IMPLEMENTING COMPUTER AIDED DESIGN

IN

SMALL BUSINESSES

by

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ABSTRACT

The lack of real and speedy success in the implementation of Computer Aided Design (CAD) in small firms has been a cause for concern for the author for some years. Whilst much has been written about the implementation of Management Information Systems and about Advanced Manufacturing Technology in large firms, the literature on small firms is very sparse, and the implementer has nowhere to go for guidance.

This research looks at the implementation of CAD in six small firms against the background of the current literature in associated areas. It focusses on the aspects of implementation most commonly featured in the implementation texts, developing some 32 Propositions on the basis of the six cases.

A review of the propositions suggests a parallel between their sequence and what may be regarded as a "traditional" business plan, which addresses the questions:

- where are we now?
- where do we want to go?
- how do we plan to get there?
- what steps must we take?
- how will we know when we get there?

The link between the propositions and the structure is strong, and the consequence is clear. If the propositions indicate a structure, then a structure developed specifically to incorporate the propositions should result in a methodology for implementation.

The framework for this methodology is developed, based upon five phases or stages:

- strategy
- company audit
- design
- action
- review

The framework has been tested and amended, and the inputs to the phases have been identified. Sources for these inputs have also been specified where necessary.

The framework provides a significant step forward in the understanding of Computer Aided Design implementation in small firms. In particular:

- it is constructed using "hard" data
- it provides guidance on a "best" way of implementing
- it forms the basis of an implementation "toolkit"
- it addresses the needs of the small firm, which can least afford specialist help and can least afford failure.

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APPENDICES

1.0 INTRODUCTION

The Author is a Director of a management consultancy company based in the North of England and providing a wide range of services to manufacturing companies predominantly throughout the UK. Operationally, the Author is responsible for two Divisions of the Company. One of these, the Technology Division, has a high profile in the field of Computer Aided Design (CAD).

A typical project for a company would involve a number of days on site, learning about the products, their design parameters, the types of design and draughting work normally carried out, the organisation of the drawing office and its relationships with other departments. In particular, the relationships between design, manufacturing and planning departments would normally be of interest, since CAD is often seen as a bridge between these departments.

Over the years the Author has become aware of a number of problems associated with the successful implementation of CAD.

In particular, he has been concerned at the low level of systems integration tackled and achieved by these companies, as some of the texts discussed later seek to demonstrate that higher levels of integration lead to greater benefits.

As a consultant, the Author's role usually ceases once the system has been specified, benchmark demonstrations have been completed and quotations have been obtained.

Feedback on success or failure is therefore not often available. Indeed, when following up on projects after some months have elapsed, it is often clear that many of the benefits have not been obtained, yet those responsible for the system are reluctant to admit it.

As will be seen in Section 2.2, integration can be regarded as a multi-stage process. Of the 20 projects carried out by the author in a two year period, only two had developed to a high level of integration with any success. Ten of the systems had achieved satisfactory performance at low levels of integration. That is to say the implementation team had reached the targets they had set themselves of achieving linked systems. Some of the ten companies had gone further to produce non-graphical information from the systems.

Of the remainder, two were experiencing problems with achieving the higher levels, five were having problems with low levels and one had been abandoned as a total implementation failure. Some of these projects are discussed in a later section.

This was a far from encouraging picture, and clearly something was going wrong between the selection of a technically competent system and its final implementation. It was against this background that the case material was developed which forms the basis of this work.

The amount of literature on the implementation of integrated CAD systems in small businesses is very small indeed, although some work has been carried out on integration in larger firms. Therefore it was decided that an appropriate way forward would be to carry out a review of the cases to identify and define the common threads.

Whilst CAD integration per se had been neglected, Computer Aided Production Management (CAPM), Information Technology (IT), Advanced Manufacturing Technology (AMT), Flexible Manufacturing Systems (FMS) and Materials Requirement Planning (MRP) implementation were well documented in larger firms, if not in small ones (i.e. less than about 200 employees), and parallels were therefore sought between these, which are in essence integrating technologies, and CAD.

Integration is discussed further in Section 2.2, but it is worth examining briefly at this stage what is meant by integration. Any system which crosses traditional functional boundaries can be regarded as potentially integrating. For instance IT pervades a number of functional areas, CAPM as a minimum involves Sales, Planning, Manufacturing, Stores and Purchasing. Both of these are integrating technologies.

CAD qualifies as an integrating technology once it grows beyond the Electronic Drawing Board stage, and takes in Design, Development, Draughting and, with CAM, parts manufacture.

The structure of this work is as follows:

Chapter two reviews the literature on implementation of technologies of all types, but concentrates on the integrating technologies. In doing this it demonstrates how this work will extend the knowledge and in what areas.

Chapter three defines and defends the methodology used in the work, and in particular the principle of moving from a relatively small base of case material to theory. It also examines the alternative methodologies available.

Chapter four consists of a number of case studies, one per company, selected to show a broad spectrum of problem areas and demonstrating a common need for an integrated system.

Chapter five develops a number of propositions from the data gathered in the preparation of the case studies. It looks at such areas as organisation structure and familiarisation with high technology.

Chapter six develops a structure for a methodology for the implementation of CAD in small companies, and suggests how this should be developed into a management tool. It also suggests suitable areas for further research.

2.0 IMPLEMENTATION OF TECHNOLOGY - THE CURRENT LITERATURE

Literature on the implementation of Computer Aided Design and integrated systems tends to be somewhat sparse, and it has therefore been necessary to look for parallels in similar technologies. In particular, the field of Information Technology (IT) has proved to be well documented, and appears to be very similar so far as the complexity and major implementation issues are concerned.

When we come to implementation and integration of systems in small businesses the literature is minimal, and a much wider sweep is needed, to encompass such integrating technologies as Flexible Manufacturing Systems, Materials Requirements Planning, Advanced Manufacturing Technology and the like as well as the literature on technological innovation.

Whilst there may be dangers in translating experience in one technological field to another, there would seem to be some aspects of implementation which are technology independent. For example, the training aspects of implementation, and the planning for change.

It is these aspects which make a wide sweep of the literature meaningful.

So far as possible, the search has concentrated on literature no more than about ten years old, ie post 1980, on the assumption that technological change may well have invalidated some aspects of the work done prior to this.

2.1 System Justification

In the author's experience, companies rarely if ever implement systems or purchase items of capital equipment without first justifying the expenditure.

With a piece of machinery, the justification is often very simple - it produces items at a particular rate, allowing the Company to cut costs or to meet a particular schedule.

Systems, however are never quite so simple, and much research has been done into the justification of systems investment. However, the literature on justification for investment in Computer Aided Design is sparse, and it is therefore necessary also to look to the microelectronics and information technology fields, where empirical data has been more readily available.

Bessant reports on a variety of case studies carried out for the Department of Trade and Industry, Anglo-German Foundation, Policy Studies Institute and the United Nations (in Winch (ed) 1983a pp14ff), and describes 12 common motives for the adoption of I.T. based manufacturing innovations. Many of these would appear to be directly relevant to CAD implementation. These include:

* savings on direct labour costs
* savings on skilled labour (coping with skill shortages by using the capacity of I.T. to embody skills within the software)
* savings on indirect labour (through improved reliability, easier maintenance, outline monitoring etc.)
* improvements in machine operation - greater accuracy, flexibility etc.
* reduced cycle times
* space savings

The remaining six factors which are of less relevance are:

* shorter set-up
* improved reliability, easier maintenance
* improved production control, better information availability
* energy savings
* material savings
* improvements in process safety

It is, of course, possible to find close parallels even for these six points

Gerwin and Tarondeau (1982) in Gerwin (1988 p90) found from their studies of computer integrated manufacturing systems that half the firms adopted computerised systems in a bid to reduce production related uncertainty. Bessant and Dixon (1982) note that manufacturing innovation produces an overall trend towards increasing operation controllability, but stop short of claiming this as a justification for implementation.

Hage (1980) and Zaltman et. al. (1973) both emphasise the relationship between a performance gap and motivation for innovation. A performance gap is the perceived difference between aspiration and achievement resulting from an increase in aspirations or a reduction in performance.

Gerwin (1984) found evidence of both these factors in computerised manufacturing technology, but does not claim that the resultant performance gap has been a prime motivator.

In terms of Computer Aided Design justification, Primrose et. al. (1985 pp 293,294) have listed the benefits which may be derived from a successful implementation, and whilst this may enable a company to identify the areas of potential saving, no specific claim has been made that any of these factors have been or would be used for justification.

Senker (1984b p138) emphasises the benefits of integration of CAD with manufacturing processes, and reductions in design lead times. He claims that several existing users are likely to expand their systems because they have found significant benefits in competitiveness, including substantially shortened tender documentation prepared more quickly.

He also notes that knowledge of successful applications is spreading rapidly through the industry via personal contacts, journals, exhibitions, conferences and through the efforts of the system suppliers.

Carnall and Medland (1984 p52) cite a survey by Coopers and Lybrand which discusses the use of the Productivity Ratio as a justification factor. The Productivity Ratio is defined as the time required to complete a task using CAD compared with manual methods. The report notes that productivity claims such as 4:1 for detail draughting are rarely supported by good evidence. Carnall and Medland argue that the benefits of CAD are too complex and interdependent to make justification purely on the basis of Productivity Ratios.

Arnold and Senker (1982a) in Carnall & Medland (1984 p53) report four main areas of benefit:

* increased productivity within the design and drawing function
* improved design quality
* improved links between design and manufacture
* indirect benefits flowing from the process of introducing computers, leading to a review of design systems, improvements in access to data and so on.

However, they claim that most of the CAD systems investigated by them had been cost-justified on the basis of saving draughting labour, despite the lack of evidence of this being the most productive use of CAD, but perhaps because of the ease of quantification. They argue that this narrow justification could inhibit the reaping of other benefits.

In their paper for the EITB, Arnold and Senker (1982b) in Arnold (1983 p36) list four motivations for the involvement in CAD, by industrial sector.

The largest positive identified motivator (eight out of twenty six cases) related to lead times and threats to viability. Some distance behind (five cases) related to flexibility of design and complexity.

The third factor (four cases) was a need to reduce dependence on contract draughtsman or to meet a skill shortage. However, the largest group (nine cases) covered the category including experimental implementations or where the motivation was unclear. Arnold (1983 p36) has his own list of benefits, which may or may not be related to motivation, and which includes:

* increased productivity reduces design cost, speeds documentation and reduces lead times
* high productivity allows firms to tender for more jobs
* accuracy and presentation of tenders is improved and more design work is possible at the tender stage, impressing potential customers
* CAD installations are perceived as "high technology"

Kaplinsky (1982) points out that users cannot calculate the exact benefits likely to arise from a CAD implementation because the available benefit will relate to the efficiency of the newly organised design process and cannot therefore be assessed. This issue is dealt with in further detail elsewhere.

Technological justification, then, appears to be a minefield, where system proponents are, in many cases, pushed into claiming savings in draughting labour time - a moot point amongst most researchers.

When it comes to financial justification, hackles are raised by the need to use "traditional" accounting procedures. Primrose et. al. (1985 pp92,93) hint at the potential problem of justification by criticising companies who do not take a company-wide look at the costs and benefits. They claim those who invest in major capital projects without a detailed financial appraisal run a number of risks.

The first is that they may invest in a project which is incapable of generating an adequate return on capital. The second is that they might invest in a project which does not represent the best potential application, failing to identify the project offering the greatest return. The final risk is that they may refrain from investing in a project, even though such an investment would be more advantageous than continuing with current practice.

In order to identify the company wide benefits they have identified 16 cost factors for CAD and 29 areas of potential benefit. They claim that the costs and benefits can be quantified with sufficient certainty - and with a sufficiently low level of uncertainty - to enable a sound justification to be made.

They note that non-discounting methods such as payback and accounting rate of return are inappropriate because of the protracted nature of the benefits, and suggest the use of Discounted Cash Flow (DCF) techniques, measuring Net Present Value (NPV) or Internal Rate of Return (IRR), which are

"...acceptable to accountants...".

Senker (1984a p228) takes a similar line on the use of payback for CAD justification, but also criticises the use of DCF as being an inadequate method. DCF, he states, encourages projects which yield quick returns, since anticipated profits for future years are heavily discounted. This may happen regardless of whether the project is vital to the future of the Company.

He also criticises the emphasis on profit-centre control, which may reduce cooperation between divisions with the subsequent tendency to discourage managers from promoting projects which depress short-term profitability. This despite the potential long-term benefits.

Hayes and Abernathy (1980 p164), similarly argue that short-term financial measurements and 'management by numbers' have been a feature of management in the US in recent years. The use of the profit centre as a primary unit of managerial responsibility has led to a greater dependence upon short-term financial measurements such as Return on Investment (ROI) for the evaluation of managers' performance. This in turn has caused managers to make financially 'safe' investment decisions at the expense of projects with larger but longer term payoffs.

Gerwin (1988 p91) notes that:

> "since short run quantifiable factors will be emphasised by strategic management in making capital investment decisions, computerised technology will be discounted. Its primary advantage of flexibility is a long run intangible consideration".

Meredith and Hill (1987 p58) argue that justification techniques appropriate for low-level systems are inadequate for higher-level systems, because they do not measure critically the primary use for which the technology is being considered.

They suggest that financial techniques cannot reasonably be used to justify a strategic investment, which a fully integrated system represents.

Figure 2.1 shows Meredith and Hill's justification "model".

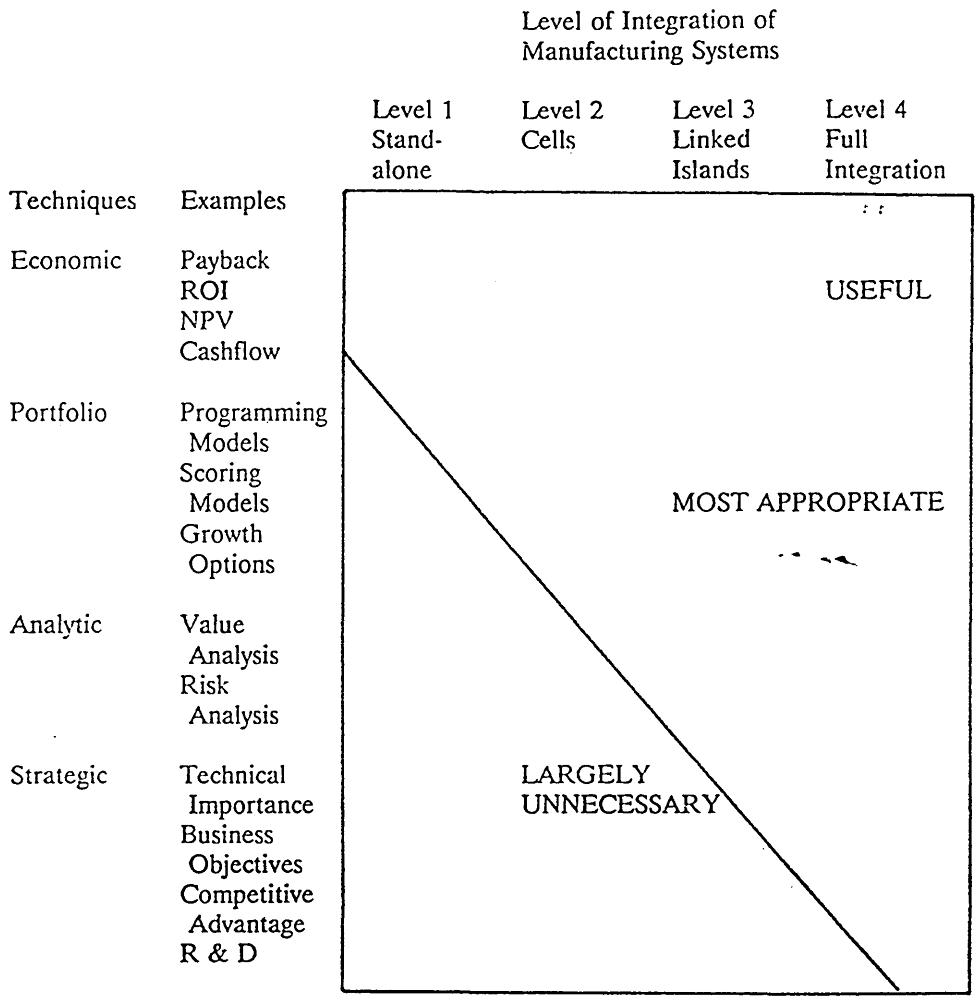


Figure 2.1

According to the literature, then, we have three types or systems of justification. The first is the technological justification, based upon technological need regardless of the financial implications, or at least with finance as a secondary feature.

It concentrates on benefits related to productivity, efficiency and quality, and whilst it is largely ignored by accountants it can have implications for revenue measures, e.g. cash flow.

The second type of justification is a short-term financial viewpoint, perhaps based on Discounted Cash Flow or Internal Rate of Return methods, and occasionally on payback.

The third type is the long-term viewpoint, and while several writers suggest that this is the "correct" means of justification, there seems to be little evidence that it is commonly used.

Meredith's consolidation of the three justification methods has some attraction in that it relates the three methods to their most appropriate application. What is clear, however, is the importance of the initial justification method, since this will provide the yardstick against which the implementation is eventually measured. It will also determine - in a somewhat arbitrary manner, according to the literature - whether or not the system will be implemented.

2.2 Systems Integration

A Computer Aided Design system must be considered as part of, and not necessarily a major part of, the manufacturing information system, which itself is part of the company's overall management information system. It is clear, therefore, that systems integration will be an important factor in the implementation of CAD.

Carrie and Bannerjee (1984 p252) identify trends towards both horizontal and vertical integration of systems, with horizontal integration crossing the horizontal boundaries between functions and vertical integration linking different managerial levels. They see these trends as fundamental in leading away from a corporate mainframe concept to distributed turnkey systems. This is a bold concept for 1984, when data transfer protocols and standards were in their infancy. It is particularly bold when faced with the evidence of Arnold and Senker (1982 p5) that:

> "Most CAD Systems we saw are primarily used as draughting systems and were cost-justified on the basis of saving draughting labour".

At around the same time Carnall and Medland (1984 p56) touch on the need for integration, but concentrate on the discrete design/draughting system. It is clear that in the early 1980s systems integration was something of a pipe-dream, certainly on the level that we would consider today.

Winch (1983b p62) describes CAD/CAM as an

> "integrating technology which requires stronger organisational linkages for its effective use".

However, whilst he sees true integration of CAD and CAM through a common data base he regards this as a technological island, which requires organisational changes to enable it to be integrated into the other systems.

By 1987 integration was taking on a much broader meaning. An integrated CAD/CAM system incorporated design, draughting, engineering machine tools and manufacturing documentation systems, referred to as Computer Integrated Manufacture (CIM). (Adler and Helleloid, 1987 p101). They note:

> "The competitive significance of a CIM environment derives less from the power of the component technologies and more from their progressive integration".

This emphasis on synergy still remains with us in the 1990s.

One interesting proposition raised by Adler and Helleloid (1987 p104) is that computerised information systems must be well developed in the various functional areas before integration can take place. The argument for this is that integration is more problematic in terms of acceptance than in technological terms. Technological Integration is the easy bit. The hypothesis supports the top-down/bottom-up approach to advanced technology. The two - stage implementation starts with the top-down parameter setting to ensure systems have compatibility followed by bottom-up system choice and implementation.

The case studies will show that several of the companies investigated took a modified version of this approach.

A number of the writers including Adler (1988 pp44ff) have commented on the "people" differences between implementing discrete systems and implementing integrated systems.

The former may be approached by skills development whereas the latter requires significant organisational and procedure changes. This is taken further in the following section.

Waterlow and Monniot (1986) in their State of the Art study of Computer Aided Production Management (CAPM) identified four levels of CAPM integration, which they qualified as follows:

LEVEL		DEFINITION
0	No CAPM	No CAPM or installing now
1	No integration	Several functions computerised but without regard to integration
2	Partial integration	Several functions linked via common files and co-ordinated controls
3	Full integration	All CAPM functions using common databases
4	Integration of manufacturing systems	CAPM systems designed in conjunction with material conversion, handling and quality systems against manufacturing strategy objectives.

This classification is of limited value for CAD/CAPM integration, and will be expanded in later sections.

2.3 Organisation and Management Changes

One of the best documented facets of the introduction of Information Technology and Advanced Manufacturing Technology is that relating to people issues. In particular, the changes in organisation and management structure has attracted much attention. Whilst, as in other areas, the literature specific to Computer Aided Design is sparse, there would appear to be a number of parallels worthy of investigation.

Collins and King (1988 p182) in their investigations at R & M Corporation look at - amongst other factors - the management of the CAD implementation. They conclude that draughters whose work involves more routine technology may derive more motivational benefits from CAD than those whose work is inherently complex. Managers should therefore anticipate changes in job design among those users employing highly routine technology, and should resist the temptation to manage CAD users in the same manner as non-users. They should develop implementation plans calling for more training, longer payback periods and the implementation of CAD in those areas where greatest improvements in performance can be produced - by implication the routine tasks.

Winch (1983a), as described earlier, notes that CAD/CAM is an integrating technology, which requires stronger organisational linkages for its effective use. Whilst the change is only a shift of emphasis, it is of such a magnitude as to generate considerable organisation stress. This occurs when the "mutually incompatible" organisation structures for CAD and CAM come into the conflict. Mintzberg (1979a) and Galbraith (1977) suggest the use of matrix organisation to resolve the problem. However, Winch argues that this is only one solution.

> "If the environment is such that engineering can be functionally organised ..... then there is no need for organisational change. If, on the other hand, the technology is such that the economies of scale in manufacturing allow the abandonment of functional organisation, there is again no need for matrix organisation."

Haywood and Bessant (1987) studied eight small to medium sized firms which had adopted flexible manufacturing systems. They claim that it is clear that organisation change is important for the successful implementation of new technology, but that there is no clear "best" pattern. Each organisation needs to seek the most appropriate arrangement for its circumstances.

Five of the eight companies had experienced organisational problems during the implementation. They were convinced that companies of their size could not operate without the collapsing of boundaries between previously traditional operations. However, resistance to such change was common amongst managers, particularly middle managers.

Also, Marchrzak et.al. (1987 p160ff) acknowledge the need to develop new organisational structures for enhancing communication among parties within the CAD design function and external to it. A management system is required which reduces the barriers to the engineering/manufacturing interface. However, they offer no ways of achieving such a structure.

Arnold (1983 p37) makes the interesting point that re-organisation is often forced on a company to enable it to cope with a computer. This in turn leads the company to think about its systems, procedures and standards for the first time in years. As a consequence, improvements are brought about in the management and efficiency of the design process which could have been obtained without the implementation of CAD. The suggestion in this is that most companies change their organisation as a reaction to implementation rather than in a proactive manner.

Adler (1988 pp34ff) takes a different approach to the common reorganisation philosophy. He accepts that the more sophisticated technical changes require changes of procedure and of structure. He goes further, to suggest that the more major changes require changes in strategy and culture. However, at that stage he appears to back away from organisational change, suggesting that:

> "A key challenge .... is, therefore, to adapt (sic) organisational cultures to maximise spontaneous cooperation".

This is a "softly-softly" approach compared with the structural changes preferred by Mintzberg, Galbraith et.al.

Tranfield and Smith (1987/1990) suggest that successful implementation of technological change:

> "... requires a revolution in management thinking in many companies".

Major technological change will have an influence on and will be influenced by the business strategy of the Company, and may impact on business performance.

This is evidenced by the number of companies in which the management has failed to take a strategic view of the whole design/production system, and which have "islands" of automation.

Where CAD/CAM is used as an integrative technology, implementation problems are often due to:

> "..... the failure to recognise that new organisational realignments are needed".

In their study of 13 Advanced Manufacturing Technology (AMT) applications, Tranfield and Smith note that the most significant issue raised was that:

> "exploitation required a radical change in how management think and organise manufacturing".

Those companies which had regarded AMT implementation as a step function change, and changed the organisation accordingly were more likely to succeed. This requires, in their terms, a morphogenic change, based upon a clear vision of the planning horizon, rather than the conventional morphostatic change associated with organisational growth.

It is clear, from the implications of morphogenic change, why managers are reluctant to take this approach, and that the impetus must come from the top of the organisation tree.

The research identifies nine elements of a methodology for successful AMT implementation, seven of which have direct or indirect implications for the organisation structure or managerial style.

It is interesting to look at the wider issues of organisational change suggested by Delbeke (1983), Perez (1983) and Perez and Freeman (1988). Tranfield and Smith (1990 p51), following Perez and Freeman (1988) argue that the present trends in technology represent part of a paradigm shift in manufacturing. The paradigm being discussed is the set of rules which govern the workings of society and set the pattern of best practice. It is argued that the paradigm persists for an extended period of time, becoming increasingly inappropriate, until eventually it shifts and a new one emerges. Tranfield and Smith, building on the work of Bessant represent this as a series of 'S' curves and suggest that the current position is as jumping from the fourth to the fifth curve. This is shown graphically in Figure 2.2.

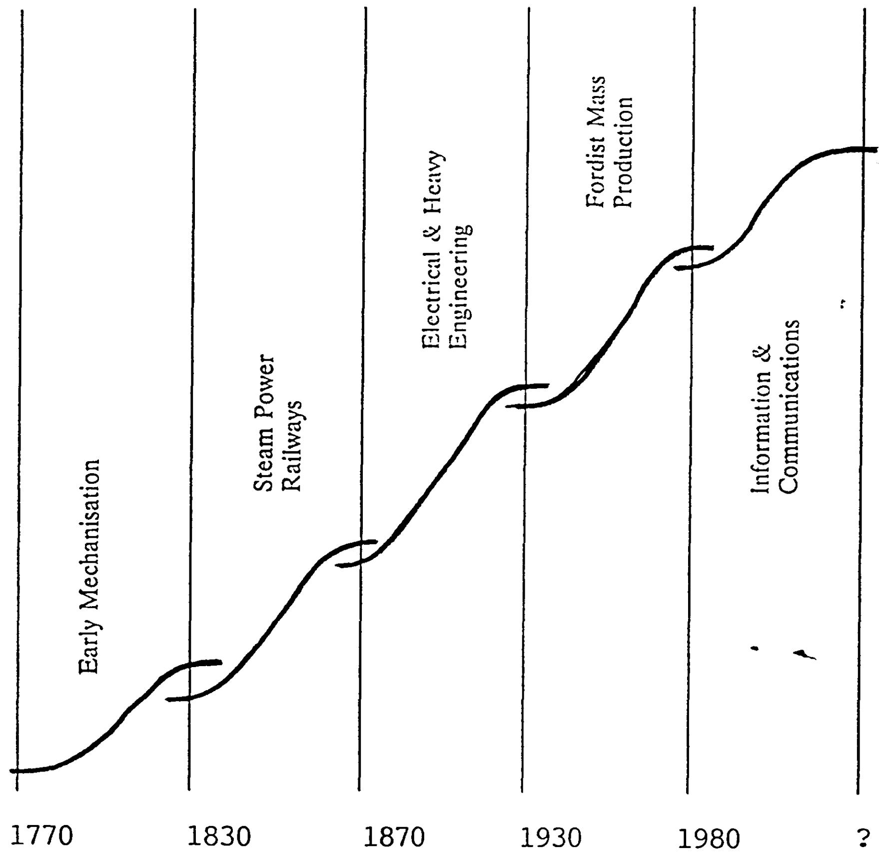


Figure 2.2

The consequence, or corollary of such a shift is that organisational form is changing in many companies, and whilst the "old" form is clear, the shape of the "new" form is not, and companies are experimenting in an attempt to define "best practice".

