then be used to evaluate those apparently viable investments where it was thought that the above mentioned calculations underestimated the full effects upon overall business performance.

Relating this procedure to the VHME case study (chapter 5), at present the management mainly use simple payback and their intuitive judgement to evaluate a new machine. The model now gives them the scope to evaluate an investment to a further level of analysis, and by varying the assumptions of the model, they will be able to see if a new machine complements the existing production setup. A key aspect being that it gives the financial director the ability to test for himself some of the stated economic benefits of a new machine suggested by the production manager.

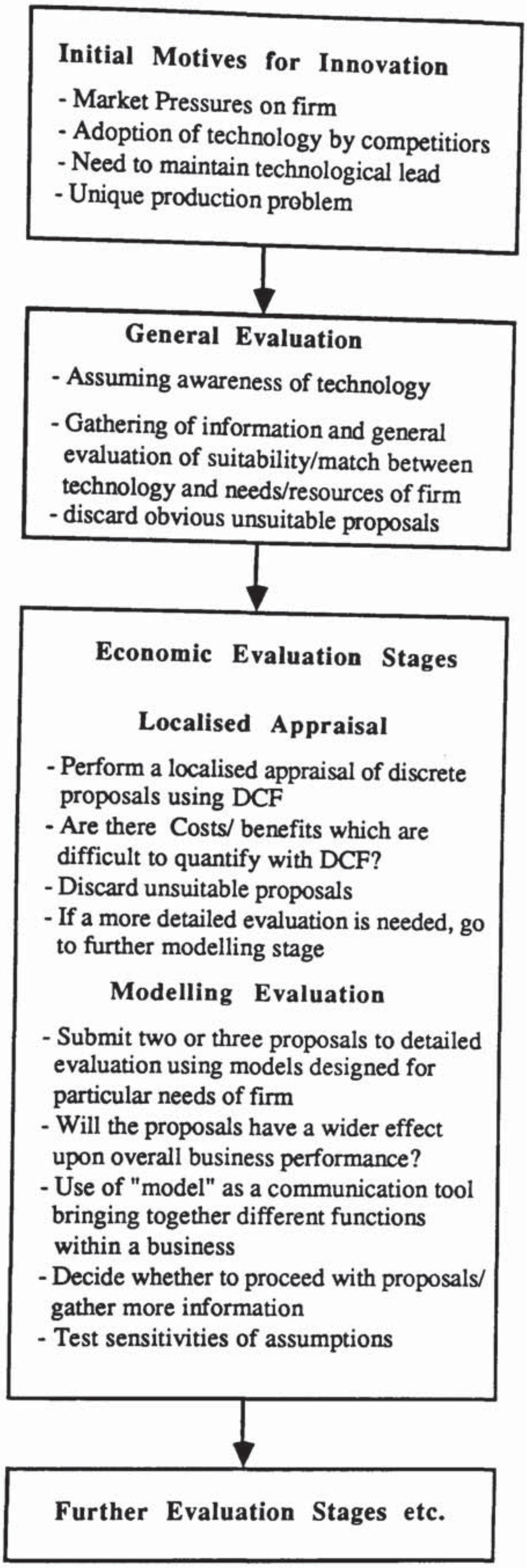

Figure 9.2

Context of use of modelling approach in evaluation of new technology

9.3 Conclusions

The research has shown strong support for the initial propositions of the research: - that the results of AMT have frequently not been fully realised as originally expected in terms of improving overall business performance, and that the reason for this is that inadequate attention has often been given to the integrated nature of the technology and its effects on parts of the business not immediately associated with the innovation. For this reason the main findings of the research confirm previous work in the field of AMT which suggested that the implementation of new technology should ideally be carried out as part of an overall business plan, which takes as its starting point the total manufacturing task of the company and the competitive advantage new investment can bring.

In contrast with previous generations of technology, where the main motivation for new investment has arisen from a need to reduce direct labour costs, AMT, with applications in design, manufacture, assembly and the supply of managerial information provides the firms employing it, not only with increased productivity and higher quality products, but also enhanced business performance in relation to the reduction of manufacturing lead times, improved design and product innovation, and reduced product life cycles. However, the technology requires not only technical change on the part of the companies employing it, - by often changing the underlying economic relationships within a business, it also requires considerable organisational adaptation in order to obtain best advantage. The research has shown that the introduction of AMT forces managers to move away from an emphasis upon investment to overcome problems at what might be termed the "operational level" to one where the "holistic nature" of the technology is taken into account and viewed in relation to how it improves overall company performance. For well established manufacturing companies with long experience in relatively slow changing technology, this shift in emphasis is a considerable one. This implies managers taking a proactive response to the need for technical change, rather than a reactive one.