The implication of this thinking for organisations undergoing major change, particularly where it involves information technology and communications, as CAD/CAM does, is very significant.

Whilst it may be clear that implementation of CAD/CAM involves increased organisational integration, the "best" form for that integration may not be identified for some years.

In addition to the organisational change brought about by the implementation of an integrating technology, there are several other interesting 'human' changes which may take place. Multi-skilling has already been hinted at earlier in the section, but Bessant et al. (1992) suggest that the skill life itself may be shortened, and may indeed be shorter than the employee (working) life.

Accountability was another feature noted by Bessant et al. (op. cit.), whereby individuals would be formed into "cells" with devolved authority, and be responsible to those cells. In terms of management, these cells tend to be supervisor supported rather than supervisor controlled. Management has effectively been devolved to the "shop floor" units which then have more autonomy.

These changes are not, of course, limited to drawing/design offices, but are now commonplace throughout the manufacturing units of forward - looking companies.

2.4 The System Champion

The need for top management to be involved at the early stages of systems strategy formulation has been documented for many years. As far back as 1973, Ettlie (1973 p36) found that management's commitment to:

"...the philosophy of the new approach to manufacturing..."

to be second only to degree of workflow integration in correlation with utilisation rate (tape time) on NC tools.

Carrie and Bannerjee (1984 pp251ff) and others working in the same era note that the "top-down.. bottom up" approach as described earlier is necessary in implementing a manufacturing information system. This implies that senior management will be involved at the specification stage.

The role of the "Project Champion" comes into the literature in the early 1980s (see for example Altschuler et al. (1984), Twiss (1984) p.16). The prerequisite of such a "champion" is that he or she shall be influential in the management structure and shall work closely with the specification/implementation team.

Such a person will have the authority to cross boundaries between departments, reducing inter-departmental conflict. He will also have the ability to make the necessary changes to the organisation.

Haywood and Bessant (1987), looking at Flexible Manufacturing Systems (FMS) in small to medium sized companies found that seven of the eight companies they studied deemed the project champion to be very important or even vital to maintaining process efficiency. The role was often fulfilled by the Managing Director, as may be expected in small enterprises, or by the Production or Technical Director.

The research of Tranfield and Smith (1988) supports the top-down philosophy and in particular the senior management "champion". They take the concept further by involving all levels of management in a "cascade" of ideas generated by the top team.

If these are handled correctly, perhaps in a series of workshops, useful feedback can be obtained on the effectiveness or otherwise of the strategic decisions. There is nothing particularly innovative about this process, which underlies the communications philosophy of many successful firms. However, its express use in Advanced Manufacturing Technology (AMT) implementation is not well documented. Its main strength is, of course, in developing commitment, in this case to the new technology.

Gerwin (1988 p93) picks up on the same sorts of concepts, giving the technical task force, including the new technology champion, the responsibility of recommending hardware, software and vendors. The task force is not, however, a decision making body, and the final decisions on the recommendations are taken by the Company's strategic management. Gerwin notes that this has a number of inherent problems. The greater the technical complexity of the recommendation, the less likely is the strategic management to question it. Unable to judge the future effectiveness and benefits, or even compatibility with its needs, strategic management is faced with a great deal of uncertainty and may make uninformed decisions.

The models described by Tranfield and Smith and Gerwin would not appear to be uncommon nor need they be mutually exclusive, particularly in the small firm where the technical task force and the strategic management team have at least some common members, including the "champion".

2.5 Measuring Implementation Effectiveness

The measurement of the effectiveness or success of an implementation has been discussed by many writers against an abstract background, and few have defined the parameters clearly. The first question to be answered is quite basic - what do we mean by success?

It is logical to look back at the initial justification for purchase, but where this is related to survival or some element of "me too", this is not particularly helpful.

In any case, it is reasonable to suppose that, particularly in companies which are implementing AMT for the first time, expectations will change as the implementation proceeds. In other words, the definition of success, even where it is quite specific in the case for justification, may be inappropriate as a true measure.

Several writers have addressed the thorny problem of defining success in implementation, and these fall into three categories. The first is the proposition that success is measured by the extent that the organisation uses the technology. This was first propounded by Bikson et. al. (1981 p226) and referred to as "'degree' of implementation". Note that the focus is on the organisational use, and not on the use by the individual.

The comfortable factor in this definition is the ease of measurement, since total machine usage time can be used as a broad-brush indicator. What is not so easily defined is the yardstick against which this usage can be measured.

The second category, as supported by Johnson et. al. (1985) is the definition of success as depending on the sophisticated use of technology. This has a number of attractive features, not least of which is its appropriateness for CAD implementation.

Whilst the success of a word processor can possibly be measured by the amount of use it gets, the same cannot be said for CAD. A simple measure of usage time is hardly a satisfactory measure of its use to the Company. By identifying several levels of sophistication, a more precise measure is achieved.

They define the lowest level as "low integration" - use of the word processor (their target system) as a typewriter. This may correspond to using a CAD system as an electronic pencil. Their second "clockwork system" level relies on the development of procedures to speed up the process and reduce keystrokes. The analogy here may be the use of symbols, macros or parametric programs.

The third level of sophistication they called "expander systems". At this level, centres of expertise are developed to handle all word processing. The analogy is wearing a little thin, but the use of a common symbol library may be the equivalent level.

The fourth and highest level was known as "system-wide adaptation", with decentralised systems and operators responsible for their creative use. At this stage the analogy falls down totally, since such a move in CAD terms would be retrograde. A more meaningful fourth step for CAD would be a fully integrated system of CAD workstations. Unlike the word processor situation, this would leave several more levels of sophistication available for CAD/CAM systems.

This is a more meaningful definition of success than the first, but it leaves open the question of the aspiration level of the implementation team at the start of the project.

Different companies will certainly seek differing levels of sophistication, and the success must be measured against this sub-optimal (in most cases) satisficing level.

The third category of definitions contains what Bikson et. al. (1981 p227) refer to as the "fidelity of implementation". This relates to the extent to which the technology is exploited rather than the extent to which it is utilised. There may be situations where CAD is the only way of carrying out a particular design exercise. This would satisfy this implementation criterion even if the usage were low. This definition is, then, more to do with design innovation than with drawing office throughput.

These three categories of measurement can be classed broadly as "business success" categories. Voss (1988b) highlights another series of categories involved with technical success. He, of course, is looking at the problem from an AMT viewpoint, where success can in principle be measured in technical terms. He quotes several measures of success and failure, including:

Success = % uptime

= use in actual production

= has been in use for a year

Failure = Limited number of parts actually made on the system

He also refers (Voss (1988b p58) to the work of Ettlie (1984), who found that manufacturing organisations....

> " would seem to believe that they have successfully implemented new operating technology when two conditions are met. Firstly, when all the bugs have been ironed out and it is working technically. Second, when the operation is working reliably and there is little downtime, and/or the new technology has a high utilisation rate".

This is very similar to the definition of success which Bikson evolved for IT.

Finally Voss develops his own definition of implementation as:

> "the user process that leads to the successful adoption of an innovation of new technology".

Whilst it is difficult to fault this as a definition of the implementation process, it does not further the search for a measure of success.

Wainwright and Bowker (1988 p396) take up Voss's definition of implementation and expand it to incorporate problem definition and performance evaluation of what constitutes success. Their definition is:

> "The user process that spans problem awareness through contextual criteria, which directs the adoption and subsequent development of the requisite process technology".

All we have to do, then, is to define the relevant contextual criteria.

Smith and Tranfield, in discussions with Wainwright and Bowker (Wainwright & Bowker 1988 p396) suggest the following four dimensions for the interpretation of the implementation process:

1) Business validity which represents essentially an examination of the exploitation problem eg Was it worth it?

2) Technical validity an examination of the installation problem eg Did it work?

3) Organisational validity an examination of the change problem or in other words eg Can we cope with it?

4) User validity asks the question did the operators use it?, in essence an examination of the introduction problem.

This analytical tool has a great deal to recommend it, and comments on three of the four dimensions will generally be elicited from different people within the organisation. As Clegg (1988) points out in his tongue-in-cheek review of CAD personalities, the influential Luddite may take a totally different view of implementation success from that of his colleagues, demonstrating that truth may not be absolute.

One aspect of what Wainwright & Bowker refer to as the "business dimension" which merits a good deal of discussion in the texts is the potential for financial benefits.

As was argued earlier, it would appear that many strategic investment decisions are taken on a short or medium term financial basis. Where this is the case the measurement of success or failure is relatively simple, provided that the financial controls are sufficiently good to isolate the effects of the investment.

Hayes and Abernathy (1980 p164) point out the disadvantages of reliance on this method of justification, which produces an environment where no-one can afford failure or a reduction in profitability. Nevertheless, the simplicity of the method seems to be attractive. Senker (1984a p226) suggests one reason for this in CAD implementations is that most CAD suppliers in the past have attempted to sell their systems based upon savings in draughtsmen's labour time. This would seem to be flawed, in that labour costs are normally a very small percentage of a company's total costs. Haywood and Bessant (1987 p8) found that in the eight companies they studied the wage costs were only 20 percent of total costs. In the USA, Senker (1984b) suggested that this figure was greater than 10 percent in only a few industries.

If this is the case, then a company turning over £10 million at 10 percent net profit will have labour costs of £900,000, and design costs (at 10 percent) of no more than £90,000. A cost saving of 20 percent will therefore yield only £18,000 - a very small sum for a drawing office with say, eight draughtsmen.

Success on this criterion is therefore going to be hard to demonstrate.

2.6 Significant Problem Areas

The problems associated with implementing high technology systems are covered widely in the texts. They centre around the two basic issues of people and systems. The people issue revolves around such factors as organisation, skills, resistance to change and commitment, whilst the systems issue includes the "hard" factors of system quality, development, implementation and integration.

2.6.1 Organisation and People Issues

By far the greatest incidence of problems noted in the texts is associated with people, either in terms of management, in resistance to change or in organisational issues.

Keen (1981 p361) looks towards a strategy for the implementation of Management Information Systems (MIS), of which CAD/CAM can be regarded as a subset, based upon the premise that the organisation is the major issue.

He looks closely at the problem of "social inertia", and the human aspects which cause it, supporting this with a tactical approach to dealing with it.

Keen also looks at the issue of "counter-implementation" - a political approach to causing implementation failure, which includes diversion of resources, deflection of goals and dissipation of energies.

Again, he looks at some tactical methods of coping with counter-implementation. Compare this with Clegg's (1988) "Influential Luddite", who has the power and motivation to take this sort of action.

Eason (1982 p58ff) also looks at the organisational end of implementation, taking as a starting point the "traditional" consequences of implementing computer systems which pervaded the texts at that time; job losses, changes in job content, health problems, retraining, increase in formality, changes in power and influence and industrial relations changes, all of which are social system factors.

He expresses strongly the desirability of user involvement during the whole of the selection and implementation period, but argues that there is, in practice, a rather narrow window of time in which effective contribution can be made. This is bounded by the level of understanding or learning at the bottom end and the need for system finalisation at the upper end.

His methodology for systems development seeks to keep organisational learning about technology ahead of system development so that the former can inform the latter.

Eason's approach is "bottom-up" and "user-led", which has certain merit. For instance, it is particularly good for gaining the commitment of users and others at low levels in the organisation to the change about to take place.

It does not guarantee commitment, but it increases the probability. However, it leads to morphostatic change rather than morphogenic change, and it is particularly poor where a system needs to be reconfigured strategically. It takes little account of the need, if any, for major, system-wide change. It could, indeed, lead to a situation where functions are automated which may have no place in the planned system.

The author has observed this frequently in organisations which have computerised discrete functions to provide "islands of automation" rather than looking at the overall need for integrated systems. The result has been on occasions that the "islands" have been subsumed at a later date, rendering the equipment redundant.

In a study of eight FMS/FMC implementations, Haywood and Bessant (1987) found that five of them stressed that it was organisational problems which presented the major interfacing problems and contributed to excessive timescales. Managers were more likely to resist change than the shopfloor workforce, and being in a more influential position they could have a greater effect on the implementation. In particular, they could influence the attitudes to training, which was considered as an essential adjunct to FMS introduction.

Haywood and Bessant also noted that the change in skills needs led to a problem of recruitment of a satisfactory level of people. It is usually assumed that existing personnel can be retrained to cope with the new technologies. This may be so in the majority of cases, but the training in itself makes the staff marketable, and a more rapid staff turnover may be the result. Hence the need for continuing training and for skills recruitment.

Adler (1988 p43) quotes a McKinsey & Co survey of CAD/CAM implementation ("Forging CAD/CAM into a strategic weapon". January 1984) which claims that the benefits of CAD/CAM could be tripled in terms of reduced cycle time were it not for the lack of managerial commitment.

Adler further suggests that labour requirements are amongst the least well managed of all the implementation issues. He claims that the skills impact of new technology is low priority compared to the technical capabilities and cost savings. Similarly, when the equipment arrives, training comes second to debugging the system and getting production rolling again. The result is that the attention to optional skills mix tends to be a firefighting exercise brought on by a need to absorb displaced people or to deal with job classification grievances.

Haywood-Farmer and Hill (1989 pp71ff) in their survey of CAD implementation in the Canadian consulting engineering industry found a general acceptance amongst users that CAD demands more management skills. However, they also found that half the respondents who accepted this felt that their senior staff were not prepared for CAD systems to be a success. Unfortunately the measure of success is not reported.

This work is interesting, in that it is the only recent work which looks at the managerial skills level in actual implementations despite the wealth of theoretical writing on the topic. All other implementation studies involving skills reporting concentrate on the skills of the users - designers, engineers or draughtsmen - rather than the management.

We have to go back almost a decade to Arnold and Senker (1982) to find further empirical evidence of the shortfall in managerial skills. A number of examples of the failings of management serves to highlight the need for training prior to implementation. The authors go as far as to suggest government promotion of the raising of skill standards in management in the short term and in influencing the long term education and training of managers. It could be claimed that this need is still present ten years on.

In summary, there is a consensus that organisation and people issues feature strongly in system implementation, whether the implementation involves morphostatic or morphogenic change.

It is interesting to note the apparent general shift in emphasis from user resistance in the early 1980s to management resistance in the late 1980s.

The one exception cited is Arnold and Senker (1982) who were preaching the need for management training a decade ago.

The reason for the apparent shift has not been investigated or assessed, but it could have something to do with the decline in organised labour over the period since about 1979. It is probable that the texts of the early 1980s reflect the needs of the day to take operators into account, particularly in the larger businesses such as the automotive industries where advanced manufacturing technology was being implemented and trades union were very strong.

Later in the decade, as managers were given the authority to manage, and as the technologies became more complex, the need for skilled implementers at managerial level appears to have become more acute.

2.6.2 Technical Issues

Not all writers consider the technical issues to be a vital area of study. Indeed Wainwright and Bowker (1988 pp395ff) attack the traditional approach to implementation of advanced manufacturing technology in general for its concentration on mechanistic issues without regard for the organisation and management dimensions of the process. This is quite a switch from the situation only six years or so earlier when the reverse appeared to be the case.

They build on the work of Tranfield and Smith (1987) to create a multi-dimensional implementation model. This model suggests merit in looking to four important factors - technical, organisational, business/strategic and user issues.

Adler and Helleloid (1987 p104) expand upon the technical issues of implementation and integration, which would appear to be particularly relevant in terms of CAD/CAM.

They suggest that:

> "Computerised information systems must be well developed individually in both engineering and production functions before integration can occur. In other words, system effectiveness will be greater when all potential users of the system have already developed their own computer capabilities before the integrated system is developed".

However, they go on to suggest that the most difficult task is not the integration of software but the acceptance of the tools, which will be more acceptable if they are well designed. This supports the hypothesis propounded by Lucas (1985) discussed earlier. They further suggest that this can be better achieved if the users are able to take an active part in the development, again supporting work of Eason (1982).

Peccei and Guest (1984 pp84ff) take a totally different perspective on the problems of implementation effectiveness. They suggest, quite reasonably, that the measurement of effectiveness depends upon the definition of success. What may be regarded as successful in one company may be inappropriate in another. Goals may be vague, ambiguous or simply unrealistic, and therefore may not provide a sound basis for assessment.

Goals may also be different across the various interest groups, and Voss (1988) notes that the goals may well change during the implementation.

These factors are clearly going to be important when attempting to define the problems associated with implementation. Peccei and Guest (1984 p95) have therefore developed a new framework for evaluation which focuses on three areas; the outcome/effectiveness of change, the nature and quality of the change process and the ratio of inputs to outputs in the change process. They use the framework in an analysis of a word processor implementation at British Rail.

Lucas (1985 p75) takes a more balanced view of implementation than those already discussed. He accepts the importance of the human aspects:

"Favourable attitudes on the part of users should be extremely important in implementation: attitudes have an action component, and favourable attitudes are consistent with high levels of use and satisfaction with a system".

However, he also takes into account the possibility that other factors may be equally important.

"The technical quality of systems is important; it directly affects our attitudes as users and also makes it easier to use the system physically. For example, a system with difficult input requirements or a difficult language for user input will be used less than one with a good technical design".

He acknowledges that lack of these two factors may lead to lack of system usage, ie implementation failure. This more balanced approach to the problems of implementation would appear to provide more scope for further work than the unilateral approaches described previously.

2.7 System vs Implementation Success

An implementation can clearly be a failure for one of two reasons. Firstly the system itself may not be a success. In Quality Assurance terms it may not be "Fit for Purpose". Indeed it may even, in consumerism terms, be "Not of Merchantable Quality". More likely, though, it may simply not be user-friendly, to the extent that it cannot be implemented successfully.

Secondly, the system may be perfectly satisfactory, and may be a good match to the Company's needs, but may be implemented badly.

In these terms, a successful implementation can only be achieved if a technically satisfactory system is implemented well. The best possible implementation of a poor system, or the mediocre implementation of a satisfactory system can at best be moderately successful, whilst a mediocre implementation of a mediocre system will almost certainly be regarded as a failure.

Looking back at the section on Justification (Section 2.1) it is clear that justification of a system is based entirely on the assumption of a successful implementation. Consideration is given only to the benefits to be obtained, in financial or other terms once the system is up and running.

As examples of this, Arnold (1983 p36) lists as the potential benefits of a system, which include increased productivity. accuracy, presentation and perception of the Company. Primrose et. al. (1985 pp92,93) concentrate more on the company-wide costs and benefits of a system, whilst Gerwin (1988 p91) sees advantages in flexibility, which he regards as a long-run intangible consideration.

Justification, then, appears to be a comparison of the benefits of a system with the costs of a system. It is normal to ignore the cost of "getting it right", which may be significant, or in some cases even prohibitive.

As a criticism of the justification process, this is perhaps unfair, since the aim of the company in installing CAD is not to fail but to be successful. To justify a system on the assumption that it would not be successful would clearly be folly. Whilst justification concentrates on the "systems" factors, Section 2.6, which deals with implementation problems, focuses predominantly on the implementation process and its level of success. The reasons for this are not enumerated in the texts, but there are at least three possibilities:

a) A system manager is going to be reluctant to admit that the system which he and his team have chosen is not satisfactory for the job in hand.

b) Success of the system as a whole, in financial and time-saving terms is difficult to evaluate, since it may be affected by changes in the type of work being done, the volume of work being done, technological advances etc, which in turn may be affected by the value of the pound, market changes and company strategy.

c) Implementation problems are easy to spot, and in management terms are less painful to acknowledge than inherent system problems. How odd this is when effective implementation is surely a management function

We find, therefore, a great deal in the texts about organisational change (Keen (1981), Eason (1982), Haywood and Bessant (1987)) and managerial commitment, or lack of it (Adler (1988), Haywood-Farmer and Hill (1989)). We also find a considerable amount written about the systems themselves, but on looking deeper we can see that they concentrate on the 'implementation' end of systems rather than on systems failings. This can be seen in Adler and Helleloid (1987) and Lucas (1985).

The other factor missing from the texts is any criticism, constructive or otherwise, of what we may call the 'mechanistic end' of the implementation process. In this we include the use of a Project Champion and the Implementation Team.

It seems strange that the features which are considered as essential by a high proportion of writers should have so little written about their effectiveness.

2.8 Summary

As was noted earlier, the literature on the implementation of CAD systems is a little thin, and it has been necessary to look for similarities in the field of Information Technology. Even there, the coverage of small businesses is sparse, whilst the field of CAD in small businesses is virtually untouched.

The literature which has been surveyed has been broken down, somewhat artificially, one may argue, into categories which can be studied independently. The categories were, to some extent, self-selecting, in that they were the major issues perceived by the majority of writers, even though the section titles may not correspond to the terminology used by those writers.

The section on Justification highlights the perceived benefits of a CAD (or I.T.) system. Many of the writers list the benefits which would form the basis of the justification argument, and the writer has seen such lists in small and medium sized firms used for just that purpose. One important factor in this is that justification in these terms is regularly found for a first investment in CAD.

It would be interesting, but beyond the scope of this work, to look at the justification for expansion of a system or its replacement by a more sophisticated system. It is felt that the factors for justification may be quite different.

Financial justification is regarded with some scepticism by a number of writers, particularly where techniques such as Payback, Discounted Cash Flow (DCF), Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) are concerned. Primrose et. al. (1985), Senker (1984), Hayes and Abernathy (1980) and Gerwin (1988) are particularly scathing about such short-term quantification methods. It is interesting to compare these traditional accounting methods with modern Japanese investment decision making, which takes a much longer view of the investment. It would be interesting, but again beyond the scope of this work, to compare the justification methods of small Japanese companies with those in the UK.

Whatever justification method is used, the outcome of it will be a decision on whether to proceed, and if it should do so we may expect the justification to form the basis of the measurement of success.

The section on Systems Integration starts off with the premise that the CAD system is not an end in itself, even for the very small firm, but a step towards an overall Manufacturing and Management Information and Control system. Integration of systems implies linking across "traditional" functional boundaries, both horizontally and vertically, and several writers, including Adler and Helleloid (1987) point to the "people" issues of these cross-functional systems.

This is taken further in the section on Organisation and Management Changes, where the management of a CAD drawing office is contrasted with a traditional drawing office. The need for, and the form of organisational change is discussed by Mintzberg (1979a) and Winch (1983a) who argue for and against matrix management respectively.

The need to break down the traditional barriers between departments is identified by several writers. Adler (1983) goes so far as the suggest that these organisational changes can in themselves bring about efficiency improvements over and above those provided by the CAD system.

There is scope here to compare and contrast the changes which take place in UK based companies with those in German or Italian companies, which tend to have much more clearly defined structural boundaries and with Japanese companies which generally have flatter structures.

The need for organisational change is accepted by most writers, and several suggest, quite reasonably, that this needs to be driven from the top. The concept of System Champion is therefore propounded by several writers from Altschuler (1984) onwards. Those who mention such a champion agree that it is an essential for successful implementation.

Tranfield and Smith (1988) take this further, building it into a "cascade" of information dissemination not dissimilar to the concept of team briefing now used by many large and medium sized companies and increasingly by small companies as a communications tool.

The correlation between effective communication within a company and the ease of implementing integrating technologies would make interesting research.

It would be reasonable to expect success of a system implementation to be measured against the same factors as were used for the justification, but the section on Measuring Implementation Effectiveness shows that this is not so simple as it seems. Back in 1981 Bikson et. al. (1981) suggested that a good measure would be the extent to which the organisation uses the system. Johnson et. al. (1985) recognise that the level of sophistication of use of the system is important, but do not recognise that some companies, particularly small companies, may not seek sophistication. Bikson et. al. (1981) look at the "fidelity of implementation", i.e. the exploitation rather than the usage of the technology.

The potential for financial benefits is discussed widely in the texts. Whilst in the past CAD salesmen have sold systems on this basis, there is general agreement that success on the basis of financial savings is likely to be hard to demonstrate.

Not all systems can be regarded as a success, regardless of the measures used, and the section on Significant Problem Areas highlights what can go wrong. In general, it subdivides into Organisation and People problems and Technical problems.

Not surprisingly, this section covers much of the ground of earlier sections in which writers described "how to" implement, based upon what they observed to be the problem areas.

The final section deals with the twin factors for eventual success - system success and implementation success. It suggests reasons for the justification of systems concentrating on systems features whilst the problems tend to home in on implementation issues. There is potential to expand this section by researching the implementation problems in more detail, looking beyond the "claimed" problem areas to the real problem areas, to see whether systems feature strongly.

2.9 Research Focus

The literature search raises many more questions than it answers and it is clear that a number of significant areas for research are opened up. It is difficult, however, to overlook the overwhelming mass of literature which suggests that in advanced technology implementation, the people and organisational issues are as important if not more important than the technological issues.

Some writers go so far as to to suggest that the success of an implementation hinges around the way in which an organisation can change or adapt to the requirements of the new technology.

In looking at the success and failure of CAD implementation in small firms, there are several areas which could be explored in the light of the findings, and some of these are described below.

a) Concentrate on the people aspects of the six chosen implementations to the exclusion of the technological aspects, following the work of earlier writers. One problem with this approach is that with such a small sample size, it is quite conceivable that one or more may have experienced the sorts of technical problems encountered in the texts. This could lead to conclusions based on invalid or erroneous information.

Consider, for instance, the unlikely scenario that CAD implementations always fail in small firms because inexpensive CAD systems are technologically inferior. An examination of the people and organisational issues in this instance may yield a perfectly reasonable thesis that had little to do with the actual causation.

b) Ignore the overwhelming body of literature on the basis that for all the research which has been carried out, no "solution" has been found, and seek a "solution" based upon technological issues. This is the other extreme to that described above, and is equally unlikely to be fruitful.

c) Compare and contrast the implementation of systems in large and small firms, and seek out the common factors which run through the successes and failures. This gives rise to two fundamental problems. Firstly, the writer has no access to large firms, and the literature on CAD implementation in large firms is insufficient to support a comparative study. Secondly, we cannot be sure that the reasons for failure or success would be the same in small and large firms, so drawing parallels may be counter-productive. Indeed. research in this area could be most interesting.

d) Take an open-ended look at the case material available, using people issues as a focus in deference to the writers who have highlighted people and organisational issues. Look, at the same time, for other, non-people issues, which may be relevant in the context of the small firms studied. In other words, keep the research focus deliberately blurred so that no doors are closed too early.

This approach gives the impression of being woolly, but it has a certain attraction that open-mindedness and lateral thinking can, on occasions, give rise to revolutionary ideas and concepts.

To avoid the focus being too blurred, and giving rise to masses of extraneous information, a small number of minor foci should be identified, and it would be logical to use those most commonly encountered in the texts.

In summary, the research should have the following foci or parameters:

1 People and Organisations - this may be sub-divided

2 Level of Integration

3 Prior Computer Knowledge

4 Expectation of the System

5 Justification of the systems

6 Level of Satisfaction.

3.0 RESEARCH METHODOLOGY

This chapter sets out to define the methodology used in the work, and to compare and contrast it with alternative methodologies. It also seeks to place the work into the spectra of research methodologies developed by other writers.

Section 3.1 looks at the inductive/deductive spectrum, and the way in which it can be perceived as a cycle into which one may break at any point.

Section 3.2 examines the definitions and descriptions of case studies developed by various authors. Whilst there are very few of them, they are telling about the approach of the author to the case study. The section develops a working and purposeful definition of a case study.

Section 3.3 recognises the dangers of collecting free-form data, and highlights the need to have a well-defined focus prior to the data collection.

Section 3.4 describes the approach taken to the research. It explains the reasoning behind the use of a questionnaire for data collection and how it was used.

It places the approach into the context of current research thinking by such writers as Schein (1987), Fredricks and Ludtke (1975) and Bogdan and Taylor (1975).

Section 3.5 describes the actual process of the methodology, from the selection of cases through to final exit discussions. It includes details of the questionnaire and the process used in data collection. It explains how cases were "deselected" to give a shortlist for detailed investigation.

The arguments for and against the use of case studies in research are presented in Section 3.6 which also argues the case for the use of a small number of such studies.

Section 3.7 looks briefly at a method of analysis of case study material, taking a three-stage approach of within-case investigation, cross-case pattern searching and within-case pattern investigation.

3.1 Induction vs Deduction

It has long been established (Brewer & Hunter (1989); Eisenhardt (1989); Evered & Lewis (1981); Gill & Johnson (1991); Mitchell (1983)) that research falls into two categories: Deductive - a process which leads from theory to observation, testing the theory, and Inductive - a process which builds theory from observation. Kolb, Rubin and McIntyre (1979) tie the two methodologies together in a model which they refer to as an Experiential Learning Cycle (Fig 3.1)

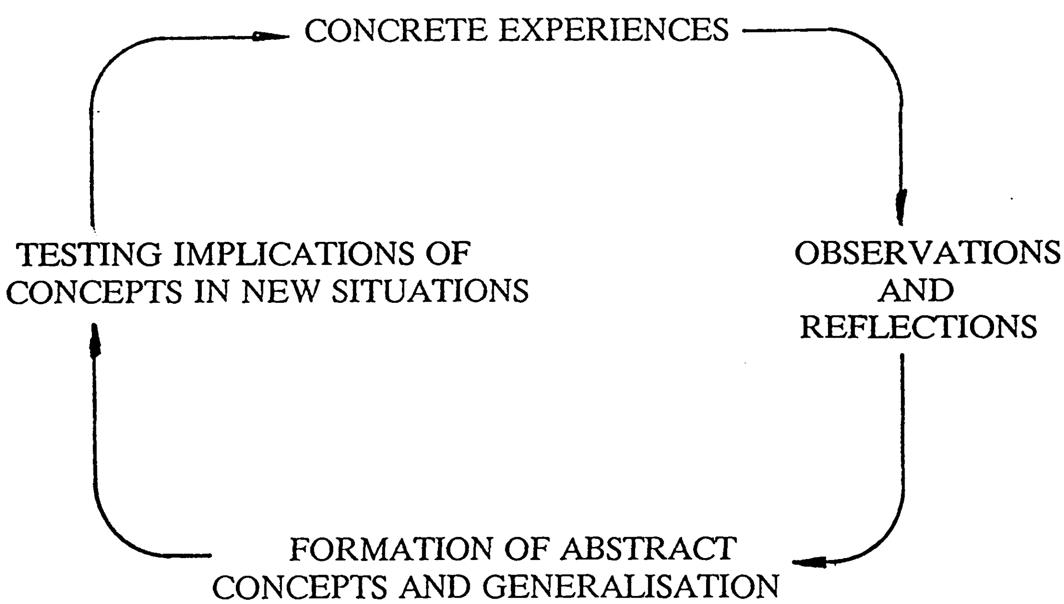


Fig 3.1

The two methodologies can be seen to be represented and described by the two sides of the cycle. The left hand side corresponds to deductive research whilst the right hand is akin to inductive research.

As a model of learning this seems to be sound, but it misses a fundamental point that in practice research often encompasses elements of both methodologies. Indeed Gill and Johnson (1991) suggest that Induction and Deduction are at opposite ends of a spectrum of methodologies, and research will take its place on this continuum between an emphasis on nomothetic methods and an emphasis on ideographic methods. At the nomothetic end of the continuum the methods might include laboratory experimentation, whilst the ideographic end encompasses ethnography.

Note that the work of Kolb et al. (1979) is based on Wallace (1971 p18), who developed it as a model of the scientific process.

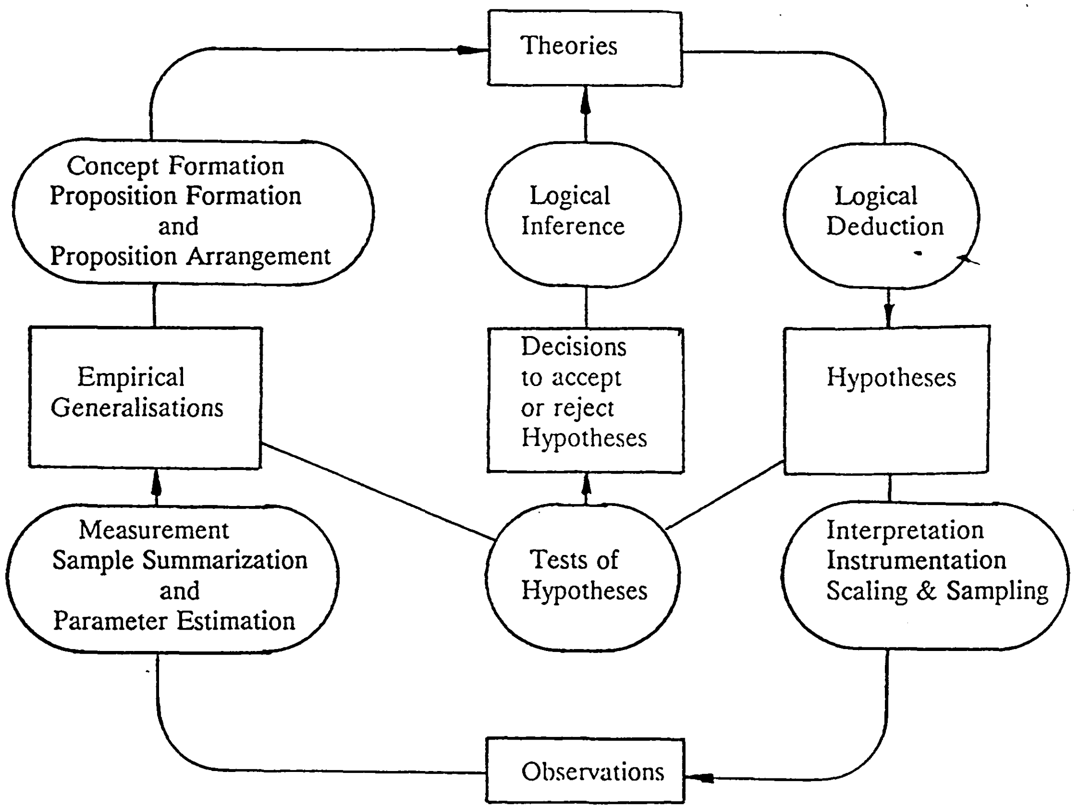


Figure 3.2

The Principal Information Components, Methodological Controls and Information Transformations of the Scientific Process

One of the problems with theory orientated research, whether it be inductive (theory building) or deductive (theory testing) is that:

> "... most empirical generalisations are logically consistent with a good many theories, and, as this implies, different theories lead to many of the same predictions". (Brewer and Hunter (1989) p35).

They point out that the generalisation that homicide rates increase after wars is consistent with a variety of theories, which in turn can lead to a variety of expected outcomes.

Often the only or at least the most logical way out of this impasse is to establish a second or a third empirical generalisation which will narrow the range of possible theories. A second possibility is to test the validity of the inducted theory.

In effect this means we have taken Kolb's cycle (fig 3.1) a full circuit, and the second time round the theory should be more plausible.

Testing theory in this manner may not be so straightforward as it seems. If we take Denzin's (1970) approach to qualitative research as a pattern, he suggests a six stage process:

1 A rough definition of the phenomenon to be explained is formulated.

2 A hypothetical explanation of the phenomenon is formulated.

3 One case is studied in the light of the hypothesis, with the object of determining whether or not the hypothesis fits the facts in that case.

4 If the hypothesis does not fit the facts, either the hypothesis is reformulated or the phenomenon to be explained is redefined so that the case is excluded.

5 Practical certainty may be obtained after a small number of cases have been examined, but the discovery of negative cases disproves the explanation and requires a reformulation.

6 The procedure of examining cases, redefining the phenomenon and reformulating the hypothesis is continued until a universal relationship is established, each negative case calling for a redefinition or reformulation.

The problem is clear. The researcher needs to set out on a search for negative cases in order to disprove the hypothesis, since he is unable to prove the hypothesis. Whether six cases would be sufficient to establish any type of hypothesis is open to debate, and the alternative approaches are discussed further in Section 3.6 where Mitchell's (1983) single case deductive approach is investigated.

3.2 Definition and Description of Case Studies

Over the years there has been much written about the case study and the use of case study material, but the number of writers who have committed themselves to a definition of a case study is very small.

Goode and Hatt (1952) define the case study as:

> "a way of organising social data so as to preserve the unitary character of the social object being studied".

Yin (1981 p59) extends this somewhat:

> "... the distinguishing characteristic of the case study is that it attempts to examine (a) a contemporary phenomenon in its real-life context, especially when (b) the boundaries between phenomenon and context are not clearly evident."

Mitchell (1983 p192) takes this even further, identifying the reason why case studies should be of interest, and building this into his definition:

> "A case study (is) a detailed examination of an event (or series of related events) which the analyst believes exhibits (or exhibit) the operation of some identified general theoretical principle."

A case study, then, is not a case study unless it falls in with a set of predefined criteria. This would appear to damn in one sentence the whole ethos of inductive methodology, although the assumption is clearly inaccurate, since later in his paper he writes (p197):

> "...most social anthropological and a good deal of sociological theorising has been founded upon case studies".

Indeed it has, and the literature is the richer for it.

More recently, Eisenhardt (1989 p534) has produced not a definition, but more of a series of statements which encapsulates the meaning of the term Case Study. She writes:

> "The case study is a research strategy which focuses on understanding the dynamics present within single settings."
>
> "Case studies can involve either single or multiple cases.."
>
> "Case studies typically combine data collection methods such as archives, interviews, questionnaires, and observations. The evidence may be qualitative (eg words), quantitative (eg, numbers), or both."
>
> "Finally, case studies can be used to accomplish various aims: to provide description ..., test theory ... or generate theory."

Whilst not being a definition in the true sense, this encapsulates the essence of the case study without presupposing the intent of the researcher.

These diverse writings between them lead to a working definition which will suffice for the present. Case Study research is a research strategy which examines an event or a series of events for the purposes of providing description or testing or generating theory.

This definition takes the case study away for the realm of general ramblings and makes it purposeful. Unlike Mitchell's (1983 p192) definition, this does not preclude the narrative account of an event or a series of events, since it does not presuppose that those events portray:

> "... features which may be constructed as a manifestation of some general abstract theoretical principle".

The rationale behind the case study approach is discussed in Section 3.4.

3.3 <u>Theory Building</u>

Free-form data collection in even a small number of companies without some form of research focus is a recipe for the generation of vast volumes of data which cannot reasonably be analysed or even assimilated.

Mintzberg (1979a) recognised that some initial narrowing of the field of research was necessary.

> "No matter how small our sample ... we have always tried to go into organisations with a well defined focus".

This appears, on the face of it, to be contradictory to the theory-building ideal that there should be no hypothesis to test, but this is not the case.

We may identify the research question in order to constrain the field of research, but it has to be accepted that this constraint, and indeed the research question, may shift in the light of the research itself. In other words, whilst we start with a research focus, the developing theory may cause this focus to be moved. This brings us back to the Experiential Learning Cycle of Fig 3.1.

3.4 Methodological Approach

In order to understand fully the approach to the current research it is important to place it in the context of the environment whence it arose.

As described in the Introduction, the author was in an excellent position to observe the implementation of Computer Aided Design systems in small companies right from the conceptual stage. He was instrumental in the selection of systems for all the companies described in Section 4. Being aware that of the 20 or so systems implemented, not all could be described as unqualified successes, he sought to identify the reasons for this by closer investigation.

Several research methodologies were open to the author. Whilst experimentation in its various forms was not an option in the later stage of the implementation, some degree of participation was almost inevitable. Having considered the two broad-based techniques of Ethnography and Survey, and acknowledged the advantages of each methodology, it was decided to use elements of both.

It was clearly not going to be feasible, as a consultant, to revisit the sites and discuss the CAD implementations passively. Having been involved in selection of the system, the author would inevitably become involved beyond the pure observational role. Nevertheless, the objective of the exercise would be to collect information, not to continue the consultancy role, and this would need to be agreed explicitly with the company representative.

Prior to the post-implementation visit to the companies some information was already available. The initial reports gave a general background to the companies, and the reasons for implementing CAD. This did not necessarily go as far as listing the expectations. The "stories" were, in fact, far from complete, yet the wealth of data and their variety was substantial and relatively unstructured. If an inductive approach were to be taken, then the collection of further data would need to be much more structured.

The two-pronged approach would consist of observation - participant or non-participant, structured using a questionnaire or research instrument. It was never intended that the questionnaire should be followed slavishly to the exclusion of other information, but that copious field notes should be taken during the visits.

In this way, the best elements of observation and open-ended questionnaire survey would be utilised.

Whether the observational style at this stage would be participant or non-participant was open to conjecture, and arguably not too relevant. On first impression it would be what Freidrichs and Ludtke (1975) would describe as "non-participant, controlled, standardised", where the observer is not directly involved in the action, but where there is an observation schedule. Participant observation, interventionist or non-interventionist, was not to be sought specifically, since the event being studied - the implementation act - was less relevant than the effects of the event.

However, the author would be conscious at all times of his former participative role. No problems were expected regarding the language of implementation or in acceptance as an observer, since the implementation itself and not the implementers was to be the focus of the observation.

In practice this may not be totally acceptable to the participants, and some elements of the situation may be excluded as a result.

If we take Schein's (1987) breakdown of qualitative research into the Clinical and Ethnographic methods, accepting that these are points on a continuum and not discrete perspectives, the aim of the exercise would be to take up a position towards the ethnographic 'end' of the spectrum. Previously, of course, the author had been working towards the clinical end in selecting the CAD system for the company - intervening in order to change the status quo within the system.

The phrase "...towards the ethnographic end..." used above was chosen with care. It is difficult to visualise a situation whereby observation of this type could be anything but interventionist. The very fact that the system is of interest to an external observer causes those involved to take more notice of it and probably change it or their perceptions of it. In Schein's words (Schein 1969 p 97):

> "If I interview someone about his organization, the very questions I ask give the respondent ideas he never had before. The very process of formulating his own answers gives him points of view which he may never have thought of before."

This is most relevant in the current research, where the author sought to elicit the thoughts, feelings and opinions of those close to the CAD systems. This would inevitably cause some of them to analyse their own thoughts. In open discussion, they may even change their opinions in the light of the opinions of others.

It was hoped that having worked at both extremes of the spectrum would bring its own benefits. A breadth of information would be obtained from the ethnography, as predicted by Schein (1987), whilst the elements of the clinical perspective - the probing in particular areas - would give a quality of data not available to the ethnographer in those specific areas. However the collection of qualitative data by these means means that the researcher may affect the validity of the results of the observation, acting as a "sieve" to collect non-representative data.

The same can, or course be said about the survey researcher, who may unwittingly (or wittingly) choose:

> ".... questions which correspond to the notion of what is important and consequently force reality into a preconceived structure" (Bogdan and Taylor (1975)).

On the the hand, it can be claimed (see Mintzberg (1979a) in Section 3.3) that a research focus is essential.

It was in recognition of these inherent dangers that a multi-pronged approach was formulated. This would combine participant observation (system selection) with non-participant observation (system re-visit) and survey (structured open-ended questionnaire). Whilst it is accepted that the same bias may run through all three techniques, the fourth element of ethnography (free-form field notes) may eliminate some of the risk.

The whole of the information collected by whatever means and from whatever source would be collated and case studies developed. These would not be large scale in-depth single-case stories, but would be short summaries with sufficient depth to enable patterns to be observed and conclusions to be drawn both within and between the cases.

3.5 Methodological Process

This section describes the actual process used for data collection, against the background of the approach already described.

All the initial selection work for the companies was well documented, and this included a description of the Company, its approach to design and a detailed breakdown of its needs in CAD/CAM terms.

Where the Company was already computer literate, this was also recorded. As the outcome of the original study had been a CAD/CAM system selection, a short-list of systems was described and the merits discussed.

In all cases, whether or not a higher level of integration was intended, the potential for expansion was explored and the potential benefits listed and costed where applicable.

The potential cost savings were usually included in the reasoning for eventual implementation, although in most cases a purely financial justification based on the normal financial measures of payback, return on capital employed, discounted cash flow etc. was not possible.

However, the reports were not limited to financial measures, and in all cases other benefits such as reduction in design turnaround time were stated and argued.

The selection reports had been carried out over a period of several years, and the style had changed in that time, as had the overall competence of the consultant. The result of this was that the later cases homed in much more quickly on the selection process itself, and were higher in technical content. The information peripheral to the selection process had been reduced to the bare minimum, and was not sufficiently detailed for useful comparisons to be made.

In order to bring all the information up to the same base level, it was decided to prepare the questionnaire shown in Appendix 1. A "Standardised Research Instrument" had been prepared by Winch (1988) for interviewing senior manufacturing and engineering managers and key departmental heads as part of a study into CAD/CAM implementation. Whilst much of the instrument was inappropriate to the current research, parts were directly relevant, and the whole acted as a prompt for some of the more important issues in CAD/CAM implementation.

The resultant questionnaire covered a great deal of ground. Indeed it covered all the topics included in one or more of the original 20 case studies, plus others which had been raised by Winch's work.

It was considered important at that stage not to narrow the field of data collection by being selective with the questioning, but to collect as much data on as wide a front as was practicable. One of the reasons for this was essentially practical.

Whilst the relationship with the target companies was good, it would not be possible or desirable to return to the companies time after time for further information. A second reason was that at that stage the "important" issues had not been identified, and a deductive approach was not feasible.

Of the 20 or so original studies, six were selected for further investigation. Deselection of the companies was carried out firstly on the basis of geography. Those over two hours' drive from Sheffield were discarded. Next, those companies where the implementation had been influenced to a high degree by external factors were discarded.

One such Company had substantially changed its product mix, and hence its design/draughting style since the initial study. One other had had major problems with the system supplier and had abandoned the system in favour of an alternative vendor. Finally, those companies where the consultant or his associates were carrying out further work were discarded.

Primarily this was to avoid any compromising of the further work being done by other consultants, but there was a secondary reason.

Two of the companies were undergoing management training, which involved some restructuring of teams. Since in both cases this work involved the design section, the implementation may have been affected in a way which could not be identified. This was considered too high a risk.

The result of the deselection process provided a shortlist of eight. This was further reduced to six by discussion with the chief executives of all eight companies. Two considered that the information which they may be asked to provide would be too sensitive commercially, and they would prefer not to be involved.

The six remaining companies formed a good cross-section of the studies in all respects. One, for instance, was a well documented and spectacular failure in terms of implementation.

A second was equally spectacular and even better documented, but had progressed exceedingly well against ambitious targets.
All six had extremely cooperative management teams.

Without being too particular about definitions or units of measure at this stage, the cross-sectional nature of the cases can be shown diagramatically, as in Figure 3.3. Each point on the continua represents a case.

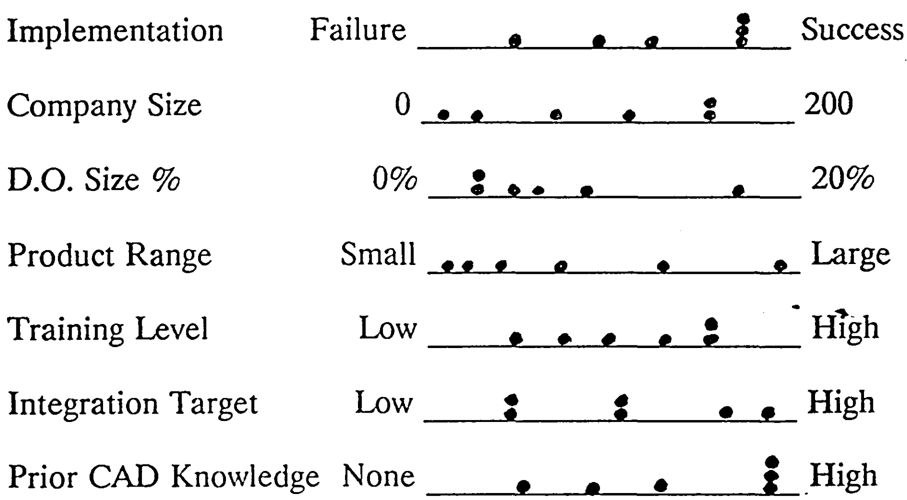


Figure 3.3

Taking the admittedly narrow spectrum of criteria, it can be seen that the "scatter" across the figure is good, and there is little bunching.

It is not claimed that these cases are typical in any way of British industry, or even of small businesses, and as will be argued elsewhere, this is not important in the present context. The important factor is that the cases appear not to be unrepresentative, in other words, apart from all being small firms, there does not appear to be any significant bias, at least on the factors chosen.

Interviews with the respondents took place over a period of about eight weeks, some six to eighteen months after the initial CAD study had been completed, with approximately two half days being spent with each company. The interviews were structured by using the questionnaire as a prompt.

The relationship with all six companies was sufficiently good to allow for unrestricted access to the systems, the management and operators of the systems and to those involved peripherally in their implementation. The diversity of the questions being asked made it essential to interview at least two people at each company. One of these was always the individual responsible for managing the implementation.

The second was generally the chief executive, and where necessary a third member of the management team was involved. The schedule was used to ensure a baseload of essential data. No time limit was put on the interviews, and the respondents were encouraged to talk in general about the CAD/CAM system. The whole of the conversation was documented by hand.

3.6 Case Selection and Validity

There are two distinct and conflicting stances on the validity of using case studies in research. The first is that a single or very small number of case studies cannot give rise to valid theory, whilst the second suggests that a single case is adequate. The argument for the former stance is that it is impossible to ensure that a case is 'typical' - that it is representative of a large number of other cases which could have been used had the necessity arisen.

If we take a numerical analogy we can see that there may be some validity in the argument. Consider for instance the sequence of numbers:

$$2 : 4 : 8 : 16$$

We can draw relationships from these numbers which would lead us to believe that a similar sequence starting with 3 should be:

$$3 : 6 : 12 : 24$$

This is based upon the hypothesis that the numbers are doubled as they progress. Equally, we could conclude that the sequence should be:

3 : 9 : 27 : 81

This uses an equally plausible hypothesis that each number is the multiple of the previous number and the first number. This is a very convincing argument against using a single 'case' for theory building. If we take this further, and look at the field of statistical analysis, we see an emphasis on taking 'representative' samples which are free from bias, so that the outcome of the sampling procedure can be assumed to be typical or representative.

The counter argument is overwhelmingly stronger under certain conditions. Any competent detective will tell you that a crime can be solved - ie a hypothesis developed - from a single 'case'. This analogy has been used by many other writers, including Cook and Campbell (1979) and Yin (1981).

The "case" in this instance consists of a quantity of information on motives, methods and opportunities which allows a hypothesis to be developed which fits the information. Not only that, but where alternative hypotheses exist, the best one can be selected. If insufficient data are available then a case cannot be made, ie the case material is inadequate.

Eisenhardt (1985) favours the multi-case approach which, although theory generating in principle, includes many of the attributes of hypothesis testing research such as sampling. She is a proponent of early identification of the research question and possible constructs.

Eisenhardt's approach is not without its critics. Whilst her approach argues for the use of a number of cases, there are many instances of "classic" case studies involving a single case. Dyer and Wilkins (1991 pp613 ff) cite a number of such cases where the researchers have tended to focus on the comparisons within the same organisational context rather than across organisational contexts. They argue that this approach, which in no way invalidates Eisenhardt's approach, can provide a rich description of the social scene.

They quote:

> "Theory that is born of such deep insights will be both more accurate and more appropriately tentative because the researcher must take into account the intricacies and qualifications of a particular context" (Van Maanen 1979).

They continue:

> "Those who would attempt to use Eisenhardt's method are necessarily constrained by the number of cases that will be studied, and descriptions will be rather 'thin', focusing on surface data rather then deeper social dynamics".

It is clear that there is some danger in Eisenhardt's approach that the research will focus on existing theories. That is not to say that the single case researcher may not do he same, but it is suggested by Dyer and Wilkins that the depth of insight in the "storytelling" will avoid this.

Coming back, then, to the single case study or the small number of case studies. Hypotheses may be developed from a single case, and the case does not have to be typical or representative.