The case studies illustrated several of the problems that the smaller firm can encounter in the process of adoption. It was found that most managers were aware of what the literature stated about the introduction of advanced manufacturing technology, but that as a result of short term productive pressures, few had the time or inclination to follow a rigorous methodology. Short term payback was still the main method of financial appraisal used. The research identified that the decision making process of managers to invest in new technology was a complex one and behind such decisions a wide variety of motives was found. The important factor being how the motives linked together to form coherent strategies for improving overall business performance. The idea of managers having a conceptual model of the "ideal" production pattern to which they intend to progress can be a useful one in explaining the decisions taken. The methodology of spreadsheet models and other techniques used in the research was found to be an effective means of assisting the investment decision process within companies.

While the technology has been integrating upward to affect overall business performance, capital budgeting procedures have tended to remain at a "machine level" emphasising single valued criteria like payback. This has previously fitted in with the short term horizons of the smaller manufacturing firm. However, as they progressively acquire more advanced technology there is a need for them to use evaluative methods which are able to better take into account the effect of AMT upon overall business performance, and the financial benefits of faster throughput time, reductions in inventory and improved design. The research would suggest that complex financial evaluation procedures are inappropriate to the smaller firm due to limited managerial resources available, and the author has instead put forward a more flexible modelling methodology based on spreadsheets which it is believed is better suited to the level of expertise available within such companies. It is suggested that such a modelling approach is useful where:

(i) The evaluation problem confronting a business is large enough to warrant more detailed attention.

(ii) Localised DCF calculations are not considered to fully reflect the overall effect of a new investment upon the business, such as result from so -called "intangible" or indirect benefits

For these reasons, a two stage economic evaluation procedure was put forward as shown in figure 9.1 which would form one part of a company's overall appraisal of a new investment. The first stage would comprise the use of conventional evaluation methods and, if the above criteria are met, would then go on to the use of a modelling approach for a more detailed evaluation. It is also suggested that the most benefit from a model will be derived when it is developed in close collaboration with the intended user and tailored to meet a specific problem.

Given that the complexity and pace of technological change is one of the most powerful influences upon an organisation, and is likely to be more so in the future, the need for AMT to be implemented as part of an overall strategic business plan "*the deliberate and conscious articulation of a direction creating a vision of a possible future*" is essential in successfully introducing AMT for the following reasons:

- The implementation of AMT requires an ongoing effort over several years, and a clear direction is needed in order to ensure commitment.

- The capabilities of AMT offer new business options, and its widespread use changes the underlying economic relationships within an organisation

- The evaluation of new technology within the productive area cannot usually be analysed adequately from a standalone basis, but needs to be made in relation to how it fits in with the overall manufacturing task of the business.

- The payback on AMT investments can often be longer than the two years typically required in manufacturing industry and justification procedures need to reflect this.

- The learning curves of new technologies are often longer than anticipated, and the expected benefits and problems frequently materialise in areas where they are not envisaged.

- Effective planning will assist in overcoming the resistance to change that is a feature of all organisations. The importance of the non-technical issues in implementing new technology must not be underestimated.

- It is necessary to develop a "systems" strategy in tandem with the implementation of new technology in order to ensure hard/software compatibility and the development of management information systems.

In addition to the main research findings, an important insight gained was the way managers in the case study firms often facing at best, a problematic existence, lacking extensive resources and not following the "right guidelines" for adopting new technology, were still able to display a remarkable degree of innovative ability by identifying opportunities and linking them to the available resources of the business. In many respects it is their very closeness to the "front end" of production, and dynamic nature of their environment, which gives them the ability to "think on their feet" and synthesise their own unique solutions to the problems of their business. What is even more surprising is the long term potential that new technologies hold for smaller firms. Given that larger firms have generally been technologically ahead, and that the well established smaller engineering firm in the UK has traditionally suffered from underinvestment, if the case study examples are representative, then in future years, in terms of the magnitude and impact, the potential of AMT for transforming the small firm sector is possibly greater than that which has been witnessed in larger firms.

9.5 Recommendations for Future Research

After several years of research, the insights and experiences obtained point out many potential avenues for further research in the implementation of advanced manufacturing technology. The author would suggest that the special needs of the smaller manufacturing company in adopting new technology merit further attention and four ideas appear appropriate for further consideration.

(1) Further development of the modelling approach used in the research. In particular, monitoring how,as a firm progresses in terms of automation over a period of years, the cost structure changes as it becomes more capital intensive.

(2) Further exploration of the factors which determine successful and unsuccessful manufacturing innovation in the smaller firm. In this respect a modified Project SAPPHO (1973) type approach would be of value.

(3) Attention needs to be focussed on how outside sources of technical assistance can be more effectively linked to the problems facing the management of the smaller firm in evaluating new technology and dealing with the subsequent problems that can arise from its implementation.

(4) The rapid changes taking place in the relationships of the smaller firm with their market environments as a result of the demands of Just-in-Time delivery and higher product quality, provides great opportunities for research into the organisational adaptations required of the smaller firm.

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