It is not the typicality of the case which is important, but the analysis of that case. In the words of Mitchell (1983 p200).

> "... the features present in the case study will be related to a wider population not because the case is representative, but because our analysis is unassailable."

It is therefore not only unnecessary but also pointless to attempt to find a "typical" case.

Where the number of cases exceeds one but is still small, the principles above still apply. However, several advantages are opened up by the second and subsequent cases. As the number of cases which can be studied is necessarily limited, selecting the cases can be done to effect. Pettigrew (1988) noted that it makes good sense to choose cases in which the process of interest is "transparently observable" - possibly by selecting extreme situations. So far as was possible, the cases used in this work were selected in such a manner, as described in Section 3.5.

3.7 Case Analysis and Evaluation

In order to generate form from the volume of data generated by a number of case studies, it is necessary to tackle the analysis systematically. Eisenhardt (1989) describes a multi-stage process from case to hypothesis construct. The first step is within-case analysis, which involves a detailed case-study write-up, with a view to becoming intimately familiar with each case as an entity.

This is followed by cross-case search for patterns, looking at the data in several divergent ways. It is at this stage that a systematic approach is needed, such as comparing pairs of cases to highlight similarities and differences. By taking this approach, some of the arguments of Dyer and Wilkins (1991) are countered.

Having done the cross-case comparison, there is a further vital stage to the process. At this point there are likely to be patterns emerging which may not be present in all the cases. One reason for this could be that the relevant data may not be available, bearing in mind the relatively focused data collection method. This need not be a problem, since the intimate knowledge of the writer of some of the cases may enable deeper insights into the patterns to be made.

The analysis and evaluation then takes place in three stages:

Stage 1 : within-case investigation

Stage 2 : cross-case pattern searching

Stage 3 : within-case pattern investigation

4.0 CASE STUDIES

This section has been developed to provide a background to each of the cases involved. It gives general information on the companies, sufficient for the reader to understand the context of the outcomes developed in Section 5.0. It was not considered necessary to include in this section all the information collated outcome by outcome in the later section, since this would have resulted in a great deal of repetition. Section 5.0 can therefore be regarded as an extension of Section 4.0, in that the cases are only fully developed by reference to both.

4.1 Company 1 : Road Tanker Manufacturer

Company 1 is a wholly owned subsidiary of a large public limited company. Established in its present site in 1856, it employs about 160 personnel and has a turnover of around £4 million.

The Company undertakes the design, manufacturing and sale of road tankers, bulk carriers and car transporters using free issue chassis and also a range of helicopter refuelling tanks. The main customers are the petroleum industry and the Ministry of Defence. Although the Company has a standard product range, almost every order demands modification to the standard to suit customers' specific requirements.

In 1984 the Company had a drawing office staff of nine people undertaking draughting work and the associated design calculations. At that time a decision was made to retain a management consultancy to develop a specification for a computer aided design system and to select a proprietary system.

The design of road tankers is very calculation intensive. The first stage is to draw the cab and chassis from the supplier's data sheets, and to calculate the centre of gravity of the unit with all the ancillary items attached.

This is done by distributing the load of each ancillary between the two axles and subtracting the fixed weights from the gross vehicle weight at each axle to give the tank and payload weight and distribution.

The centre of gravity and vehicle wheelbase define the ideal length of the tank, and using the capacity of the tank the section of the tank can be calculated.

Several standard sections are available, and the nearest one is chosen, allowing an actual length to be determined. The tank can then be drawn onto the chassis, and the positions of its partitions, manholes and sumps marked. All other detail such as pumps, run-off pipes and drain tubes are then drawn.

From the drawing, further calculations are necessary to determine the number and sizes of sheets required for fabrication, the walkway length and mass and the centre of gravity of the assembly.

Using the information collated from the drawing a full list of components is prepared, and piecepart drawings are done for any non-standard items and for the tank.

At the time of the Consultant's report, the Company was installing a manufacturing control system. This was Kewill's Micross running on Extel Hi-net hardware, and it was deemed necessary to provide links between the manufacturing system and any proposed CAD system.

By November 1984 the Consultant had finished his analysis of the Company's requirements and had shortlisted the potential suppliers for final selection.

The specification called for a three workstation system with capacity for further expansion. In addition to the normal 2D draughting facilities, extensive parametric facilities were specified, to allow designs and calculations to be carried out simultaneously.

This would enable not only general assemblies to be designed, but also enquiry and tender documents to be produced quickly and accurately.

At this stage, the analysis showed that implementation would produce savings of around 4500 hours per year in draughting time, and this was broken down into types of design. For example, a tank barrel taking 12 hours of design and draughting time was targeted at 4.6 hours using CAD. General assemblies were expected to reduce from 24 hours to eight hours. Achieving or bettering these figures would constitute success in implementation terms.

The Consultant's report was shelved at the end of 1984, and no further progress was made until September 1985, when the Consultant was invited to update the report in the light of changes to CAD technology. By that time the Bill of Materials module of Micross had been installed, and the part file was complete. It was decided that since the BOM was present on the manufacturing system, it would be illogical to regenerate this on the CAD system. Instead, parts lists would be produced on the system and passed electronically to the manufacturing software.

No additional benefits were highlighted by the updated report, and the indicators of success were unchanged.

Following the second report, a decision was made to purchase a three workstation system. Installation was planned for mid January 1985. The Chief Draughtsman was relieved of his normal duties to enable him to manage the implementation with assistance and advice from the Consultant. Up to the time of the decision to proceed with the purchase, the impetus for the project had been from the Company Secretary, acting on the delegated authority of the Managing Director.

Whilst the initial investigation had been approved by the Board of Directors, the instigator had been the Managing Director, who maintained an active interest in the project throughout.

Towards the end of 1985, detailed discussions took place between the Company and the suppliers of the CAD and Computer Aided production Management CAPM software, to ascertain the precise form of the link between the two systems. In parallel with this, work was started on writing the parametric program for designing tanker general assemblies. This was done by the CAD supplier against a verbal specification.

The first implementation plan was developed by the Consultant in December 1985, updated by the Chief Draughtsman in January 1986 and consolidated into a CAD/CAPM implementation plan by the Consultant later in January 1986. At about the same time, the CAD supplier was in the middle of updating from 16-bit to 32-bit hardware, and this looked likely to cause software problems in file transfer. It was therefore decided that a well tried and tested 32-bit machine should be installed, so that the software could be ported onto the supplier's own 32-bit hardware when it became available.

The CAD system was installed in January 1986, with an agreement that the supplier's 32-bit machine would be installed in May 1986. By June 1986 it was clear that all was not well, and the Consultant was called in to resolve some of the problem areas.

It was at this point that the lack of formal specification for the parametrics became an issue. The aspirations of the customer clearly did not match the comprehension of the supplier, and this had caused slow progress, bad feeling and excessive costs.

The Consultant was able to bring the two sides together and formalise the specification. Further training was also arranged for the Chief Draughtsman and one other. The 32-bit machine delivery had at that stage slipped to August 1986.

The Company entered a period of intense design activity during the summer of 1986, and the pressure to produce drawings led to a reduction in CAD output. Only one draughtsman was using the system on a regular basis, and overall usage was only about 70 percent. However, work with the parts listing software was proceeding well, and the parametrics were being used extensively and expanded. A revised implementation bar chart was issued.

Changes to the CAD supplier's customer support structure late in 1986 led to short-term problems of response which caused problems to the Company. This was compounded by the lack of movement on the 32-bit hardware which had still not been delivered. Changes in the top management structure of the CAD supplier led to a review of the hardware policy, and a decision was made to offer a commercially available system rather than continuing development of the 32-bit machine. This was accepted by the Company late in January 1987.

At about that time the Consultant reported that certain important elements of system management and housekeeping were not being carried out effectively, and it was decided that the System Manager (formerly the Chief Draughtsman) was to be replaced. The Consultant was retained to oversee the system in the short term until a replacement could be found.

A deadline of 23 February was set for replacement of the hardware. By 3 March 1987, the hardware had been installed and was running well. It had been expanded to six screens.

The relationship between supplier and customer had improved dramatically, the parametric development programme was back on course, and procedures for operation had been developed. The Consultants therefore handed back command to the System Manager, who had not at that stage been replaced.

In May 1987 the Consultant was again invited to intervene, this time by the system supplier. The problems again related to the management of the system, and criticism was made of the System Manager. With the agreement of the Company, the new Chief Draughtsman was brought into the picture, and trained in system operation.

A minor restructuring of the Technical Department led to the replacement of the System Manager by the Chief Draughtsman, and this eliminated the personnel and inter-personnel problems.

4.2 Company 2 : Filter Press Manufacturer

Company 2 is a manufacturer of filter presses and associated equipment. In 1985 it had a turnover of about £3.5 million and employed 70 personnel. The filter presses range in size from 1 metre square up to 2.5 metres square, and are typically used in collieries for filtering coal slurry.

All orders are placed on the Company against a formal quotation, prepared in response to an Invitation to Tender (ITT). Where insufficient detail is available on the ITT, a site visit will be arranged to measure up the building or site area and to note any height or access constraints. Following this visit a Press General Assembly will be prepared. This is drawn to scale, but contains less detail than is required for manufacture. In addition, one or more plant layouts will be produced for discussion.

A site plan may also be drawn, showing the relationship of the press or presses to the remainder of the plant. Piping diagrams and civil engineering drawings may be required, particularly for export tenders.

On receipt of an order, the necessary calculations and drawings will be done to enable the side-bars to be ordered. The side-bars are the structures which carry the filter plates and are the main load-bearing beams. They run longitudinally down each side of the press, and are usually ordered before the remainder of the design is started since they are very long delivery items.

A general assembly drawing is often required by the customer, and this is usually prepared within the first week and sent to the customer for approval. Whilst approval is awaited, the design work proceeds, starting with the two end castings and the nut end fabrication. This is the structure which translates the rotary motion of the press screw into linear motion for opening and closing the press plates. No drawings are released for manufacture until the general assembly drawing has been approved.

After approval the remainder of the design can be done. Whilst a press may be significantly similar to a previous design, allowing for the use of standard parts, there are invariably substantial differences requiring modifications to existing drawings.

The way these have been done in the past is by taking interprints - copies on film - which may be modified, leaving the original intact. This reduces draughting time significantly, and whilst the drawing quality is not high, it is acceptable for manufacturing purposes. However, whilst first and second generation films are usable, third and fourth generation are sometimes produced, and these are rarely acceptable. At that stage a new drawing is therefore required. Where no similar drawing exists, or where the degree of similarity to previous drawings is low, a new drawing will also be created. In 1984 over half the drawings created were films of previous drawings.

At the time of the feasibility study in 1985, eight draughtsmen were involved in the design of filter presses and ancillary items under the control of the Chief Draughtsman. In addition, one designer was responsible for all contract design and estimating work.

Apart from the filter press drawing office, a separate drawing office was responsible for the design and draughting of pumps. Unlike filter presses, standard pumps were generally offered. Approximately 30 standard pumps were available in the range, and each of these could be produced with alternative flanges, flange locations and electrical controls. About one third of all enquiries required a special general assembly drawing. Over half of the drawings created for manufacture were modified films of an earlier design.

A fourth design office was investigated during the feasibility study. This was at a site remote from the other three, and consisted of two draughtsmen. On this site, filter plates were designed for the filter presses.

The plates, manufactured from either polypropylene or rubber, required quite different approaches to design. Whereas the rubber plates were built up from strips of rubber and vulcanised together, the polypropylene plates were milled from solid polypropylene, and tapes were required for the Numerically Controlled (NC) router.

The aforementioned feasibility study was carried out in June 1985, prompted by a need to increase the throughput of the filter press design office without increasing the number of draughtsmen, which by that time was giving cause for concern. Not only was the drawing office overcrowded, but the wide fluctuations in load necessitated the extensive use of contract draughtsmen who were a scarce commodity.

The Managing Director perceived the introduction of CAD as the solution to the throughput problem, but accepted that this would not alleviate the problems of peak demand. The pump and filter plate drawing offices were seen as a lower priority.

The report, prepared by Consultants, highlighted significant savings of the order of 3000 hours in the filter press area following the implementation of a three-workstation system. Approximately 80 percent of the savings could come from new drawing creation, making the savings achievable early in the life of the proposed equipment. No facilities were to be made available for the pump and contract drawing offices other than occasional use of the main system. This was seen as a future expansion path.

The Company decided that a single workstation should be purchased rather than installing the full system from the start. Consequently the workstation was purchased in August 1976. This coincided with a period of intense activity in the drawing office, and other than basic training, no significant work was carried out for some weeks. However, the Consultant was retained on an ad-hoc basis to advise initially on the structuring of directories and the setting of standards.

The operation of the equipment was in the hands of the senior designer - an extremely capable draughtsman with vast experience in filter press design. Unfortunately, his position also necessitated a relatively high degree of supervisory effort, and responsibility for the more complex designs.

Consequently the time available for the CAD system was somewhat restricted, and the equipment was used for only about 20 percent of the time.

In order to improve the utilisation of the equipment, it was agreed that it should be used for electrical schematic design. The Consultant was requested to prepare a number of electrical schematic symbols together with data sheets which would form part of the standards book. The completion of these symbols coincided with the resignation of the electrical draughtsman from the Company, and progress was suspended.

From early September 1986 to late February 1987 the single workstation was used increasingly for the creation of new drawings - predominantly of pieceparts rather than general assemblies or fabrications.

No parametrics had been created during that time, although the need had been highlighted in the original consultancy report. This had slowed progress, and the Managing Director was concerned that the equipment was not being used productively. Consequently the Consultant was asked to advise.

Following discussions, it was agreed that the workload of the drawing office precluded the release of a designer for parametric creation. It would therefore be necessary to bring in a contract CAD draughtsman to do the work. As the system was in frequent use it was deemed necessary to provide a second workstation.

Whilst the Company was prepared to purchase a second workstation like the first, the supplier had ceased supply of the equipment, although it was continuing support. This created two problems. Firstly, the original hardware, whilst supported by the supplier in the short term, would not be supported in the long term. Secondly, the Company would have two dissimilar pieces of hardware, making communications between the two difficult. To compound the problem further, the replacement for the original hardware was still being developed, making it necessary to supply third party hardware.

The agreed solution to the apparent impasse was to rent the third party hardware as an interim measure until the replacement hardware become available. At that time the Company would be offered the new hardware at a discount to allow for the rental costs, with an option to sell back the old hardware.

At the end of March 1987 the rental machine was delivered and communications with the older machine were established to enable drawings to be passed between the systems. A contract designer was set on with a programme of work covering seven sets of drawings over a three month period.

In April 1987 the problem of the hardware upgrade came to a head, and the Consultant was called back in to help resolve the situation. Discussions took place between the Consultant and the supplier. At the same time a review of the systems and procedures in the drawing office was undertaken. This review found a number of major changes since the previous study, and a number of areas of concern around the issues of CAD implementation.

In the six months since first implementation, the only standard symbols were those which had been created by the Consultant in the early stages of implementation. Usage of the first machine had been ad-hoc and infrequent, with a utilisation of only about 20 percent. No pattern of usage could be identified in terms of the draughting of similar or families of parts. Only one draughtsman - the senior designer - was competent in using the system. Although two others had had basic training, they had not used the system sufficiently to become fully efficient.

The other major change had been introduced gradually by the D.O. Manager, who had not been trained in the use of the system and had remained uncommitted to its success. This involved extension of the use of interprints - film copies of original drawings - which could be modified, albeit at a low copy quality. This had produced a low cost, if short-term alternative to the CAD system, and had negated many of the potential cost savings.

As a result of this investigation, a decision was made not to proceed with expansion of the system. The second, rented machine was taken out, and the contract draughtsman's work was abandoned.

Virtually all progress was suspended by the end of May 1987. Eighteen months later, the equipment had been relegated to the production of charts and tables, and no drawings were produced.

4.3 Company 3 : Cast Fibrous Product Manufacturer

Company 3 casts fibrous plaster products, mostly for the building trade. Part of a small group of companies in a variety of different but related types of business, the Company is itself spread across several sites, all within a five mile radius, with each site being responsible for a part of the product range.

The products of the Company fall into two broad categories. Standard mouldings are made to stock and are sold from an extremely extensive catalogue of architectural mouldings.

Specials, on the other hand, are made to order. They may be variants on a standard moulding or may be quite different from anything tackled previously. For instance the Company may be asked to produce a length of cornice to match that existing in a building, or may be asked to tender for a complete ceiling scheme. Standards and specials can be supplied and fixed by the Company, but the majority of sales are supply only.

All design and draughting work is carried out by a single designer who is responsible for both the commercial and the domestic work. His experience and knowledge are fundamental in producing designs which are both aesthetically pleasing and easy to manufacture. Domestic design and draughting is relatively simplistic, often using one or more of a range of standard mouldings from the extensive catalogue. These mouldings include cornices, niches, columns and arches.

Whilst the catalogue defines the shape and size of standard mouldings, it is not unusual for a customer to ask for a pictorial representation of his precise application. This activity is not complex, but is very time-consuming and may involve several iterations before an acceptable design is achieved.

Much of the domestic work is strictly two dimensional, even though the parts themselves are three dimensional. However, there is an occasional requirement for an isometric or perspective representation, particularly for new designs or "specials". This may involve freehand sketching of capital architecture or other sculptured surfaces.

Drawings are prepared at two levels - pictorial for customers and dimensioned detail drawings for the workshop. The manual system of design dictates that this involves the creation of two separate but substantially similar drawings.

The commercial contract work is quite different from the domestic work in both style and size. Typically, four or five projects are live at any time, varying in size between £40,000 and £300,000. Examples of commercial contracts are shopping malls and large suspended ceilings.

The first stage of design on receipt of an architectural drawing, is the production of a layout. If ceiling work is involved, as it usually is, the layout will be done in floor-line reflection, usually at a scale of 1:50 or 1:20. The layout defines the shape of the various ceiling panels, all of which may be different by virtue of the lighting requirements, but many of which may be substantially similar and may be created eventually from same mould.

From the layout a fixing drawing is created for the fixing team. These drawings are often at a different scale from the layout, and therefore cannot be traced. From two sets of drawings the panel construction drawings are created.

Each panel requires a drawing, but there are usually many similarities between the drawings. From the panel drawings, detailed workshop drawings are created. These are fully dimensioned to allow the moulds to be built in the workshop.

Again, there is strong correlation between the drawings, and many features which may be picked up from the higher level drawings.

A number of serious pitfalls cause problems at the design stage. The first is that the single designer working on five projects runs the risk of making mistakes particularly when dimensioning a drawing which may have been created some time before. A second is that the continual redrawing of panels may lead to errors of transcription which would then be perpetuated.

A third problem is that when a feature is changed on one drawing, it may need to be changed on several others. Failure to do this would cause problems later.

In addition to the shopping arcade type of work, two other types are worthy of note. The first is upgrading work, where mouldings are required to replace or match existing mouldings. In this case site drawings are usually created as a result of a site survey.

Items such as replacement ballusters need to be drawn full size for the benefit of the moulding shop, whilst cappings are drawn to scale and fully dimensioned. Typically this requires at least two redraws of part of the site plan.

The second type of work, which is relatively infrequent, is the free-space drawing of ceiling panels, usually for domestic applications. This type of work is creative, involving many sketches and partial drawings before the final drawing is created. One example of this type of work involved drawing a quarter of the panel onto A0 paper, then copying it three times for layout purposes in the workshop.

In August 1988 the Managing Director became particularly aware of a number of problems. Firstly, the designer was working excessive overtime, to the extent of working every Saturday and a minimum of eight additional hours during the week. It was thought that this was having an adverse effect on his health.

The second problem was that the designer was working on anything up to ten projects at the same time, and this was causing inefficiency. The pressure of work was also leading to drawing errors, and although they were generally of a minor nature, the risk was growing that an error would occur on a major project.

As a great deal of the work consisted of redrawing all or part of each design, perhaps at a different scale, the Managing Director decided on two lines of action. He seconded a junior draughtsman to the designer to take on some of the workload, and he retained a consultant to investigate the feasibility of implementing Computer Aided Design.

The parameters of the system, as defined by the Managing Director were:

a) it should be a single workstation capable of being expanded and networked at a future date.

b) it should be capable of being used by a fully trained CAD draughtsman for the creation of drawings, but should be simple enough for the casual user to access and plot drawings.

c) it should be capable of creating parts lists for complex designs and passing them to a future manufacturing computer as yet to be specified.

d) it should be available in a reduced cost version so that agents throughout the country could produce draft designs and pass them to the manufacturing unit for checking and costing using modem links.

e) it should provide links to other CAD systems using recognised protocols to enable site plans to be ported onto the system from architects' systems.

The consultant's analysis was concluded in September 1988, and a number of points were raised by the report.

The nature of the design task within the Company precluded the need for a link between the CAD system and a manufacturing system. The main reason for this was that the cost of a contract was closely related to the time taken to construct the necessary moulds and the time taken for fixing on site.

Neither of these estimates was produced at the design stage or by the designer, who took no part in the job costing. In addition to this, the parts list was limited to fixing hardware only, since the cost of raw materials for the panels was insignificant. As the fixing hardware was rarely drawn, the automatic creation of parts lists was inappropriate.

The Company had not considered the use of parametric programming, although this was seen to be essential by the consultant. The repetitive nature of the domestic work and the amount of "same as-except ..." work offered excellent savings for simple parametrics.

A survey of the CAD facilities used by major customers and other architects and specifiers showed a need for DXF, IGES and SIF (Intergraph) exchange protocols.

A database facility was deemed to be essential for several purposes. The time lapse between initial drawing creation and final manufacture could be considerable - often several months, and it was seen as essential to find the drawings quickly and easily. Changes to a feature on one drawing often led to changes on several others, and the database would give the ability to provide cross-references to reduce the risk of errors.

A system specification was created for the CAD software, and four suppliers were invited to submit tenders for turnkey systems. A cost/benefit analysis on the preferred system showed that it could not be justified purely on the savings likely to be achieved, and that other factors such as fewer errors and more rapid throughput would need to be considered.

Following several demonstrations of the software and informal benchmarking, a system was chosen, and the Company went ahead with the purchase of a single screen system.

The first few months of operation were extremely difficult for the Designer, who still had to cope with his manual systems whilst transferring some work to the CAD system. Had it not been for a fall-off in orders at that stage it is likely that the pressure would have suspended work on the CAD implementation.

The Designer took advantage of the three days of training offered, and this enabled him to become productive very quickly.

Within six months, approximately half of the new contract work was being done on the system, and savings in time were being observed, but not evaluated.

The Designer and his draughtsman were both able to use the system proficiently, and often shared projects. At that stage no attempt had been made to download from other systems, and only very simple parametrics were being used, predominantly for domestic work. The database had not been implemented fully, although full drawing records had been maintained. Overall, the drawing office was less pressurised and a much more comfortable environment.

Two years on from the implementation, the picture was quite different. Two systems were being used, sharing the common database and peripherals. Several drawings had been downloaded from customers' systems, with few problems, although it had been necessary to borrow additional hardware in one case to overcome apparent problems with disc formats. The ability to download had provided an additional and unexpected benefit that the Company was able to return the layout drawings to the customer electronically, speeding up the acceptance process.

Several more parametric drawings had been created, some of them quite sophisticated, but virtually all were for domestic work.

No agents had been persuaded to buy the necessary systems to create designs locally, and no attempt had been made to link the systems to the manufacturing systems.

It was clear that the systems were being used in preference to the drawing board wherever possible. An occasional 3D drawing was created on the system, but generally these were still done on the board or freehand. The system was nevertheless a success in the eyes of the Directors and the Drawing office.

4.4 <u>Company 4 : Refrigeration Engineer</u>

Company 4 was founded in 1976 to provide a refrigeration service to the fishing industry. This involved the provision, installation, commissioning and servicing of fish freezing and ice-making equipment on trawlers. Some years after its launch the Company took over an ailing manufacturer of ice-bank equipment. Unlike the ice-makers and fish-freezers, ice banks could be used in a variety of non-fish applications such as vegetable chilling.

At the same time as the takeover, the Company invested much money and effort in the development of a range of modular equipment for water chilling, moist air production and ice making.

These machines all had refrigeration technology in common, and were conceived and designed by the Managing Director. The design work and prototype testing of the machines was completed, with external help from a Value Engineering Consultant in late 1986, and the Company embarked on a period of non-developmental consolidation.

Having taken the time and trouble to design the products in modular form, it was clear to the Managing Director that the design effort in the immediate future would be limited to modification of the existing design to provide variants.

For instance in the case of shipboard fish freezers, the freezing capacity would be satisfied by installing a number of standard freezers, all of which would have a known capacity and would stand alone. No central freezing plant was necessary, and a breakdown would affect only a fraction of the freezing capacity. However, the freezing requirements of a trawler would depend on a variety of factors, including the type of fish to be frozen, the expected maximum catch rate, the seawater temperature range (seawater is using for condensing the refrigerant) and, not least, the space allocated or available for freezers.

All these factors would have an effect on the design of the freezer - the number and size of plates, the size of the compressor and condenser etc.

A similar situation appertained for the ice-making machines. These were capable of producing a continuous supply of dry, thin ice, an ice/water mix or iced water, depending upon the requirement. Again there would be a variation in demand for different applications, necessitating design changes. These changes would, because of the modular nature of the units normally be minor.

It was the expectation of repeated modification work that caused the Managing Director to consider the use of Computer Aided Design, and in July 1987 a consultant was retained to select a suitable system. Links with other computer based systems were not seen to be necessary at that stage.

At the start of the project in late July 1987, the Company had some 250 drawings varying in size from A4 to A0, and no fewer than three drawing number systems. In addition, many drawings had no reference number and some were without title or date.

The drawings were held in mixed sizes in a horizontal storage unit, and some were being damaged. In short, the drawing office housekeeping was poor. On the other hand, however, a very effective seven-digit part numbering system was in use, and this system had been followed to the letter.

Most of the drawings were A4 or A0 size, and the vast majority were orthographic. However, about 12 percent of the drawings were isometric drawings of structural frames. These were fully dimensioned and in most cases equivalent orthographical drawings did not exist for the units. Many of the drawings were at a second or third issue, and almost ten percent had been redrawn at some stage.

At the time of the study there was no full-time draughtsman employed, and the Managing Director was acting as designer and draughtsman, creating the bulk of the design concepts and many of the drawings. Other drawings were done by an engineering postgraduate on temporary placement at Company.

With each project taking around 150 hours of drawing time, this was causing problems for the Managing Director, and a major benefit of a CAD system would be to relieve him of the draughting task. His intention at that stage was that he should develop the designs on the system, and employ a draughtsman to take the designs through to full working drawings, again on the system. The draughtsman would also be able to create variants of the design.

It is important to note the design philosophy of the Company, which is based upon the principle of offering a range of standard products within each product group. For instance only one plate freezer was designed, but a range of variants on this one design gave a family of seven different sizes of plate freezer. At the start of development, the decision was taken on which sizes to produce, and these were offered as standards.

All the design and development work for the whole family was completed prior to offering the unit on the market.

This principle relies upon an extremely good knowledge of the available market, since there is a risk of losing orders for units not in the standard range. The benefit, however, is that the market is manipulated to a certain extent into accepting one of the wide range of standards offered. Since the designs and working drawings are available, the lead time is very much shorter for a standard than for a special, and requirements for units outside the range are rare. Some minor layout changes may occasionally be required, and ducting and pipework is generally specific to a particular trawler.

A specification to the CAD system was developed during August and September 1987. The prime software requirement was to speed up the generation of families of parts, by using symbols and parametric programs. In view of the relatively small number of designs created in the average year, a single workstation was considered to be adequate, with the capability of networking systems were not computerised at that stage no links could be developed in that direction. However, it was agreed that this would be desirable in the future, and that the target would be a linked system creating parts lists.

It would have been impracticable to load all the existing drawings onto the system, and it was decided that only the latest design - the fish freezer - would be loaded, allowing for modifications as necessary.

A cost/benefit analysis was carried out by the consultant, which showed a payback of around six or seven years. In purely financial terms this would not normally have been acceptable, but there were additional factors which influenced the decision to purchase.

The main factor was that much of the time to be saved was that of the Managing Director, and as this was a high priority, the payback argument was overridden.

A second factor was that a variant for a particular trawler or type of fish could be generated very quickly and accurately, reducing overall lead times and making costings much more accurate.

The estimated reduction in drawing time was very significant, amounting to some 120 hours of actual drawing time. Adding the traditional checking of the drawings gave a further saving of 40 hours. The total represents some four weeks of concentrated effort, or six weeks of elapsed time for a draughtsman.

This was seen as a major advantage in gaining orders for trawlers undergoing a refit, since a significant part of the refit cost is associated with lost revenue from time out of the water. A supplier who can design, build and install shipboard equipment on or ahead of schedule can therefore make significant cost savings for the operator.

A database package was specified as part of the software for two purposes. Firstly it would allow drawings to be accessed, modified and grouped easily and quickly. Secondly, and more importantly, it would allow records to be held for each installation by trawler name. Any subsequent work or repairs could therefore be planned in advance in full knowledge of the installed equipment.

Following the development of a detailed system specification, five systems were considered in detail; three selected by the Consultant and two for comparison purposes with which the Managing Director was familiar. An informal benchmark was set up to enable each supplier to demonstrate his offering to the full, including parametric design and database facilities.

Four demonstrations were arranged, and a clear leader was identified and examined in further detail. It proved to offer a remarkably close fit to the needs of the Company in the short and long term. A whole - life costing of the system also showed it to be the cheapest of the five.

Following the demonstration and final selection, nothing further happened for about a year until August 1988.

At that time the systems were again reviewed, and a single screen system was purchased. A young graduate was employed by the Company to implement the system and to load the latest design. He and the Managing Director were both trained to the basic level by the vendor.

Progress on the system was slow, partly because of pressure of work in other directions, which left the draughtsman with insufficient screen time to do justice to the task. This situation continued until the end of 1988, when the draughtsman left and an experienced designer was taken on who had previously worked for the Company.

Whilst he was an extremely competent refrigeration designer, he had no CAD experience, and even with the basic training he was very slow to get into the system.

In February 1989 the Consultant was invited to review the system and make recommendations. At that stage the dexterity of the designer on the CAD system fell well short of that of the previous draughtsman. Whilst the whole of the freezer had been transcribed onto the system it was not being used to its full potential, and as an electronic drawing board it was taking longer to create designs than the manual method.

The first action taken was to provide the designer with a refresher course. This had two effects.

Firstly it increased his speed by reinforcing technique. Secondly, it gave him more commitment to the system, and he was prepared to make it work rather than fighting it. The second action was to have a number of parametric designs generated by the vendor. Whilst these could have been done by the designer, it was considered by everyone concerned, including the designer, that he had insufficient time to do justice to them.

Within three months things had changed dramatically so far as the CAD system was concerned. It was now creating drawings at the full target speed, and most of the planned benefits had been achieved. The database was the one weak link, and had not been used to the full.

Records of installations were still maintained manually, and since the number was very small it was not considered to be a problem.

By August 1989 all the targets for productivity had been met. The Managing Director had virtually stopped working on the drawing board and spent little time on the system. In all respects the implementation was regarded as a success.

This continued to be the case for about twelve months, when the Company was liquidated because of a shortage of orders.

4.5 Company 5: Municipal Furniture Manufacturer

Company 5 is a long established manufacturer of municipal furniture including lighting columns, bus shelters and fencing, plus a range of street furniture. It employs about 160 people and turns over approximately £7 million, of which columns, shelters and fencing represent a very large proportion.

In September 1987 the Works Director decided to obtain the assistance of a consultant in the selection of a computer aided design system. The reasons for the decision were twofold.

Firstly, the designs were recognised as being, to a great extent, variations on a theme. The columns, for instance, not only looked alike but also fell naturally into about six families, within which the main variation was size rather than structure. Secondly, the Company had recently installed MAAPICS - a manufacturing control software - on an IBM System/36, and was eager to simplify the procedures for creating bills of materials for new products.

At that stage the Company had had no exposure to Computer Aided Design, although some departments were computer literate, having worked with Computer Aided Production Management (CAPM) software. A consultant had been retained to implement the CAPM system, and it was decided that he would manage the integration of CAD and CAPM. It was therefore necessary that he should work closely with the consultant selecting the CAD system.

Orders for lighting columns can be as simple as a single standard catalogue item or as complex as a complete lighting scheme for a goods yard or football pitch. For the latter, the lighting engineer uses a purpose written lighting design system running on a Hewlett Packard (HP) 9000 Personal Computer (PC).

This is used to calculate the lighting requirements, positions and types of lanterns. A plotter is used to produce a hard copy of the footprint of each lantern. The structural engineer uses this information together with details of terrain, type of column (raise and lower, fixed, etc) and bracket style. Using a similar HP PC he will check the suitability of standard products.

If a non-standard is required, he will set the design parameters using pre-calculated stress limits, and specifying one or more of the 18 stock materials.

All the above work is necessary in order to prepare a quotation, and a drawing of the scheme is generally required by the Client.

When an order is received, a works order is issued, and the drawing office is required to produce detail drawings and parts lists. If the product is simple, the parts list may be put on the drawing, otherwise a separate list is produced. The draughtsman is responsible for selecting the parts and materials to be used from a list of around 14000 materials, components, sub assemblies and finished items.

In most cases, a draughtsman will be fully responsible for an order, including drawing production, parts listing, customer liaison and preparation of the erection specification.

Shelters, fences and other similar items usually only reach the drawing office when an order has been placed, and are processed in the same manner as columns. Once the drawings and parts lists are complete they are passed to the planning department.

Here, the drawings are "exploded" to component level, and material lists and route cards are prepared. Production control are then involved in scheduling the jobs, issuing manufacturing instructions to the works and progressing the jobs.

Even on non-standard jobs there are many standard or near-standard items. On columns these would include raise and lower gear, door and door openings, base sections, electrical instructions, spigots and brackets. Shelters, which are built up of modular sections are much more standardised, but need variations for the terrain or for non-standard lengths. Even on the non-standard section, many standard components will be used, such as roof sections, ground fixings, seating, frames and municipal logos. Fencing is also modular, and any variations in length are normally taken up in the end panel, which is often a scaled-down standard panel. Other products such as bollards, litter bins, "olde worlde" lighting and toilet blocks are generally standard and require no drawing office involvement.

A detailed system specification was developed by the consultant to a level at which vendors could be invited to tender.

The first stage was to be very modest, with two workstations sharing a plotter and with common files. This would allow the creation of drawings up to A1 size and the generation of parts lists from those drawings.

Very quickly, a second stage was to be targetted whereby the files generated by the structural design system could be imported for incorporation in parametric drawings. A third stage would allow the parts lists to be delivered electronically to the IBM System/36 where they would be converted into BOM structures. This was to be done using an intermediate IBM/PC for data validation and transfer purposes.

In addition to preparing a specification for the CAD system, the consultant made recommendations on the elimination of a number of barriers to effective systems integration.

The structural calculations for columns were written in BASIC, and were incomplete in that they did not cover the full range of columns designed. A decision had been taken to update and expand these programmes, and they were being rewritten in PASCAL. This was seen as a misguided decision, since the programs were very simple, making BASIC adequate, and there was no in-house expertise in PASCAL.

A more useful approach would be to create the structural programs as parametrics on the CAD system. This would, of course, cut across one of the Company's traditional barriers, moving much of the structural work into the drawing office.

Creation of parts lists had always been the responsibility of the drawing office, although material lists and routings were produced by the planners. If the CAD and CAPM systems were to operate together, there would be a need to redefine the roles of the designers and planners, and to make inventory data available to the designer to facilitate part standardisation.

The consultant presented his report in early December 1987, and a number of further questions were raised by the Company regarding the communications between the proposed systems.

Following clarification of the issues, demonstrations of the selected systems were set up. These initial demonstrations were somewhat informal, and no benchmarking was carried out.

The Company was, however, happy to select one of the suppliers, who was invited to proceed with further developments to prove the feasibility of linking to the CAPM system.

This was to be done jointly between the Company's CAPM consultant and the CAD vendor, although no formal specification had been written for the link.

By July 1988 there were clearly problems in proving the communication link to the satisfaction of the Company, and the CAD consultant was invited to intervene on behalf of the Company to resolve the situation.

The problems were found to be of a technical nature, although not sufficiently complex to have warranted a six month delay. The vendor promised an early solution, and this was accepted by the Company. By mid August, however, the situation had still not been resolved, and the CAD consultant again intervened and independently developed a formal communication link. This was presented to the vendor and the Company in late August and the link was demonstrated to the satisfaction of all parties in mid September. This removed all the obstacles to the system purchase.

Demonstrations were controlled at each stage by the Works Director, although he was not always present. It was he who had the final decision on acceptance or rejection, and he insisted on all aspects of the justification being demonstrated.

Implementation of the system was the responsibility of the Drawing Office Manager, although he delegated much of this to the Chief Draughtsman. When the DO Manager left the Company part way through the project, the new DO Manager picked up the project and much faster progress was made.

Within nine months all aspects of the initial criteria for success had been achieved, although the use of parametrics was still limited.

The DO Manager claimed to have achieved the major targets in 3-4 months, and apart from the parametrics saw the project as a total success at that point. No action had been needed other than that originally planned to achieve the success.

The structuring of BOMs had been brought into the DO at an early stage by importing a planner. He passed on his skills to the designers so that they could develop structures, and in the process became a designer himself.

Plans are now well advanced for producing an open system, which will also incorporate the facilities for plasma cutter generation and the necessary CAM links.

4.6 Company 6 : Aluminium Window Manufacturer

Company 6 is a private limited Company formed in 1966 as a designer and installer of shop fronts.

Over the years, the scope has widened, and now includes curtain walling, security screens, commercial windows and ground floor treatments. The Company is on two sites about 180 miles apart, with about 110 employees in total and a combined turnover of £4 million per annum. Approximately three quarters of the employees are on the larger of the two sites.

The Company's customers are predominantly specifiers, local authorities or architects, who place contracts varying in size between £5,000 and £150,000, with the bulk being up to about £50,000. Typically 10 to 20 such jobs are concurrent in the factory.

The products are manufactured from extruded aluminium alloy together with castings and fittings as required. Most of the extrusions are designed in-house, as are many of the castings.

Fittings such as handles and locks are usually proprietary items, and are often specified by the customer.

The majority of contracts require full drawings, with only about five percent needing an elevation drawing only. The number of standard parts and the repetitive nature of much of the work led the Company to consider the use of Computer Aided Design in the creation of designs and parts lists.

Each contract is usually completed by one designer. The format of the drawings changes only in scale and complexity, but there is inevitably an elevation, one or more plan views and a number of sectional details. The elevation is generally pictorial, but is used at a later stage to produce a cutting list for the extrusions.

The sectional details are built up from standard sections and are extremely repetitive and tedious to produce. An earlier experiment to build up sections from pre-printed self-adhesive section drawings was abandoned because of the cost of producing the self-adhesive film.

Copies of drawings are submitted to the contractor for checking and amendment as necessary. On their return the originals are amended and copies are resubmitted if necessary. Once they have been agreed, a surveyor is sent out to measure up the actual dimensions of the site, and the drawings are again amended to take into account the precise dimensions.

It may be necessary to reissue the drawings to the contractor at this stage, before they can be released for production.

From the drawings, four cutting lists are prepared for the materials. These are:

* perimeter materials and windows
* doors
* components for assembly : shop
* components for assembly : site

The final task is the preparation of shop drawings. These include pressed metal, brackets and section drilling details.

If any stress analysis is required, for instance for wind loading on curtain walling, this is done by the local University.

The Company has developed its range of products based on standard items. There are 12 standard shop-front drawings, each of which may have single or double doors, side and top lights. The range of sections shown on these drawings is very small, and the elevations within a standard are substantially similar although variable in overall size. In addition to the standard shop fronts, non standards may be constructed, using the 30 extrusions.

Windows are built up in bays, with up to five sections per bay. Each section may have fixed glass or all or part of it may have a side or top hung opening. The drawing of windows is therefore extremely repetitive. Window drawings contain significant amounts of text detailing the closures and furniture. The elevations call up standard sections by sequential number, and these are drawn on supplementary sheets.

Curtain walling consists of large areas of glass or infill panels, several storeys high. The drawings show a matrix of rectangular bays, which contain windows or panels, some of which may be openers. Each transom and mullion is numbered and referred to a section on a separate sheet.

The wall matrices are full chain-dimensioned, involving a high degree of over-dimensioning. Each transom and mullion is drawn on a separate drawing, showing the cutting and machining details and the stud fixing positions.

The Managing Director in conjunction with the Chief Draughtsman and Project Manager had identified the potential for CAD in the drawing office. Therefore he retained the services of a consultant to carry out a survey and select a suitable system for use at the larger of the two sites, with expansion to the other site at a future date. The survey was carried out in September and October 1988, and the consultant presented his report in November.

The report identified the main requirements of the software and hardware. In software terms the requirement was complex.

Whilst to produce pictorial elevations and sections by symbol building and step-and-repeat was straight forward, translating these images into cutting lists was more complex. The problem was exacerbated by the need to overlap adjacent lengths of aluminium extrusion used to make up a section, so that a joint did not go right through the section. It was clear that a significant amount of editing would be required prior to creating a cutting list. This editing would need to be done on the graphics rather than on the parts list.

The report identified the principles behind this method of drawing construction, but in order to produce a meaningful benchmark a small committee was set up to develop the methodology further. This committee brought together the designers, draughtsmen, planners and buyer, and turned out to be the first phase of a company-wide consultative and implementation process.

The benchmark developed by the team was explained fully to two vendors, together with the reasoning behind the techniques, and each was given time to prepare a demonstration. From this demonstration a clear front-runner was identified, and asked to quote for a two workstation system. The system was to have the capability of sharing files between the two screens.

In order to cut down on the amount of lost time in the drawing office, the vendor was also asked to quote for the loading of extrusions and sections and the construction of three simple parametric designs.

The system was installed as specified, and three draughtsman were trained by the vendor. Over the next three months the other three were trained initially in-house but with some input from the vendor.

The symbols for sections had been created prior to installation, but significant changes were needed to these over the first two months of operation, taking up the time of one of the draughtsmen and one screen full time. The parametric designs were more successful and needed only minor changes taking just a few days. As a result, one of the screens was operational and doing constructive work within about a week of installation. This was clearly insufficient for the throughput required, and manual systems were retained for the more complex schemes.

A review of the system was carried out in August 1989, six months after the decision to purchase had been made and five months after installation. At that stage some of the shop fronts were being designed using parametrics, and further parametrics were being constructed to extend the range.

Windows were nearly all done by a combination of parametrics and symbols. Curtain walling schematics were being generated by the use of grids, which reduced the draughting time by almost two thirds.

The database had been set up to allow schematics created at the tender stage to be archived and recalled for manufacture. This was working well. No progress had been made on the specialist software required to create cutting lists from the elevation drawings, and it was decided to bring the vendor back in to review this.

A further six months passed before the software was sufficiently robust to produce cutting lists for windows and the simpler curtain walling. At this stage the Company considered that it had exceeded its reasonable expectations as declared at the concept stage, although it now saw ways of moving to further levels of integration.

One of the major features of this implementation was the rapid turnover of CAD draughtsmen over the first two years, which remains unexplained. The working conditions were good, and qualified people were easily acquired to replace those lost.

One of those who left returned within two months for the same salary.

5.0 OUTCOMES AND PROPOSITIONS

5.1 Case Study Outcomes

5.1.1 Level of Integration

It was established in Chapter 2 that integration is a continuum with a well-defined bottom end of no integration and an ill-defined or even moving target upper end which we can call "full integration". This is not particularly helpful when defining the point on the continuum which a Company has reached, and it is necessary to make some (arbitrary) sub-divisions, on similar lines to Waterlow and Monniot (1986 p7). Meredith and Hill's (1987 p52) four-level model is not sufficiently precise for a detailed study.

For the purpose of this investigation, six levels of integration have been identified, each of which has a fairly clean-cut break to the next level. These are described as follows:

Level 1 - Electronic Drawing Board

This is a single stand-alone design, draughting or numerical control system which may be linked to non-active peripherals such as printers and plotters.

It is also used to describe multiple systems where they are not linked electronically, even when files may be shared by the exchange of magnetic media.

Level 2 - Linked Systems with Common Database

This is the first step on the integration ladder. Two or more systems are linked electronically such that each may read from the common domain files of the other and, given the necessary access, write to those files. The systems are still, at this level, used only for design and draughting work, whether in two or three dimensions.

Level 3 - Linked Systems Creating Parts Lists

A second category of software is invoked, which can interrogate a design to produce a simple part listing. This listing may require to be edited prior to use, depending upon the CAD software used and the creation method for the listing.

At this level, one system can be used to create parts lists for accessible files on the other system(s).

Level 3a - Linked Systems Creating Numerical Control (NC) Files

At this level, a design is created which may then be passed to NC software for profile generation. To reach this level, design software must be linked to NC software, ie it is insufficient to have two linked NC systems, which would be classed only as Level 2.

One system must be capable of accessing CAD files on the other for NC generation, but it would be acceptable for only one of the systems to have NC capability. The systems may be linked to other non-active peripherals such as tape punches or magnetic tape drives.

Level 4 - Linked Systems Creating Bills of Materials

This is an extension of Level 3 in that the parts list, generated from the drawing, can be extended to produce a full Bill of Materials. This requires access to a third category of software - a database - in which full stock information may be maintained, including supplier information. The Bill of Material (BOM) software requires the ability to produce part structures which show the inter-relationships between parts.

At this level of integration we have broken through a traditional barrier between Design and Production Planning.

Level 4a - Linked Systems Linked to NC Equipment

This level is an extension of Level 3a in that once a profile has been designed, tools have been chosen and toolpaths have been defined and proven, the cutting data can be passed electronically to the NC equipment without producing hard media such as cards or tapes. An extension to this which is not to be considered further in this work is the addition of automatic gauging which can be used to adjust tool offsets to compensate for wear.

Level 5 - Linked System to Computer Aided Production Management (CAPM) System - One Way

Having produced a structured Bill of Materials the next step is to use this in a CAPM system for the creation of costings, production planning and materials requirements planning (MRP).

Data are transferred electronically from the BOM files held on the CAD equipment, usually into transit files on the CAPM system for validation prior to use.

Level 6 - Two-way CAD/CAPM Link

The problem with a Level 5 implementation is that it requires parts information to be held on both the CAD and the CAPM systems, which is problematic when changes have to be made.

Level 6 avoids the need for this by allowing the CAD system BOM software to access part files on the CAPM system, create structures and send the structures back to the CAPM system. Flags can be used on the parts file to identify those items which are not available in graphic form on the CAD system.

This level is the highest one would expect to find in a Small to Medium Enterprise (SME) in the UK in 1991, although Open Systems are becoming more acceptable to other than the very large firms. One would expect a Level 6 implementation to be keyed in to external access points such as purchasing and supply and sales order entry.

Table 5.1 puts the six case studies into the context of the six levels of integration described above.

Case	Initial Level	Interim Level	Target Level
1	2	3	5
2	1	-	2
3	1	1	3(note 1)
4	1	1	2
5	2	4	6
6	2	3(note 2)	3(note 2)

Table 5.1

Notes 1) The target was to have parts listing on one system and draughting on each of two with floppy disc transfer.

2) Cutting lists were also created.

The Initial Level corresponds to the first hardware configuration purchased by the Company together with the software implemented within the first two months.The interim level is that reached in the first phase of operation, and usually corresponds to an elapsed time of 12 to 18 months.The Target Level is that declared as a long-term objective prior to implementation.

Implementation, like integration, is a continuum, along which companies move. Three of the six companies have reached or are approaching their target level of integration within three years of the initial purchase, as described in Section 4.

5.1.2 Computer Knowledge Base

It is possible that the degree of success in implementing CAD systems relates in some way to the prior computer knowledge base of the Company. In other words, where computer systems are in full and free use within the Company we may expect a different level of understanding and hence a different level of acceptability of CAD, be it higher or lower.

The cases present a wide spectrum of prior knowledge from virtually no experience to wide experience with sophisticated CAPM and design software. A ranking of experience has therefore been developed as follows:

Level 1 : No systems in use within the Company

Level 2 : Computers used by some sections of the Company eg Accounts, remote from the Designers

Level 3 : Discrete packages used freely throughout the Company but not for Design work

Level 4 : Integrated CAPM systems used throughout the Company but not by Designers

Level 5 : Integrated CAPM systems available to the Designers for reference

Level 6 : Computer systems used by the Designers, eg for non-graphic design, databases or part structures.

The initial levels of the six companies were:

Case	Level	Note
1	4	
2	6	Limited to one designer
3	2	
4	3	
5	6	
6	6	

Whilst the lower levels of prior computer knowledge may be of some interest, Levels 5 and 6 are of particular interest, since they relate to the exposure of the designers to computer systems.

5.1.3 Expectation of the System

Expectation of the system is extraordinarily difficult to define after the event, and the best guide can be obtained by looking at the case notes for each project made during the early discussions with the Companies. The expectation is a combination of the initial aspirations of the individuals within the Company as amended by the experience of the Consultant during discussion. It is made up largely of two components; targets and timescales.

If expressed verbally, an expectation would be "...to achieve level A by time B". It may indeed be more complex than this, with several targets and timescales embedded in it.

We can deal with expectations in one of three ways. Firstly we could look to see what level was reached in the given time. This is difficult, since it requires a subjective view of the level reached.

Rather easier is to look at the time taken to reach the target. In theory this is objective, but it takes no account of the probability that a satisfactory or sufficing level may be achieved well within the time.

The third method is to combine the two targets in some type of mathematical formula. Since a higher level and lower time are "better" in relative terms, one simple formula would be to express the expectation as A/B. Satisfaction is guaranteed when A/B exceeds a predetermined value. Whilst this is fine on paper and mathematically tidy, it requires a continuous subjective assessment of A. It also has the problem of having no limits on A, so that a satisfactory position could be considered to be reached if a low target were achieved in a very short time. This is clearly unacceptable.

For the purpose of this study, since we are dealing with a small number of cases which can be compared easily, a more pragmatic approach has been taken. Mathematical satisfaction is calculated at a stated point on the implementation programme where development has reached a plateau. At that stage the satisfaction level is taken as the combination of the estimated percentage of target reached with the inverse of the ratio of actual time and target time. This is covered further in section 5.1.8.

So far as the expectations of the six systems are concerned, the following six statements apply.

Case 1

To produce tank barrel designs in five hours and general assembly drawings in eight hours within two years of starting the implementation. To link the CAD system with Micross CAPM software within three years.

Case 2

To reduce the average time required to produce a filter press design from 200 hours to 145 hours within 18 months. The actual target was a saving of 3000 hours per year, but it was not feasible to assess the savings in this form.

Case 3

To allow the designer to increase the throughput of work by 40 percent whilst working 20 percent fewer hours.
To enable a second draughtsman to take a significant part of the workload, as a backup to the designer.

These changes were to take place immediately, with the full time savings being achieved within six to nine months.

Case 4

To enable families of designs to be created quickly and easily by people other than the Managing Director. The target was to produce a tailored version of an existing design in 30 hours, compared with the usual 150 hours. This was to be achieved within the first 12 months.

Case 5

To develop an integrated CAD/CAPM system to allow Bills of Materials to be generated on the CAPM system from CAD drawings. This was to be achieved within 18 months of implementation.

Case 6

To increase the throughput of the design department by 50 percent within 12 months without any additional manpower. To produce cutting lists from the CAD drawings within 18 months.

Summary

The expectations, whilst all expressed in simple terms, vary in the objectivity of their measurement and the length of time required to carry out the measurement.

Two of the Case Studies - 4 and 5 - opted for very easy measures. The expectation was tangible in each case.

* to produce a tailored design in 30 hours

* to provide an integrated CAD/CAPM system.

The very first tailored design could be timed, and an accurate measure of success produced in Case 4. In Case 5, the level of integration was pre-defined, and the time taken to reach that level could be measured. Even if the targets were not reached within the expected time, an estimate of the extent to which success had been achieved could be made.

Two of the Case Studies - 1 and 2 - opted for more difficult measures. Both relied on an improvement in the time to complete a project. Whilst this does not, on the face of it, seem too difficult it must be noted that the project times varied significantly in both cases, and the average project time was targeted for improvement. Whilst this is measurable in the long term, its assessment over one or two projects is somewhat objective.

The final two Case Studies - 3 and 6 - had very difficult measures of achievement. Both sought an increase in throughput of the department by 40 percent and 50 percent respectively.

For a drawing office which develops many similar products in the course of a month or year, this can be a useful measure of success, but both these companies were project based, with a 10:1 spread of project size. In both cases, therefore, the measure was extremely subjective.

Fortunately both these companies had secondary, more objective measures. The first sought to employ a second draughtsman to take the load off the designer. The effectiveness of this could be measured easily, tangibly and quickly. The second required the system to produce cutting lists. This is very easy to assess, and a measure of achievement is objective.

Table 5.2 summarises the objectivity of the cases.

Case	Measure	Objectivity
1	Time to complete a project	M
2	Time to complete a project	M
3	Increase throughput/ Second draughtsman	L/H
4	Increase speed of operation	H
5	Integrated CAD/CAPM	H
6	Increase throughput/ produce cutting lists	L/H

TABLE 5.2

The degree of difficulty in achieving the expectations was very difficult to assess objectively, but was likely to have some relevance when assessing the value of the project. It was, arguably, easier for the Consultant to assess than for the Company, since he had been involved in several implementations and had observed many of the problems likely to be encountered by the companies.

In an attempt to scale the degree of difficulty an ordinal scale has been developed as follows:

1	2	3	4	5
Target easy to achieve				Target very difficult to achieve

Using the scale the following assessment has been made.

Case	Difficulty
1	4
2	2
3	3
4	3
5	5
6	4

Table 5.3

5.1.4 Prior Justification

Justification is to some extent linked with expectation, although as we saw in Section 2, justification may have little to do with the operational milestones. In addition to that, we also saw that in many instances justification is a static activity carried out at the concept stage and may not be reviewed - indeed may be forgotten - during the system implementation. As a result, a successful system may well not achieve its justification targets, or conversely a system which has reached those targets may be regarded as unsuccessful. As a simple example, justification may be based on a four-year payback, whereas success may be based upon time savings and hence throughput. There is no guarantee that these two benchmarks will be reached at the same time.

In small companies, where the same 'team' is likely to be responsible for justification and exceptions, we would not anticipate wild differences in the two, but for completeness the measures of justification have been extracted from the questionnaire analysis.

Case 1

The main problem faced by Company 1 was the bottleneck in the Drawing Office. Justification was therefore based upon increasing the throughput of the D.O. A three workstation system would be justified if it allowed enquiry and tender documents to be produced in half the manual time whilst at the same time increasing the number of projects per year through the department by 45 percent. These measures line up fairly well with the expectations of the system.

This is an interesting concept, since it regards the cost of the system as secondary to its benefits. This approach continued through the implementation, resources being made available almost without regard to cost.

Case 2

Company 2 had the same pressing need to get more work out of the Drawing Office (D.O.) using the same number of people, but their timescale was much shorter.

The D.O. was at full capacity, and new projects were being secured more quickly than they could clear them. It was therefore essential that the CAD system produced its benefits very quickly without taking up valuable design time in the process.

The justification in this case was related to short-term time savings which were offered by the potential for parametric programming. Unlike Case 1, however, cost of the system was not insignificant in the eyes of the Company, and the ongoing benefits were expected to outweigh the ongoing costs.

As the method of justification was not expressed in this manner at the outset, the reasonable expectations of the system did not match the justification.

Case 3

Company 3 had a major problem of designer overload. It was not that the D.O. had insufficient space, but that the Company only had one designer, and he was working long and hard to keep pace with the workload. He had insufficient time available to train a second designer, and as a result of pressure was extremely inefficient.

The justification as expressed by the Managing Director was that the system should make the designer more cost-effective and reduce his workload. At the same time the design operation had to be deskilled.

This lines up fairly well with the expectations of the system. In addition to this non-financial justification, a maximum budget for hardware and software was set at £20,000, exclusive of maintenance costs. Note that the degree of workload reduction and cost-effectiveness increase formed no part of the justification.

Case 4

Company 4 was under similar constraints to Company 3, except that the designer in this case was the Managing Director. He was aware that he could not continue to run his Company and do all the design and draughting work. The justification in this case was fairly clear, but stated in vague terms. "The cost of the equipment has to be justifiable in terms of releasing me (the Managing Director) from draughting work to do design and management work".

The Managing Director's reasoning was that the system should be cheaper than the annual cost of employing a Managing Director to take over the management of the Company, thereby releasing him to do the technical work. The justification was therefore loosely financial.

Whilst the justification and expectations are different, they both point to the same end, and it can be argued that were either to be achieved the importance of the other would wane. It is difficult to envisage a situation whereby the expectations could be met without fulfilling the justification criterion.

Case 5

Company 5 developed its justification on the back of the Consultant's report. This report showed a payback for the system which was acceptable to the Company. It was decided that the system would be justified if the savings in terms of speed of operation and quality of output could be achieved. The justification could therefore be said to be purely financial, although the non-financial benefits of integration soon became paramount, to the extent that they were targeted without further financial justification.

Case 6

Company 6 was more traditional in its approach to justification. It took the expected savings less the annual maintenance costs as being the benefits. It then compared this with the finance costs of the system over four year. The system purchase was justified on the basis that the benefits outweighed the costs.

There was some suggestion that had the balance been more equal, or even tipped in the other direction, some account would have been taken of the additional benefits to be obtained by having more draughting time available. In the event, however, this was not tested.

Summary

The actual justification for implementing systems tends to be very complex, involving many different criteria. All we can do is pick out the major points made during discussion, and assume that there are no hidden factors.

In one case, as we saw, there were such hidden factors which did not come to light until well into the implementation.

It is fair to say that the match between justification and expectation is not particularly good in most of the cases. This is partly because we are comparing prior justification with expectations formulated in the early stages of implementation, when the power of the systems had been appreciated at least in some measure.

The findings of this section are summarised in Table 5.4.

Case	Non-financial Justification	Financial Justification	Match To Expectation
1	Throughput	None	Good
2	Throughput	Not Declared	Poor
3	Reduced Workload	Budget only	Fair
4	Reduced Workload	Tenuous	Fair
5	Speed and Quality	Payback	Poor
6	None	Payback	Poor

TABLE 5.4

5.1.5 Management and Organisation

As a company grows, its structure changes, and this change is often accompanied by delegation of authority and responsibility. The designer in a very small company may well report to the Managing Director, whilst someone with equivalent skills in a large company may find himself three or four steps removed from the Managing Director.

If that designer is responsible for implementing CAD in his drawing office, we may expect to find differences not only in the approach to implementation in areas such as justification, but also in the actual methodology of implementation. For instance the project team is likely to have a different emphasis, and the scale of the implementation may be different. Not only does the structure of a company change as it grows, but the management style may also change. It is not uncommon to find an autocratic manager at the helm of a very small company, but participative management tends to be more common with the larger companies. This can have a dramatic effect on the justification and implementation of capital equipment. For this reason, the organisation structure of the six companies has been recorded, noting the management style of the Chief Executive.

It was not deemed necessary to show the whole of the structure, but all the departments who may have influence on selection and implementation have been included. The structures are shown in Appendix 3.

Case 1

This Company is "directed" by the Managing Director in the true sense. Whilst he does on occasions become involved with day-to-day operation, this is rare, and the Company is managed effectively by the other executive members of the Board.

The teamwork at that level is good, with the Financial Director being the unofficial but unchallenged team leader. His personal, technical and strategic skills fit him well for this role.

The structure is quite traditional, with the pre-sales and post-sales design being handled by the Technical Director, production planning, including Bill of Material structuring, by the Production Director, and the management information, including CAPM systems, by the Financial Director. All the MIS and CAPM and systems have been computerised to some degree.

The D.O. is in the charge of a D.O. Manager, who spends some time estimating but the bulk of his time managing the D.O., issuing work to a priority list and ensuring that schedules are met. He is also responsible for new product development and the legal requirements of the new products.

At the start of the project, all the computer expertise and literacy was vested in the departments controlled by the Financial Director and Production Manager. The Technical Manager had no prior computer knowledge, and none of the D.O. staff had been involved with computers. Coincidentally, within a few weeks of the CAD study being started, a draughtsman was taken on who had CAD experience obtained outside the Company, although this experience was fairly limited.

Relationships between the "technical" and "production" departments had always been good, with free interchange of information. The drawing office personnel spent considerable amounts of their time on the shop floor, particularly when a new product was being developed, and this was seen by both parties to be quite normal.

The boundaries between the technical and production jobs were well defined. The D.O. prepared detailed drawings and parts lists, but the planners produced the structured Bills of Materials. This was seen as necessary because of the planners' intimate knowledge of production methods.

It was considered that this division was essential for efficient and accurate operation of the system. Whilst current thinking may regard this as unenlightened, it has to be said in its defence that the close working relationship of the two departments allowed it to work remarkably well.

Case 2

As with Case 1, Company 2 is "directed" by the Managing Director and managed by the senior executives. This direction is rather more hands-on, and is controlled by daily production meetings. The Managing Director is effectively running two separate companies on the same site, which share very few resources, but carry out work for each other on occasions.

The pump section is managed by the Works Director, whilst the Press section is managed by a Technical Director and a Production Director. Each division has its sales personnel, and the Financial Director is responsible for the accounts of both division.

The Pumps division has a single design draughtsman, and since an early decision was made not to provide CAD facilities for this division, it is not considered further.

Design work on the Press section falls into two categories both in style and organisationally. Major contacts are handled by a contracts designer and his small staff, working directly for the Technical Director. Again, an early decision was made that this section could not be computerised effectively in the short term.

The bulk of the design within the Company is in press work, and this is handled by the Drawing Office. The D.O. Manager works directly for the Technical Director and controls two Chief Designers. One is responsible for all the electrical design, with a single permanent designer. The other one is responsible for all mechanical design; he controls a variable sized team, depending upon the workload. At the minimum this would be four designers, but this could be supplemented by up to seven contract draughtsmen. The normal complement is four plus two contractors.

At the start of the project computer literacy was limited. A computer based accounting system had been in operation for some time, but there was no CAPM system.

The Chief Designer (Mechanical) and the Production Controller had both been to night school on basic computer courses, and were able to programme in BASIC and PASCAL. They were, of their own volition, developing unofficial systems between them to help the production planning process.

In doing this they had developed a very close working relationship, and their departments worked closely together as a consequence.

Within the D.O. environment the jobs were not particularly well defined, with the exception of the electrical section. New products were handled initially by the D.O. Manager, who decided, in conjunction with the Chief Designer whether the product would be designed by the Chief Designer himself, or whether it could be designed by one of the other team members.

If a decision was taken on the former course of action, a team would be set up to handle the design, headed by the Chief Designer. In the case of the latter course of action, the management of the projects was much less well defined. Some would be handled directly by the D.O. Manager, some by the Chief Designer, some by both and some apparently not at all. In short, D.O. Management was far from perfect. The uneven, and often very heavy, workload of the department was cited as a reason for this.

The boundaries between design and production were very clearly defined, with the designers preparing parts lists and cutting lists but having no part in production planning. On occasions the designers would be called onto the shop floor to resolve production problems, but this was informal and ad-hoc, and generally related to drawing errors or insufficient information.

The working relationships were far from close and at times antagonistic.

Case 3

Compared with the two previous cases, the organisation structure of Company 3 is very simple. The Company is small, and the structure reflects this.

At the start of the project, all design work was carried out by the Chief Designer, who worked directly for the Managing Director. He was also responsible for all post-sales customer liaison.

The Company was run on a day-to-day basis by the Managing Director and the Financial Director, with the Managing Director being responsible for all functions other than accounting. The Chairman was a non-executive accountant.

For a small Company, the amount of attention paid to the design process by the Managing Director was very small, and arguably reflected his confidence in the Designer. The Managing Director's main function was in sales and liaison with the agents throughout the country. His knowledge of the design and manufacturing process was good, although not to the level whereby he could take over either of the functions.

The Managing Director's "hand-off" approach was also evident in his dealings with the production unit. His Works Manager was in full control, reporting to the Managing Director infrequently.

Liaison between the Designer and production was good, and he spent a considerable amount of time with the mouldmakers. One of the reasons for this was that in many cases it was seen as simpler to communicate concepts verbally than pictorially. There was certainly benefit in this approach, since the Designer maintained an intimate knowledge of the limitations and potential of the production process.

At the start of the project all the computer literacy resided in the F.D. and one other member of his accounting staff. This was limited to sales, purchase and nominal ledgers, stock records and sales order entry, all on a single Apricot microcomputer on which the payroll was also done. The routines were simplistic, and needed to be reviewed. The designer was familiar with the concept of CAD, but had not been involved directly.

Company 4 had grown fairly quickly on the expertise and knowledge of the Managing Director, an entrepreneur who had exceptional flair but little managerial expertise by his own admission. Apart from the Managing Director there was no other manager in the Company with any authority apart from the Accounts Manager's statutory authority. The Managing Director was capable of doing all the jobs in the Company without exception, and tended to hold on to the parts he enjoyed - design and development.

Partly because of his awareness that the could not do everything, and partly because of time constraints, he employed a designer who worked under his close supervision. He also employed a Works Supervisor who worked under equally close supervision. As a result, all decision making involved the Managing Director to some extent, and there was no perceived need for the designer and supervisor to talk to each other, let alone work closely together.

At the start of the project there were no computer literate people in the Company. All the systems were manual even to the extent of having no word processor. The Managing Director was aware of the existence of sophisticated systems and had been to demonstrations of several.

Apart from accounting systems, for which he saw little need at that stage, he had looked at two CAD systems in some detail, and had been convinced that this was the way forward.

Job descriptions in the Company were nonexistent, and there was a great deal of overlap between the Managing Director and virtually all the staff who worked directly from him, to the extent of confusion in some cases. There was almost no overlap between departments, because of the Managing Director's "divide and rule" method of management.

The foregoing gives the impression of a hard-nosed autocrat, but this was far from reality. The Managing Director led by virtue of his technical ability - which was second to none in the UK - and his gentle, persuasive manner. He had also collected around him a team of relatively passive people who had neither the expertise nor the desire to challenge or push him.

Case 5

This Company is directed by a Managing Director, with a very strong executive team behind him. By far the strongest member of this team is the Works Director, who has responsibility for all technical and manufacturing functions, ie everything except accounts, sales and administration.

At the next level down from the Works Director there is a layer of first-line management.

The Drawing Office Manager controls a design/drawing office with six people including a supervisor. This D.O. is responsible for all design work and estimating for nonstandard products, excluding structures. A separate department is responsible for structural design and lighting planning, reporting to the Sales Director and feeding the structures and lighting plans to the D.O. for the detailing if necessary.

The split between design and lighting seems somewhat arbitrary, but whilst the reasons are historic, the principles work in practice, and there is little or no overlap between the departments. Installations are also controlled by the Sales Director via an Installations Manager. This is regarded as essential because of the high degree of customer contract by this department.

At the start of the project, both these departments would create designs up to the parts list stage, and then pass them to the production planning department for Bill of Materials structuring.

In this and other respects, jobs were very clearly defined. All employees had job descriptions which detailed their reporting lines and levels of authority and responsibility.

To some extent this had led to "hard" demarcation between departments, and there was a high degree of insularity throughout. That is not to say there was any animosity between departments, and they were working well together. One of the reasons for this was the participative style of the Works Director. He held regular planning/progress meetings for his first-line managers and others such as the Industrial Engineer who worked with his managers.

The Company was very computer literate. A large mainframe computer carried out all accounting functions, and an extensive suite of software was in use for production planning and control and management information.

In addition to this, there were several numerically controlled pieces of equipment on the shop floor. The lighting designers used Hewlett Packard microcomputers for their design work, linked to printers and a plotter. The CAD system was therefore one of the last links in the computerisation jigsaw.

Every department, including the D.O. was computer literate, if only to the extent of using the system to interrogate parts files.

The role of the D.O. Manager was key to the efficient functioning of the Company. Priorities on projects were set at the Works Director's meetings, but within these guidelines the D.O. Manager would coordinate the design and planning functions to ensure that the project could be completed to schedule. This may involve liaison with the buyer to pre-order long leadtime materials, and liaison with the planning department to optimise material usage. Once in production, he would also liaise with the manufacturing unit to resolve production problems related to design. This would often result in improved design practices for the future.

Case 6

Company 6, whilst not being a particularly new Company, could hardly be regarded as well-established in people terms, having had significant personnel changes prior to the start of the project.

The Managing Director is a salesman and leads a small team of sales personnel as well as controlling two manufacturing units. It is clear that his scope for hands-on management is limited, and he places a great deal of reliance on his management team.

The team is conventional in most respects, but has an 'extra' manager, who in the event turned out to be crucial to the CAD system success.

Some 12 months prior to the start of the project, the D.O. Manager had resigned to take up a post elsewhere after many years of service. He was duly replaced by an equally competent but less experienced Manager. Within nine months he had left his new post, and the Company took him back, because of his experience, as Special Projects Manager. In this role he was allocated major projects or new developments, and worked alongside the D.O. Manager and/or sales staff. In his short time away from the Company he had gained some limited experience of CAD, which was seen by the Managing Director to be beneficial so far as his future plans were concerned.

Roles within the Company were clear but flexible, with staff crossing the traditional demarcation lines whenever the need arose. For instance the designers would, if necessary, carry out some of the planner's work if he were busy. The special Projects Manager would also get involved with design, draughting and planning at times of extreme pressure.

Relationships with the production unit were excellent. This was partly because of the tendency of the designers to under-specify work to an extent where verbal instruction was required as a supplement. The Directors and Managers were aware that this state of affairs could not be allowed to continue, particularly if they were to seek certification under the BS 5750 Quality Assurance Standard.

Nevertheless, this constant contact between the department fostered close working relationships.

Unusually, the planners, who were responsible for creating cutting lists from the drawings, worked for the Production Manager, and not for the D.O. Manager. For the reasons expressed earlier, this caused no problems.

The Company was computer literature to an extent. The accounts were computer based, and the planners used a suite of bespoke software for cutting lists, part of which had been developed by the Special Projects Manager in his former role as D.O. Manager. This had not been implemented because of a shortage of hardware. There was no computer based CAPM system.

Summary

To summarise the foregoing as an aid to focusing on the similarities and differences between the companies, ten categories have been selected. These are summarised further in Table 5.5.

1. Management Style of Chief Executive

This can have a significant effect on the way in which decisions are taken within a company, particularly where costs and benefits are being traded and specifically where they are expressed in financial terms. The approachability of the Chief Executive may also be important in the way the company manages significant change.

2. Size of the Management Team

The number of people involved in strategic decision making may have an influence not only on the speed of decision making but also on its effectiveness.

3. Position of the "Driver"

The Chief Executive may not be directly involved in implementing the CAD system, and this category defines who in the organisation was responsible.

	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6
1. Management Style of Chief Executive	Direction Aloof Board	Direction Management Meetings Own Decisions	Direction Distant Sales Board Decision	Management Persuasive Hands-on Close Supervision	Direction Aloof Board Decision	Aloof Sales Team Decision
2. Size of Management Team	7	4	2	1	5	3
3. Position of "Driver"	Financial Director	Senior Designer	Chief Designer	Managing Director	Works Director	Special Proj. Manager
4. Management Style of "Driver"	Participative Encouraging	Passive No Authority Eager	Integrative Busy	See Ch. Exec.	Involvement Managing Encouraging	Participative Eager Integrative
5. Principal Tasks of D.O. Manager	Managing	Scheduling	Designing	Designing	Managing Scheduling	Designing
6. Effectiveness of D.O. Management	Acceptable	Poor	N/A	Satisfactory	Good	No Authority
7. D.O. Internal Relationships	Good	Fragmented	N/A	N/A	Good	Good
8. Inter-departmental Boundaries	Well Defined	Very Well Defined	Well Defined	Very Well Defined No Overlap	Well Defined Hard	Clear but Flexible
9. D.O. External Relationships	Good	Poor Antagonistic	Very Good	Distant	Good	Good
10. Challenge to Authority	Encouraged	None	Some	None	Encouraged	None

Table 5.5

4. Management Style of the "Driver"

As in 1. above, this may have a significant effect on the implementation.

5. Management Style of the Drawing Office (D.O.)Manager

Whilst the D.O. Manager may not be driving the implementation, his method of management may have a profound effect on the speed and effectiveness of the implementation.

6. Effectiveness of the D.O. Manager

It was clear during the studies that the D.O. Management varied between good and poor, and this may well have had an effect on the success or otherwise of the implementation.

7. D.O. Internal Relationship

Linked with 5. and 6. above is the internal working relationships between members and sections of the D.O.

8. <u>Inter-Departmental Boundaries</u>

As CAD has the capacity to be a cross-functional technology, the relationships between departments are important. This category describes the strength of boundary definition.

9. <u>D.O. External Relationships</u>

Following on from 8., this category describes the effectiveness of the D.O. in working across those boundaries.

10. <u>Challenge to Authority</u>

This follows on from 1. and 4. above, and describes the openness of the CAD implementation management to criticism, advice or questioning. It may provide pointers towards true team-work.

5.1.6 Management "Ownership"

Management commitment to a project has been recognised as being essential to its success for many years (see Section 2.4). In recent years, a new level of commitment has been identified and propounded, particularly where high technology implementation is concerned. This is the Project Champion.

It is suggested that this individual, to be successful, should be influential in the management structure, and should work closely with the specification/implementation team (Altschuler et. al. (1984)).

This section looks at the position and authority of the person most influential in implementing the CAD system at the six companies. It considers his relationship with the implementation team where this is relevant, and his contribution to the success or otherwise of the project. It also looks at the contribution of others further up and down the structure who were fundamental in supporting or counteracting his plans.

Case 1

At Company 1, the CAD project was managed by the Financial Director (F.D.). It was he who commissioned the Consultant to select a suitable CAD system, and he was involved in developing the brief for the Consultant.

Throughout the consultancy phase, all reports were made back to the F.D., and the final report was presented to him. Only after he had been through the report in detail did he involve others.

So far as the hierarchy of responsibility was concerned, he had been given the task of implementing CAD by the Managing Director, who required little involvement. The F.D. therefore saw it as his role to manage the whole of the project to eventual implementation, using whatever resources he required. He had full authority to select and direct an implementation team.

The team he selected was small. The Drawing Office Manager was a key member, and the Technical Manager was involved on the periphery. The Production Control Manager was involved as required, as was the computer specialist. The "full time" team therefore consisted only of the F.D. and the D.O. Manager.

So far as the Consultant was concerned, two sources of information were essential. Technical requirements for the system were obtained by detailed discussions with the D.O. Manager and his senior staff.

The Consultant was fully conversant with the CAPM system in use and the hardware platform, but required the expertise of the computer specialist when developing the interface to the CAPM system, particularly in terms of file structures.

Final selection of the CAD system was in the hands of the F.D. This may seem a dangerous path, but the shortlisting had at that stage been done by the D.O. Manager and Consultant, and the three systems shortlisted were all technically capable of the task in hand. At that stage the F.D. became involved in detailed discussions with the vendors, not only on system costs, but on the more technical aspects of links with the CAPM system.

It would have been very easy to alienate the Technical Manager (T.M.) who was ultimately responsible for the Drawing Office, and hence the CAD system. However, the F.D. used his considerable inter-personal skills to avoid any conflict, keeping the Technical Manager informed on progress and involving him in the more important stages of the negotiations. It must be said that the T.M. had little to contribute to the system selection or implementation, and saw himself as too busy to be involved in the detail.

The implementation of the system was managed by the D.O. Manager, but very closely monitored in terms of cost and progress by the F.D. It was during this stage that the M.D. began to take a more active role, once the implementation was running behind schedule.

Whilst supporting the F.D. fully, he insisted that the T.M. took a more active role, and took the necessary decisions to allow the D.O. Manager to be released to manage the implementation full-time. At no stage was the F.D. seen to be over-ruled, the M.D. acting purely in a supporting role.

All negotiations with the supplier before, during, and after the installation were conducted by the F.D., supported where necessary by the D.O. Manager, Consultant or M.D.

As a project manager or "champion", the F.D. was extremely successful and effective. He involved himself in the technical aspects of selection to a high level, as well as the more familiar (to him) financial aspects. By so doing, he was able to challenge statements and recommendations made by both the vendor and his own implementation team. This ability, coupled with his apparent impartiality and fairness gave him credibility and enhanced his authority.

It is not unfair to state that at Company 2 the project was not managed by any single person. The Consultant was commissioned by the Managing Director, who laid down very few guidelines for either the project or the system. It was to the M.D. that the Consultant presented the final selection report, although he (the M.D.) took no active part in its preparation.

The logical source of technical information would have been the D.O. Manager, but he expressed his misgivings about the feasibility of CAD and passed the responsibility to his Chief Designer (C.D.), who was considerably more enthusiastic. Information not available from the C.D. was available from the Contracts Designer or the Electrical Designer, all of whom worked physically closely together.

Whilst the C.D. was the main contact, he had no authority or responsibility for the project, and was not involved at the final presentation. Nor, incidentally, was the D.O. Manager or Technical Director.

Having accepted the findings of the selection study, the M.D. involved the T.D. in the final selection and meetings with prospective vendors. The T.D., whilst not being so sceptical as the D.O. Manager, needed to be convinced of the benefits of CAD.

The vendors did this to a level at which he was at least prepared to support the project, although to suggest that he was totally committed to its success would be to overstate the case.

Negotiations with the vendor were carried out by the M.D. and the T.D., with some input from the Consultant, and a little from the C.D. These were far from straightforward, as the vendor was in the process of changing his hardware platform, which involved a software change. Nevertheless, a deal was arranged between the companies which involved a combination of purchase and lease.

At the point of delivery of the system the M.D. took a back seat, and the project became the responsibility of the D.O. Manager, who delegated it to the C.D. as a part-time activity.

Software and hardware problems with the supplier caused the M.D. to become involved, and the T.D. was also brought back into the picture. Again, there was no "ownership" of the system at any level, and this caused severe problems for the vendor, who was receiving contradictory information from different levels in the organisation.

The Consultant was invited to intervene, and the immediate problems were resolved fairly amicably for the time being.

The eventual breakdown of the project came suddenly. In the absence of any evidence that cost savings had been achieved by the Company through use of the system, the M.D. requested an investigation by the Consultant. This found that the system was not being used effectively, and that by altering working practices the D.O. Manager had effectively sidelined the system.

The C.D. had attempted manfully to use it, but pressure of work and the introduction of the new practices made this almost impossible. Whilst he was still convinced that it could be cost effective, he was powerless to do anything about it. The Consultant's report stated that in the absence of records it was not possible to evaluate the actual or potential contribution that the system had been making or could make, but the short-termism of the new working practices was criticised.

The T.D. received the Consultant's report, and on his recommendation the M.D. decided that the project should be suspended.

Somewhat acrimoniously, the vendor was asked to remove the rented equipment, and the equipment which had been purchased was virtually mothballed.

Case 3

At Company 3 the decision to investigate the use of CAD was taken by the Managing Director (M.D.), although it was clear that the Financial Director (F.D.) and the Chief Designer (C.D.) had been involved in discussions on the subject prior to this. As a result there was general consensus amongst the senior management team that the project as a whole was desirable.

The case was unique amongst the six cases, in that a decision had already been taken to purchase a CAD system, and the Consultant's brief was to select a suitable system. That this had not been a fully informed decision became evident as the project progressed, although the decision turned out to have been correct in terms of potential benefits.

The M.D. retained full control and ownership of the project throughout the evaluation and selection stages, and was intimately involved at all the demonstrations, together with the C.D. He thus became something of an authority on 2D/3D draughting and was able to take an active part in the discussions. In this respect also the case was unique. At no stage was the Consultant required to make decisions. All his assumptions were tested fully and any recommendations were questioned in detail.

This not only enabled the M.D. to learn about systems very quickly, but also gave him confidence in his decision to purchase.

The C.D.'s role was to some extent a parallel to that of the Consultant. He sought out the technical areas which may give rise to problems and assured himself that the chosen system was able to meet his requirements.

The role of the F.D. was rather different. He was not so well informed on the technical aspects of CAD as the M.D. or C.D., but he had taken some trouble to look in detail at the various methods of financing the purchase. Having been kept up-to-date on the general progress of the project, he was able to step in and negotiate the purchase from a position of strength.

There can be no doubt that in this case the M.D. was the System Champion, although the other members of the team worked so closely with him that there was no conflict whatever. The final decision, when it was made, was unanimous.

Case 4

The Managing Director (M.D.) of Company 4 was an autocrat, and not surprisingly he took on the role of the System Champion. As owner of the Company his authority was unchallenged, and this remained so throughout the project.

The evaluation and selection stages of the project involved the M.D., but also the draughtsman. However, the draughtsman's input was limited for two reasons. Firstly, since he had been with the Company a very short time, his knowledge of systems, procedures and working practices was limited. Secondly, he was on a short-term contract, and had little interest in evolving systems for the future.

The M.D.'s position during these two stages was that he was prepared to impart as much information as was needed, but he did not want to take an active part in system selection.

He took the attitude that the Consultant would select a suitable system and was better left alone to do so. Whilst this was far from satisfactory from the Consultant's point of view, the M.D. had made his stance and would not be moved.

At the final selection stage the M.D. agreed to be involved in benchmarking, and introduced two further vendors of his own to the shortlist of three. He and the Consultant prepared the benchmark test and used it to select the system to be purchased.

At that point the M.D. suspended the project for about a year because of the trading situation. At the end of the period the M.D. reviewed the systems again and purchased the selected system. At that stage he had no design staff, and he employed a young graduate to load the system. Both were trained by the vendor.

It had always been the intention of the M.D. to re-employ a designer who had worked for him previously, and he did so at the first opportunity. This designer had no CAD experience, and had not, of course, been involved in the selection. He was therefore fairly unenthusiastic about the system, despite being trained by the vendor. The M.D. was unable to raise his enthusiasm at that stage.

Only after working with the system for some months and undertaking a refresher course did the designer stop fighting the system and begin to use it effectively. From that point a successful outcome was within reach, and benefits were achieved very quickly.

At no stage did "ownership" of the implementation move from the M.D., although his control of the situation was suspect at times. His inability to motivate the designer to use the system effectively was central to the protraction of the project, and in the event may have been contributory to the eventual demise of the Company.

Case 5

The investigation of the need for CAD in Company 5 was instigated by the Works Director (W.D.). It was clear from the outset that the W.D. had spent some considerable time considering how a CAD system could be linked to the existing CAPM system and making himself familiar with the types of system available. He recognised that he did not have the skill or knowledge to select a system form those available on the market.

The Consultant's main contact during the study was the Drawing Officer (D.O.) Manager, who also had a little knowledge of CAD through his extensive reading. However, at all stages of the project the Works Director made himself available for providing and receiving information. He made it clear that he wished to be involved throughout the selection procedure.

Prior to the investigation the W.D. had negotiated a budget for the proposed system at Board level, although this was deliberately withheld from the Consultant during the selection stage. Only during the system evaluation was the presence of a budget admitted.

The W.D. took no active part in benchmarking the selected systems, leaving this to the D.O. Manager and CAPM Consultant. The CAPM Consultant had been brought into the selection team by the W.D. to highlight and evaluate the potential problems of linking CAD and CAPM.

Unlike most of the other Cases, an integrated system had been specified from the start, and the links were to be demonstrated by the vendor prior to purchase.

Following each benchmark, the W.D. received reports from the Consultant, the CAPM Consultant and D.O. Manager, who agreed the next action with the team. The benchmarking and selection thus proceeded in a steady, controlled manner, interrupted only by a period of inactivity by a shortlisted vendor. All aspects of justification of the system were demonstrated to the satisfaction of the team, and in particular the W.D.

Once the technical specification had been finalised and agreed, the W.D. took over the financial negotiation and purchase of the system. Guided by the Consultant, he specified a phased approach to the implementation. Whilst the D.O. Manager was ostensibly in charge of the implementation, he delegated much of the responsibility to the Chief Draughtsman (C.D.), who reported progress directly to the W.D. This was fortuitous in that part way through the implementation the D.O. Manager left the Company and the C.D. was promoted to that position. From that point progress was faster.

The implementation was monitored in detail by the W.D., who checked progress against targets agreed with the D.O. Manager. All the necessary organisational changes, such as combination of the D.O. and the Planning Department were instigated and monitored by the W.D., who received reports of progress weekly and resolved operational problems as they arose. The fact that he had control of these two departments was clearly advantageous, and his own motivational style appeared to play a significant part in the success of these fundamental changes.

There can be no doubt that the W.D. controlled the selection, implementation and monitoring of the CAD system from beginning to end.

What is equally clear is that he had the authority to proceed as he thought fit at all stages, even to the extent of going slightly over the budget figure agreed with the Board. Whilst the writer was not privy to the Board discussions, the results of those discussions would suggest total support for the W.D. throughout. At no stage did the Managing Director or any of the other Directors become involved directly in the project, although a copy of the Consultant's report was made available to Board members.

Similarly, the extent of authority ad responsibility of the team members was very clear to all from the start of the project, and there was little or no interference from above other than that required for monitoring purposes.

<u>Case 6</u>

The situation at Company 6 in terms of managerial involvement was not unusual. The Managing Director (M.D.) instigated the investigation into the use of CAD, but thereafter withdrew from the project until the system was selected. His involvement with the consultant was at the minimum level consistent with courtesy.

The project "driver" was the Special Projects Manager. This individual had formerly been D.O. Manager, and had left the Company for a period to work for a competitor. When he left the competitor he was taken back by the Company with alacrity, partly because of his undoubted skills and partly to avoid his moving to another competitor. As the post of D.O. Manager had been filled, a new post was created for him. Whilst the post was ill-defined, the implementation of CAD was seen as an ideal "special project" for him to manage.

His knowledge of and experience with the Company made it unnecessary for anyone at a more senior level to be involved to any extent, a factor which was welcomed by the M.D.

The Special Projects (S.P.) Manager was given full authority to specify, identify and select a suitable system, with the help of the Consultant. The initial specification and shortlisting was carried out jointly by the two individuals, but at that point a consultative process was started.

Several interested parties were invited to join a small team to prepare a benchmark test. This team included designers, draughtsmen, planners and the buyer. The involvement of all these people was seen as key to the eventual success of the system.

Once the benchmarking had been conducted to the satisfaction of the S.P. Manager, the final selection was carried out and a quotation was prepared. At this point the M.D. again became involved, and conducted negotiations with the technical assistance of the S.P. Manager. From that point and for the next six months or so the M.D. remained in contact with the project, receiving progress reports and monitoring draughting times against targets set during the selection phase.

The M.D. and S.P. Manager held monthly meetings to review the system performance, and any necessary actions were discussed and agreed for subsequent implementation by the S.P. Manager.

The identification of a "project champion" at Company 6 is not so clear as in some of the other cases. Whilst the S.P. Manager had control of the selection and implementation, it became clear that he had no financial authority. On the other hand, the M.D. who had that authority relied totally upon the technical expertise of the the S.P. Manager, and to some extent the Consultant, during the project. The fact that he had initiated the project and supported it by implication during its early stages probably points to his being the "project champion", although he was not the "driver" of the project.

Summary

A "project champion" can be identified in five out of the six cases, although surprisingly in one of those five cases the "driver" of the project was a different individual. Table 5.6 shows the position of the project champion in the organisation.

Case	Project Champion	Steps Remote From M.D.	Project Driver
1	Financial Director	1	Financial Director
2	None	-	None
3	Managing Director	0	Managing Director
4	Managing Director	0	Managing Director
5	Works Director	1	Works Director
6	Managing Director	0	Special Proj. Mgr

Table 5.6

5.1.7 Commitment to the System

Before getting too involved in this Section it is important to determine what we mean by commitment to the system, since it would appear that commitment can be identified and evaluated at various levels and stages. These can be broken down as follows:

By level in the organisation:

Commitment by the	:	Chief Executive
	:	System Champion
	:	Project Team
	:	User Group

By implementation phase:

Commitment at the	:	Concept Stage
	:	Selection Stage
	:	Implementation Stage
	:	Integration Stage

By Commitment Type:

Commitment to	:	Buying a System
	:	Getting it Right
	:	Making it Pay
	:	Using it all the Time
	:	Expanding the System
	:	"Full" Integration
	:	Implementing Quickly

There are also peripheral issues which may cloud the commitment, such as the "me too" syndrome, or the need to implement because there is no other way to do the job. Both these factors could be more compelling than the level of commitment.

Clearly, then, the issue of commitment to the system is going to be difficult to define and even more difficult to evaluate, since there can be no absolute scale of commitment. If this were not sufficient, there is also the likelihood that commitment may change during the implementation, and may increase or reduce.

To reduce the complexity of this analysis, it has been decided to look at the level of commitment of two people or groups of people at four stages in the implementation.

Since the "system champion" was in all cases the most senior person directly involved, and at the same time the decision maker, his level of commitment is important. The other individual or group is the user or user group, whose commitment can make or break a system.

The four stages chosen are:

1. System selection stage.
2. Immediately before the worst setback.
3. Immediately after the worst setback.
4. When the setback had been resolved.

These stages have been chosen with some forethought. At the system selection stage the likely costs and benefits have been evaluated and the company has to decide whether to proceed. Any lack of commitment at this stage could presage problems later. The period immediately before a major setback is likely to be a honeymoon period, when all appears to be well and confidence is high. Immediately after the setback all those involved are likely to be reeling and possibly confused. This is where confidence can drop. Once the situation has been resolved, and some confidence has returned we can again look at the commitment in a stable situation.

In order to reduce the subjectivity of measuring commitment, an ordinal scale has been developed. However, it must be understood that the placing of individuals or groups on this scale involves subjective judgement by the writer based on discussions and contemporaneous notes made by the Consultant.

The scale used is as follows:

A. The participant had no interest in the project or in its success or failure.

B. The participant would rather the project succeeded than failed, but was not prepared to take an active role.

C. The participant wanted the project to succeed and was prepared to help it to do so.

D. The participant was prepared to go out of his way to make the project succeed.

E. The participant was prepared to do everything in his power to ensure success, and would not consider failure.

It has to be emphasised again that some respondents would not express their commitment, and the evaluation in this case can only be gauged from their subsequent actions.

Case 1

Company 1 had determined that CAD was an essential piece in its Advanced Manufacturing Technology (AMT) jigsaw, and could see no other way forward. This had been discussed at length by the Board, who were all committed to a high level. In addition, some groundwork had been done in the Drawing Office, and many of the draughtsmen were keen to be involved. Those who were reluctant were informed that they need not be involved in the early stages

The worst setback for the Company occurred some six months after the first installation, when a period of intense design activity caused the CAD system usage to fall and the more familiar manual draughting to rise to cope with the work. This in itself showed a lack of confidence in the system. This period lasted for around six months, and was followed by a second period of poor vendor support and hardware changes lasting two months. Confidence returned very quickly after this.

The commitment "map" for Company 1 is as follows

	Phase			
	1	2	3	4
Champion (F.D.)	D	D	E	D
Users	C	D	B	D

Case 2

Company 2 saw CAD as a convenient way of reducing the number of contract draughtsmen in order to avoid the problems associated with training as throughput increased. Whilst some of the contractors were familiar with the products, many had to go through a lengthy familiarisation as they were taken on.

As suggested earlier, their was no "system champion", and no single person "owned" the system. The commitment of the Managing Director has therefore been tabulated.

The worst setback for the Company came six months after the first implementation, when it was discovered that the D.O. Manager had introduced systems to erode the benefits of the CAD system. This led to a formal system review and a decision to abandon the project.

The commitment "map" for Company 2 is as follows:

	Phase			
	1	2	3	4
Champion (M.D.)	C	C	B	B
Users	D	D	E	C

Case 3

Company 3 was concerned at the pressure of work on its designer, and saw CAD as being able to reduce this by eliminating repetitive drawing. There was therefore some level of compulsion at the start of the project which raised commitment to its success.

The Company suffered no major setbacks, but a few months after installation of the system the pressure of work became very high on the draughtsman, who at this stage was using both manual and CAD systems. Fortunately a fall-off in work allowed the draughtsman the time to concentrate on getting the CAD system fully operational. During this period the draughtsman was supported by the M.D., who retained his belief that the CAD system was the only way forward.

The commitment "map" for Company 3 is as follows:

	Phase			
	1	2	3	4
Champion (M.D.)	D	D	E	D
Users	D	D	E	D

Case 4

Company 4 found itself in a similar position to Company 3, in that the CAD system was seen as the only way out of a manpower shortage. In his case, the designer/draughtsman was the M.D. at the start of the project. As the project progressed, a draughtsman was introduced to run the CAD system, and then a designer replaced him at a later stage.

The major setback for the Company was the replacement of the draughtsman by the designer. To some extent this was self-imposed, since the designer had no experience of and little interest in CAD. A period of intervention by the Consultant and a training course for the designer resolved the situation to an acceptable extent in a short time, and the designer's attitude to the system increased dramatically.

The commitment map for Company 4 shows the designer and the draughtsman as users.

	Phase			
	1	2	3	4
Champion (M.D.)	D	D	D	D
Draughtsman	C	C	-	-
Designer	-	-	A	D

Case 5

Company 5, like Company 1, saw CAD as being an integral part of their AMT programme, and there could be no doubting that it would be successful. A great deal of pre-planning had gone into the project and consultation had taken place withing the Drawing Office. By the time the project started there was an eager expectancy and a sense of urgency.

The approach of the Company was to resolve all the problems before purchasing the system, and a great deal of time and expense was involved in doing this. The consequence was that the most serious setback took place before the system was purchased. This was when the links between the CAD and CAPM systems could not be defined by either the Company or the vendor. This resulted in the Consultant's being involved and a specification was drawn up. From that point the links were created and proved and the system was purchased. At no stage was a serious loss of commitment noted.

The commitment "map" for Company 5 is as follows:

	Phase			
	1	2	3	4
Champion (W.D.)	D	D	E	D
Users	D	D	D	D

Case 6

Company 6 saw the benefit of CAD to be in the reduction in complexity of creating a drawing. The high level of detail was extremely time-consuming, and the repetitive nature of some of the drawings was laborious. However, when compared with some of the other cases the compulsion for implementation was not so great. That is not to say that the Company was less committed to success.

No serious setbacks were encountered during the implementation stage, and the nearest point to a setback was when the vendor was called in to review the creation of cutting lists from elevation drawings. The writing and proving of this software took about four months and opened up areas of design which had hitherto been unavailable.

The commitment "map" for Company 6 is as follows:

	Phase			
	1	2	3	4
Champion (M.D.)	C	C	C	C
Users	D	D	D	D

Summary

The commitment "maps" show a number of interesting features.

a) In all except cases 2 and 6 the "system champion" showed an equal or higher commitment than the users.

b) In four of the six cases the period of setback resulted in a higher level of commitment from the users or the "champion".

c) In Case 2, the only case where the "champion" lost commitment, the project eventually failed, even though the users' commitment rose initially after the setback.

d) In Case 1, the "champion's" commitment rose after the setback, and a short-term dip in that of the users was turned around.

In general, the commitment of the "champion" appears to override that of the users. It would appear that the users will in the long term follow the lead from above, whether that commitment rises or falls.

5.1.8 Level of Satisfaction

Satisfaction is an extremely complex and subjective emotion, yet corporate satisfaction with a system is fundamental to its acceptance. It is therefore essential that we provide a yardstick against which satisfaction may be gauged. If we can do this objectively, then we can compare the implementations one against another in a meaningful manner.

In order to produce the yardstick, phrases used by those responsible for implementing the systems were collected together and "ranked". These ranked phrases were then taken back to the original implementers and validated. The following list of phrases and statements represents the final consensus reached.

Level 1

Totally dissatisfied

System was a failure

We should not have bothered

Level 2

Highly dissatisfied

Virtually no benefits were achieved

Very unhappy

Level 3

Dissatisfied

Few of the requirements were met

Unhappy

Level 4

Not happy

The system has not paid its way

Level 5

Not unhappy

Some benefits were achieved

Marginal success

Level 6

Satisfied

Many of the benefits were achieved

Happy

Level 7

Highly satisfied

System met the majority of the requirements

Very happy

Level 8

Totally satisfied

System was unqualified success

Excellent

Using these statements, a "satisfaction curve" was plotted for each of the six cases, and these are shown in Appendix 2. The curves related the level of satisfaction and the project timescale. Note that the timescales on the X-axes are different.

It is important to note that the "satisfaction curves" combine two measures of success. Success in implementation can be measured by hitting targets and timescales, whilst success in application is perhaps measured by the degree of use of the system.

By seeking the views of several members of the implementation team and the Chief Executive, the two measures have been combined. Lack of "satisfaction" in the earlier stages of an implementation were invariably the result of lack of success in implementation, or in other words targets were not being met.

In order to clarify the position regarding the two measures of success, Table 5.7 has been constructed based upon the comments of the various respondents.

Case	Success in Implementation (%)	Success in Application (%)	Satisfaction Level (1-8)	Comments
1	50	90	7	Supplier Problems
2	30	20	2	Lack of Acceptance
3	40	80	7	Slow Progress
4	60	90	7	Limited Resources
5	90	100	7	Unqualified Success
6	70	80	7	Good Progress

Table 5.7

It must be re-emphasised that we are discussing corporate satisfaction with the system, and not the impressions of a single participant in the process. Under conditions of free discussion it soon became apparent that agreement on a level could be reached, using the phrases listed above, for each stage or milestone in the implementation process.

It was interesting to note how often the views of the "system manager" were more lucidly expressed and apparently more strongly held that those of the chief executive.

Perhaps task commitment could be one of the reasons for this. The summary of section 5.1.7 (p.217) would appear to support this.

5.1.9 Implementation Planning

CAD represents, for many companies, a significant financial outlay, as does for instance the implementation of a Computer Aided Production Management (CAPM) system. It would not be unreasonable, therefore, to expect a similar degree of planning prior to the implementation stage. In the author's view, this is rarely the case, and there may be several reasons for this:

* CAPM by its very nature is cross-functional, whereas CAD in small firms may not be so. The cross-functional nature could perhaps lead to more communication and hence better planning.

* CAPM usually involves a financial tie-up, and the statutory nature of this requires a higher level of pre-implementation planning and post-implementation monitoring.

* Accountants tend to have an eye for detail, and are prepared to take a view of the implementation which would not normally be taken by an engineer, who tends by the nature of the job to be more results orientated rather than task orientated.

Whilst we may all agree that planning for a project is desirable, it appears that many small firms are reluctant to spend time doing it. Of the six cases, only three developed an implementation plan of any sort. The other three, by implication had no method by which they could measure progress other than by intuition.

Of the three which did produce plans, i.e. Companies 1, 5 and 6, only two, Companies 1 and 5, identified milestones and target dates in any detail. Company 5 went further by publishing its plan in the form of a wall-chart in the Drawing Office, and progress was marked on the chart for all to see. At frequent but irregular intervals the project team would review progress and redraw the chart.

There was a disadvantage to this method which would not have been obvious at the start. The identification of milestones tended to concentrate effort on achieving them, possibly in some cases to the detriment of other, more useful targets. Rather like cramming for examinations, the draughtsmen tended to have tunnel vision, and some opportunities were lost.

As an example of this, one of the targets was the development of parametrics for lighting columns, and this was achieved ahead of target. However, the talking point in the office was the potential for development of parametrics for fencing.

This did not become obvious until the targets had been set, yet it had greater potential than the columns parametric. Despite this, the milestone of the column parametrics prevailed.

Company 1 used their plans rather differently. They reviewed the progress monthly against the plan and analysed the reasons for slippage. They then changed the manning level to bring the project back on target if this was feasible.

The milestones in the case of Company 1 were much wider and rather less precise. This gave some flexibility to the Design Manager, but made progress a little more difficult to assess. Misunderstandings over the targets led to heated exchanges at the review meetings on several occasions.

The plan defined by Company 6 listed the milestones and their sequence, but did not show timescales. There was a general understanding amongst the implementation team of the pace required, but the philosophy of implementation was somewhat different.

Whereas Company 1 and 5 sought to implement quickly in order to maximise benefit, Company 6 took a different view. They sought to extract every last bit of benefit from each planned stage before proceeding with the next. This is quite a sound philosophy, except that is does tend to lead to periods of relative stagnation as the law of diminishing returns takes effect.

The review for Company 6 looked at the progress on a particular milestone or topic and then sought to maximise the benefit. Only when the benefits became inconsequential did the team move on to the next target.

Summary

Case	Plan	Effect
1	Broad Targets and Timescales	Rapid Progress; Misunderstanding
2	None	No Monitoring
3	None	No Monitoring
4	None	No Monitoring
5	Detailed Targets and Timescales	Rapid Progress; Tunnel Vision
6	Broad Targets Only	Slow Progress; well Defined Benefits

5.1.10 Vendor Relationships and Training

Discussions with the six companies revealed little about the actual relationships between company and system vendor, partly because of the subjective nature of the evidence and partly because of the complexity of the relationship. When companies, or more particularly people within those companies, work closely together on a project, a kind of love-hate relationship tends to be built up. This is based on mutual respect for the other's position whilst attempting to safeguard one's own position. The result is a relationship which can fluctuate quickly and widely in terms of satisfaction and closeness.

Whilst we may expect companies to "manage" advisors as they do their own employees, there was no evidence of this in the six cases. Indeed, the vendors were often seen to be taking the lead in system development. However, the author was able to find no common threads in the treatment of companies by vendors or vice-versa.

One measure of the vendor relationship which could be assessed was the uptake of vendor training. Whilst this is admittedly not a good measure, it has some merit in that in all six cases it was an additional cost which had to be borne by the company. It could be argued that the higher the uptake of vendor training on a per-capita basis the better the relationship between vendor and customer.

This is clearly an excessive claim which cannot be substantiated by the present work, but a study of the effectiveness of that training reveals some interesting points.

All six of the companies paid for some basic training on the system. Basic training provides a skill level which allows drawings to be created in a competent manner and imparts housekeeping and elementary system skills.

Basic training is a term which is understood by system suppliers and CAD users, and in the author's experience the level of skill imparted varies little between suppliers on a day-to-day basis. There is, however, some variation in the length of training, but in the six cases studies, basic training took two or three days.

The five vendors involved in the six cases also provide an intermediate level course, which enables the user to take advantage of all the draughting facilities. They also provide a system manager's course under a variety of names. This covers elements such as operating system usage, directory structuring, archiving and other non-draughting activities.

Company 1 had a long-standing commitment to training, and provided all users and potential users with basic training. At the same time they provided the D.O. Manager with system training.

Those draughtsmen who took to the CAD system were encouraged to stay on it, and the higher level training was offered to them when they were ready to take advantage of it.

There was a great deal of informal training within Company 1, whereby the more skilled would advise the less skilled on an ad-hoc basis. However, this was not allowed to be used as a substitute for formal vendor training.

The basic training plan was to have all the draughtsmen trained to use the system, half trained to the intermediate level and the D.O. Manager and his deputy trained to the systems level. The number of intermediate draughtsmen was, in fact, exceeded, whilst the turnover in draughtsmen often meant that there were untrained draughtsmen in the Drawing Office.

Company 2 had no training plan and no history of training within the Company. Four draughtsmen were trained to the basic level, i.e. two for each work station, and one was trained to the intermediate level. He was then charged with passing on his skills to the other three. Time constraints made this virtually impossible.

Company 3 had one workstation only, and the draughtsman/ designer was trained up in three stages to systems level. He set his own pace of training, taking on the next level as and when he felt able to do so.

When the designer was joined by a second draughtsman, that draughtsman was provided with basic vendor training, and the designer undertook to increase his skill level by informal ad-hoc sessions.

Company 4 had one workstation and one draughtsman, who was given basic training only. When the draughtsman left, the designer who took his place was trained to the basic level by the vendor. His lack of aptitude made it necessary for the vendor to provide a slightly modified re-run of the basic training some months later. No formal intermediate or systems training was given, although the Company did benefit from systems advice from the vendor.

Company 5 had a training plan which had many similarities to that of Company 1. It provided basic vendor training to all the draughtsmen who may be involved in CAD or who showed an interest. As the draughtsman became more experienced, he was sent on the more advanced course to enable him to write parametric programs.

Unlike Company 1, the D.O. Manager did not undertake the intermediate training, since he foresaw no situation when he would need to write parametrics. As systems manager he needed to be able to manage the system and modify drawings where necessary. He was therefore trained to basic level and systems level.

This could only work well because the D.O. Manager was not expected to help designers with their work on a day-to-day basis. This was the role of the Chief Draughtsman, who was trained to the vendor's intermediate level.

Company 6 had no formal plan, but nevertheless provided basic training for all their draughtsmen. The Special Projects Manager took all three levels of training, and managed the system. The D.O. Manager was trained to the intermediate level, and then undertook the training of the others as required.

Summary

Case	% of Draughtsmen at Level 1	% of Draughtsmen at Level 2	No of People at Level 3
1	100	60	2
2	50	12	0
3	100	50	1
4	100	0	0
5	100	30	1
6	100	30	1

5.2 Propositions

These propositions have been developed from the case study outcomes. They are intended to form a focus for the research findings in an attempt to find a rationale for the outcomes of the six cases. Where a potential proposition cannot be verified by all six cases it has not been developed.

5.2.1 It is not unreasonable to suppose that where a potential CAD system is to cross functional boundaries, or where it involves a significant amount of capital expenditure, a reasonable amount of thought will be given to the system and its implications prior to implementation. A significant consideration is likely to be the potential cost of failure both in monetary and human terms.

1a The higher the level of integration the higher the cost of the system and the higher the potential cost of failure in monetary and human terms.

This proposition in itself is not particularly exciting, but it leads on to a more interesting proposition.

1b The higher the level of integration the higher the cost and the higher the level of consideration given to the system. Consequently the higher the likelihood of eventual success.

This is based on the premise that the rational manager will seek to reduce risk by giving sufficient thought to the project before committing funds. Of course, with a new technology risk cannot be eliminated entirely, and projects tend to go forward on this basis.

Case 5 is an excellent example of pre-planning, where no finance was committed to the project until all the possible sources of problems had been highlighted and discussed fully. Case 1 was similar in its approach, but reduced risk even further by a carefully staged implementation.

When problems do arise, they have to be dealt with by the project team, whether it consists of ten people or just one. It is likely that problems which do arise can be resolved more effectively by the combined efforts of a group than by one man.

1c The higher the level of integration the greater the number of people involved in the implementation and the higher the likelihood of speedy resolution of problems.

"Whilst there is a danger in attempting to solve problems by committee, we rather envisage task groups characterised by an effective group process." (Schein 1969)

5.2.2 CAD is predominantly about design and draughting, but it has a significant computer-related bias, particularly when handling files and directories. People with computer experience tend to be comfortable with other, more complex computers. They are keyboard literate, they understand that they can do little damage, and they know something of the jargon used by computers and their users. This is the case whether they have worked on a small personal computer or a large mainframe. If, as we may expect, fear of a system inhibits its acceptability, then the converse is likely to be true.

2a The more people in design related roles with prior computer knowledge and experience the higher the chance of acceptability and hence success.

There is some evidence of this during CAD training, which inevitably involves learning to use the computer for non-draughting work. Those with prior knowledge, even of just a games computer, tend to pick this up more quickly and end up with a greater depth of understanding.

One may expect that exposure to computer systems but not as a user may have a similar effect. For instance we may expect the non-computer-literate accounts clerk who sees the equipment being used daily to have a high empathy with it. This does not seem to be borne out in practice.

2b The level of computer literacy elsewhere in the organisation has little effect on the success or otherwise of the CAD implementation.

Case 3 bears out this proposition. The Company had used computers for financial purposes for some considerable time, but the designer and MD were computer illiterate and had difficulty with some aspects of the training. Both were familiar with the concepts of computerisation and understood the benefits likely to accrue, but this did not appear to help them in their transition from information user to system user.

5.2.3 The wide variation in the targets set for the system implementations was most interesting. Whilst some cases set a low "satisfactory" level, others seemed to set their targets at a particularly high, almost unattainable level.

As with the level of integration discussed earlier, those companies which set different targets tended to spend a great deal of time discussing the targets and planning for success. Two companies in particular built milestones into their plans (Cases 1 and 5) against which they could measure their performance and adjust the activity level. The propositions for targets therefore bear a close relationship to those for level of integration.

3a The higher the degree of difficulty in achieving the target the more consideration has been given to the measure of success and therefore the better planned the project.

The corollary to this proposition became self-evident.

3b The higher the degree of difficulty in achieving the target the higher the likelihood of success.

This does not conflict, as it may appear at first, with the work on goal setting which suggests that attainable but moderately difficult goals are most motivating (Lawler (1983) p.230). Indeed a very difficult primary target may be achieved by setting very modest goals.

It is important to note that the "degree of difficulty" to which we refer here is that as perceived by the implementation team at the start of the project, and may bear little relationship to the actual difficulty encountered.

The concept has direct parallels elsewhere in industry. It forms the basis of the majority of incentive schemes, where pay is directly linked to the effort put into the job. An incentive scheme has the chain:

TARGET -> EFFORT -> ACHIEVEMENT -> PAYMENT

The CAD implementation has a different reward at the end of the chain:

TARGET -> EFFORT -> ACHIEVEMENT -> SATISFACTION/KUDOS

5.2.4 As was suggested earlier, the expectation of a system is difficult to quantify and can be inordinately difficult to identify. One of the problems is that, not knowing what a CAD system can do, potential users are unable to get any feel for the benefits, and have to resort to advice and/or what they have read.

In the absence of well-founded expectations, it is difficult for a company to prepare a meaningful justification on which to base the capital expenditure. This is the case whether or not the company spends time looking at systems, particularly if their only exposure to systems is via system suppliers.

It would seem to follow that a company which has prior CAD knowledge should be better placed to prepare a competent justification.

4a Prior CAD knowledge causes justification and expectations of a system to be broadly similar in scope and achieved within the same time frame.

Putting this another way, and with a slightly different emphasis.

4b A clear justification may be the result of prior CAD knowledge and is likely to lead to reasonable expectations.

Where there is no prior CAD experience expectations tend to be poorly expressed. However, by the nature of justification it has to be expressed regardless of the lack of knowledge. Only when the implementation has commenced and the participants begin to understand the potential for CAD are expectations formed that are meaningful.

4c Expectations are more important yardsticks of success than justification since they are formulated in the early stages of a project implementation against a background of better information.

The word "important" may cause some raised eyebrows for any readers with a financial background, since they would claim that what is really important is a return on the investment. However, the word stays, in the belief that there may be wider issues than payback at stake in a CAD implementation.

Whilst justification is by its nature a static measure, expectation is ever-changing and at the start of a project it may change very rapidly.

As a result, justification tends to be forgotten during the implementation. Indeed it is quite possible that the implementation team know nothing of the justification. The time when justification comes back into the spotlight is when something untoward happens, and the system does not seem to be performing.

4d Where expectations are not met by an implementation, the success of the implementation is measured against the justification factors. This does not happen if expectations are met.

This could be fortunate, since in the experience of the writer many companies are over zealous when they estimate the savings to be made by introducing CAD.

Part of the fault for this has to be placed at the door of the CAD salesman, who may quote actual but inappropriate savings in order to secure an order. Part of the author's role over the years has been to act as expert witness in disputes between CAD vendors and discontented purchasers.

4e Expectations are more likely to be met than are the factors for justification.

5.2.5 The old adage "Good managers manage good companies" has more than a little truth in it. The style of the chief executive of a company can have a very significant effect on the managerial style of his managers and hence on the ethos of the company. This in turn can influence its ability to manage change.

5a A chief executive with good delegation skills or with a participative style may create an environment which is conducive to successful implementation.

In the writer's experience, the fear of failure is a significant barrier to change, and the chief executive who can remove this whilst maintaining visibility of the costs of failure will remove some of the obstacles to implementation.

Not all implementations are managed by the chief executive directly, and as with any other major endeavour, he must choose his deputy carefully and give him the authority to go with the responsibility.

5b The system "driver" needs the authority and drive to carry out the task effectively if it is to succeed.

The drive is important. Like any other project the CAD implementation must be managed actively.

The CAD implementation "driver" is an important individual, but where he is one step removed from the Drawing Office he is vulnerable to the ability - and possibly the malice - of the Drawing Office Manager. This individual must have the skills to manage change within his department and must have the will to do so.

5c Regardless of the position and authority of the "driver", the D.O. Manager needs to have the ability to manage the change effectively.

This was particularly evident in two cases. In Case 1 the D.O. Manager was a barrier to change because he did not possess the necessary skills. A change of D.O. Manager resolved this.

In Case 2 the D.O. Manager was totally resistant to the introduction of CAD and helped to cause its ultimate failure.

One may expect that companies with poor departmental definition and ill-defined boundaries would be more receptive to an integrating technology than those which had well-defined boundaries. This was not found to be the case. More relevant seems to be the level of inter-departmental interdependence and mutual assistance. Where departments have formed close working relationships, they appear to continue these in the face of change.

5d Companies with good inter-departmental relationships have more success in implementation than those where antagonism exists. This is regardless of the degree of boundary definition.

It could be argued that this is purely a reflection of the management style of a company, and there may be something in that. What is clear is that problems of implementation and integration can sometimes only be solved by talking them out, often across functional boundaries. This requires special skills on the part of the departmental managers and the co-ordinator.

5e An open management style which has authority challenge is more likely to resolve implementation problems.

What is at issue here is not the encouragement of challenge per se, but the acceptability of free discussion, which in itself can be a valuable aid to problem solving.

5.2.6 Much is made in the texts (Section 2.4) of the System or Project Champion, and such an individual was in evidence in five of the six cases. In all five cases the Champion was in a very senior position in the Company. This is perhaps not too surprising considering the relatively small sizes of the companies, and perhaps the picture would be slightly different in large companies.

This senior position gave the Champion the authority to manage the project without reference to others.

In the sixth case there was no Project Champion evident, although the Chief Designer (Mechanical) did his best to act in this role. However, his authority was strictly limited.

6a A Project Champion who has authority and responsibility for the system makes the implementation move more smoothly.

There are two parts to this proposition. A Project Champion without authority is likely to have significant difficulty when implementation problems arise, as we saw in Case 2. The second part can be clarified by a further proposition.

6b The Project Champion does not have to be the Project Driver for the implementation to be successful.

As we saw in Case 6, the Project Champion and Project Driver can be different people. In this case, coming back to proposition 6a, the Project Champion does not have the responsibility for system implementation. There was evidence in Case 6 that the split role led to minor project slippage, predominantly because of communications problems within the Company.

Whilst the implementation was successful, there was a classic symptom of bad management evident in Case 6 - responsibility without authority.

5.2.7 As described in 5.1.7, commitment to the implementation process or to the system itself is very difficult to measure and its measurement is highly subjective. However, that may not be too important if we look at the changes in commitment rather than some absolute value. If at the same time we dismiss any attempt at cross-case comparison of "commitment level" then we may get some useful propositions out of the cases.

The first area of interest is the change of commitment of the various parties to the implementation during a crisis. If we look at the Project Champions in particular, we find that some exhibit a downward change during a crisis whilst others exhibit an upward movement. Some show no apparent change. There seems to be some correlation between the changes and the success of the implementation.

7a Implementation is more likely to be successful where the Project Champion exhibits a constant or increasing level of commitment in a crisis.

Why this should be so is not clear. One explanation may lie in the type of person chosen as the Project Champion, particularly in a small firm.

These people are senior in the organisation, and have probably fought hard for those positions. This is particularly the case for those companies where the Project Champion is the M.D. and possibly the owner of the company. This fighting spirit may engender a hunger to win the battle. The Thomas International Personal Profile Analysis, a psychometric analytical tool, shows the highly dominant individual to have an innate fear of failure. This can be a very compelling driving force.

Possibly for similar reasons, it would appear that the Project Champion's level of commitment "rubs off" on his team. We should hardly find this surprising.

7b High commitment of the Project Champion can "rub off" on the user group. Low commitment can demoralise the user group.

The Project Manager is invariably senior in rank to the implementation team or user group. This seniority is reflected in the reaction of the team to a crisis. It would appear that even where the commitment of the user group falls, so long as that of the Project Champion does not, all is well.

7c The commitment of the Project Champion to the project overrides that of the user group when the project hits a crisis.

5.2.8 Two measures of success have been identified in Section 5.2.7, and there is clear evidence from the six cases that the two need not be achieved at the same time.

8a Success in implementation as measured by hitting targets and timescales and success in application as measured by usage of the system need not co-exist.

These two measures could be argued to be under the control of different people within the organisation. Usage of the system is controlled to a great extent by the system users. If they are comfortable with it, and it provides them with benefits, then they will use it. On the other hand, the hitting of targets and timescales has more to do with change than with the status quo, and it is the management of this change which brings success or otherwise.

It is unusual, despite the above, to find the users and management holding different views on the level of satisfaction with the system. This is despite the inability of either group to define adequately the meaning of satisfaction.

8b Satisfaction is a corporately held concept. Users and management tend to hold similar views on the satisfaction level.

It would seem that we have group conformity at work here. There is a tendency for all individuals to follow the corporate "line", particularly where that joint view may be threatened or questioned from outside the group. Not surprisingly, the stronger members of the group influence the group thinking more then the weaker ones.

8c Satisfaction tends to be defined by the System Champion, who communicates it upwards and downwards.

Whether this communication is formal or informal, verbal or written may not be relevant.

5.2.9 As was described in 5.2.3, the level of consideration given to a system is important if it is to be successful. This consideration apparently needs to be extended into the implementation phase, and not stopped at the justification phase.

There is evidence that slow progress perpetuates slow progress, and that the ability to monitor progress can help the management to transfer resources.

9a A phased implementation plan provides short-term targets which are more visible and hence easier to monitor than global targets.

9b A well structured implementation plan provides a means of measuring progress and hence enables the team to inject pace when progress is slow.

The latter proposition was particularly well illustrated at Company 1 where the team size was adjusted at regular intervals in order to achieve the milestones. This also supports the former, since the milestones were sufficiently close together to enable precise monitoring.

Where several people or departments are involved in the implementation, the targets need to be visible to them all. There was also clear evidence from Company 5 that the inter-departmental team worked closely together to achieve the targets. One of the reasons propounded for this was that they had all had a say in the plan.

9c The more successful implementation plans tend to have input from all those involved. This provides a high level of commitment.

No matter how small the company, CAD will have some influence on the inter-departmental relationships. As an integrating technology it crosses functional boundaries, and can leave people or sections feeling insecure or threatened. It comes as no surprise, then, to find that the companies who took note of this human problem and made moves to plan for it suffered least. They were able to make a minor cultural change within the structure relatively painless.

9d Redefining boundaries requires a rethink of the systems and procedures, but also a cultural change if the new systems are to be successful.

9e Pre-planning of the boundary changes to take into account the human aspects makes for a quicker and more effective implementation and a more harmonious working relationship.

Companies 1, 5 and 6 supported the former proposition, but Company 1 was particularly good evidence for the latter. The project started with little recognition of human needs, and would probably have foundered had the implementation not stopped to take stock and entered a consultation period. Their methodology of proceeding in "bite-sized chunks" of implementation made this possible, since the symptoms were identified quickly.

5.2.10 There is a growing recognition from Government downwards of the need for training. This comes as little surprise to academics and most industrialists who have gained benefit from a trained workforce. It therefore came as no surprise to find that training played a large part in the implementation success of all six companies.

Training took two forms. Firstly there was the formal vendor-supplied training which came as standard, but at extra cost, with all the systems in the six companies. Secondly there was the informal "sit alongside Nellie" training which happens throughout industry. All companies experienced both types during the implementation but in varying degrees.

It became clear on close investigation that vendor training had a higher value in learning terms than informal training.

10a Companies which take full advantage of the training offered by the vendor make better progress in implementation than those which take only the minimal training.

More training - more progress. Not a surprising result.

10b Draughtsmen who are trained by the vendor tend to be more adventurous with the system and develop novel ways of saving draughting time.

It is the experience of the author that vendor trained draughtsmen often produce results which could not be produced by the trainer. The type of training offered often encourages a degree of individualism and generates confidence. On the other hand in-house training can stifle inventiveness and lead to rule-following.

6.0 DEVELOPMENT OF A FRAMEWORK FOR A METHODOLOGY

This Chapter develops a framework for a methodological tool which could, if developed further, be used by small firms in the implementation of Computer Aided Design, or by consultants operating in that field. The first section deals with the initial conceptual framework developed from the propositions of Section 5.2.

Whilst the framework was developed inductively from the cases, it is inevitable that it was influenced not only by the experience of the author but also by the relevant theory, which to a certain extent focused the research (see Section 2.9). It is inconceivable that the same framework would have been developed without these three influences. Section 6.4 relates the elements of the model back to the relevant literature.

The framework was discussed in some detail with three former associates of the author, all of whom had worked or were working in Computer Aided Design. Their comments were recorded and incorporated into the framework as described in the second Section.

From the developed framework, the inputs and outputs of the stages were outlined in further detail and where possible the sources of the inputs were identified, as described in the third Section.

6.1 Initial Framework

The framework as developed initially is as shown in Figure 6.1. It shows a five-phase methodology, built on the propositions of Section 5.2. The relevant Propositions are shown in Figure 6.2. The phases are:

1. Strategy

   - answers the question "Where do we want to be?"

2. Company Audit

   - answers the question "Where are we now?"

3. Design

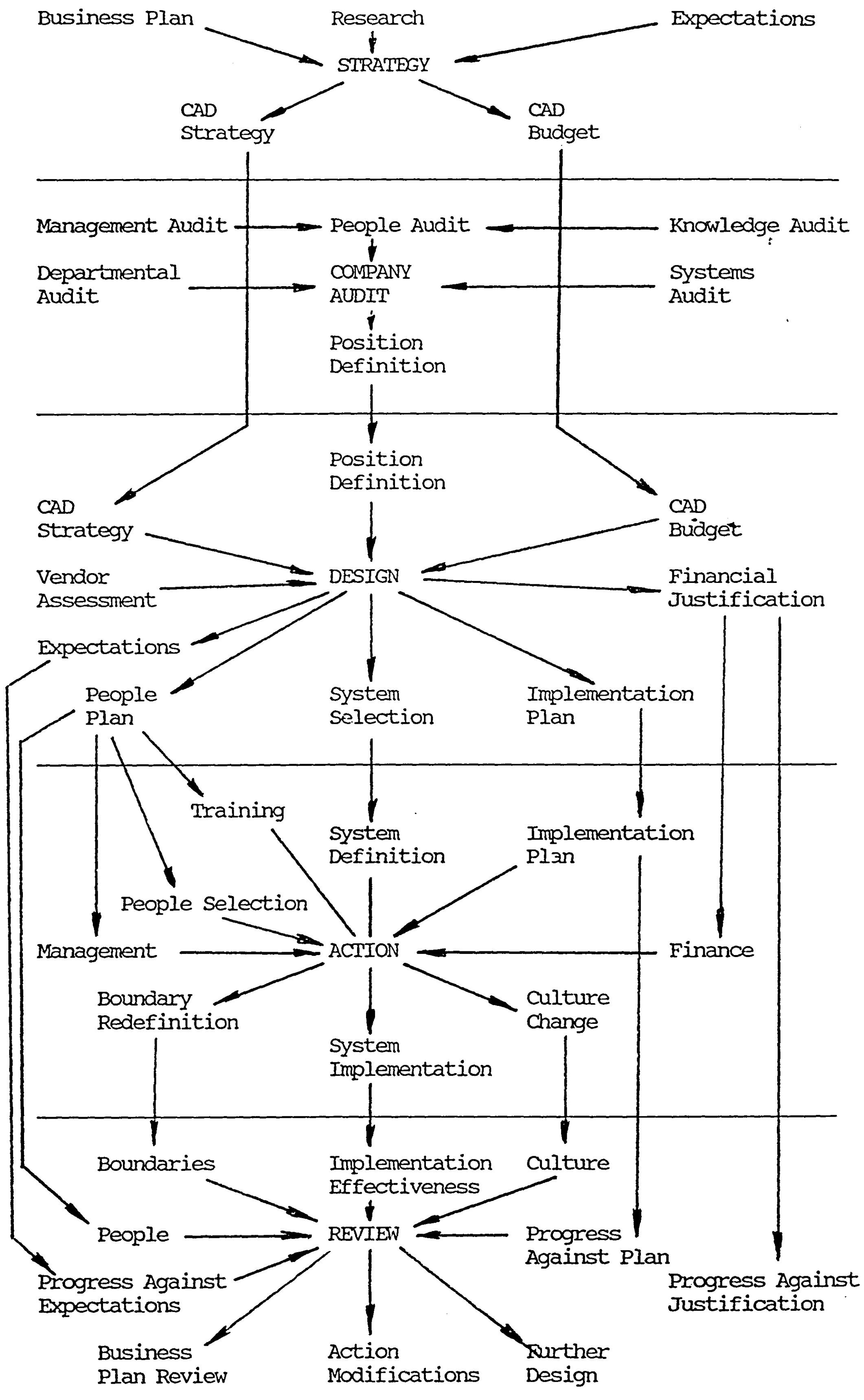
   - answers the question "How do we plan to get there?"

4. Action

   - answers the question "What steps must we take?"

5. Systems Review

   - answers the question "How well did we do?" and "How can we improve it?"



<u>Methodology Framework</u>
<u>Figure 6.1</u>

PHASE	KEY QUESTION	INPUTS	OUTPUTS	PROPOSITION
STRATEGY	Where do we want to get to?	Business Plan Expectations Research	CAD Strategy CAD Budget	1a 1b 3a 3b
COMPANY AUDIT	Where are we now?	Management People Knowledge Departmental Teams Systems	Position Definition	2a 2b 4a 5a 5d 5e
DESIGN	How do we plan to get there?	Position Definition CAD Strategy CAD Budget Vendor Assessment	Financial Justification Implementation Plan System Selection People Plan Expectations	9a 9b 4b 9c 4c 9d 5b 9e 5c
ACTION	What steps must we take	People Selection System Definition Implementation Plan Finance Management Training	Boundary Redefinition System Implementation Culture Change	1c 10a 10b 6a 6b 7a 7b 7c
REVIEW	How well did we do? How can we improve it?	Implementation Effectiveness Boundaries Culture People Progress	Business Plan Review Action Modifications Further Design	4d 4e 8a 8b 8c

Figure 6.2

As described, the phases are essentially sequential, with the output of one phase informing the next. The exception to this is the Strategy phase, which, along with the Company Audit, informs the Design phase.

6.1.1 Phase 1 : Strategy

Propositions 1a, 1b, 3a and 3b address indirectly the issue of strategy, and are restated here for clarity and convenience.

1a The higher the level of integration the higher the cost of the system and the higher the potential cost of failure in monetary and human terms.

1b The higher the level of integration the higher the cost and the higher the level of consideration given to the system. Consequently the higher the likelihood of eventual success.

3a The higher the degree of difficulty in achieving the target the more consideration has been given to the measure of success and therefore the better planned the project.

3b The higher the degree of difficulty in achieving the target the higher the likelihood of success.

What these four propositions are describing is a scenario where more planning goes into a high cost enterprise than into a low cost one.

Since we can assume some sort of direct relationship between planning and success, it is the thought going into the project and not the complexity of the project itself that gives rise to the better success. If this is the case, then regardless of the complexity, improving the planning will improve the chances of success.

This points to the need for a CAD strategy prior to starting work on the project. A consequence of this is that a CAD budget is likely to be developed, even though it may be expressed informally. This will be seen to be important in the Design phase, discussed later.

The outcome of the Strategy phase, then, will be in one of two forms. Formally it will consist of a CAD Strategy and a CAD Budget. Informally, it will consist of a better understanding at the highest level within the company of the impact of a CAD system in financial and practical terms. This will take into account any prior research done by the company into CAD and the expectations of the key players. The outcome will also be in line with the overall company strategy, since it will have been formulated at the top level.

6.1.2 Phase 2 : Company Audit

Six of the propositions address themselves to the need to take stock of the current position. These are shown below;

2a The more people in design-related roles with prior computer knowledge and experience the higher the chance of acceptability and hence success.

2b The level of computer literacy elsewhere in the organisation has little effect on the success or otherwise of the CAD implementation.

4a Prior CAD knowledge causes justification and expectations of a system to be broadly similar in scope and achieved within the same time frame.

5a A chief executive with good delegation skills or with a participative style may create an environment which is conducive to successful implementation.

5d Companies with good inter-departmental relationships have more success in implementation than those where antagonism exists. This is regardless of the degree of boundary definition.

5e An open management style which encourages challenge is more likely to resolve implementation problems.

The outcome of the Company Audit is a definition of where the company is in certain key areas. This has been called a Position Definition. Three key areas are indicated by the propositions.

The first area is broadly related to people and their skills, experience and knowledge. The management style of the key people is addressed (5a, 5e) and compared with the "preferred" open style with a participative leader or one with good delegations skills. Whilst this may be "preferred", the strength of the preference has not been addressed by the present study, and there is certainly room for further research in this area.

This investigation into management style can be loosely described as a Management Audit.

Propositions 2a, 2b and 4a address themselves to the knowledge of the people within the organisation, particularly in the related field of computer literacy. A "Knowledge Audit" seeks information in this area, and will identify members of the company who have a useful contribution to make to the implementation.

On the wider front of the People Audit, those people who will be able to assist in the implementation by providing support, whether actively or passively, by acting as facilitators or by being retrained into another post will be identified.

The second area is related to the departmental structure and arises from proposition 5d. The Departmental Audit seeks to clarify the position on departmental boundaries and inter-departmental relationships. It identifies any rivalries which may be relevant to the implementation. Proposition 5d suggests that the close working relationship across boundaries is key to a successful implementation, regardless of how well the boundaries are defined. However, where boundaries are to be removed, the Audit will reveal the implications of this.

The third area arises from a combination of all the propositions. The way in which the company operates in terms of systems, whether they involve computers or not, has a marked effect on the position of the company with respect to change. Since the Design and Action phases are about change and change management, the Systems Audit provides the platform on which to build that change.

The outcome, then, is a Position Definition which describes where the company is in terms of people, organisation and systems. It also describes how the company matches up to the "ideal" company in these aspects, thus indicating changes which may need to be implemented before embarking on the CAD implementation.

6.1.3 Phase 3 : Design

The outcome of the Design phase should be, in simplistic terms, a plan of action, but in real terms there are several outcomes.

One outcome is the system selection. This consists of an argued case for purchasing a particular configuration of hardware and software from a particular vendor in defined stages. Together with this will be a financial justification where appropriate, or a non-financial justification.

The implementation plan is also an outcome of the phase. This defines the schedule for purchasing and installing the system and the benchmarks against which progress will be measured. An outcome which is closely related to this is expectations. This is not a planned outcome, but will inevitably arise in the people involved in the Design phase. This will become important later in the Review phase.

Finally, but by no means least important is the People plan. This will indicate who is to be involved in the implementation either indirectly or directly. It will address the selection of a System Champion and/or Driver, management of the system, user group, inter-relationships and training needs.

The nine propositions which relate to the design phase are:

4b A clear justification may be the result of prior CAD knowledge and is likely to lead to reasonable expectations.

4c Expectations are more important yardsticks of success than justification since they are formulated in the early stages of a project implementation against a background of better information.

5b The system "driver" needs the authority and drive to carry out the task effectively if it is to succeed.

5c Regardless of the position and authority of the "driver" the D.O. Manager needs to have the ability to manage the change effectively.

9a A phased implementation plan provides short-term targets which are more visible and hence easier to monitor.

9b A well structured implementation plan provides a means of measuring progress and hence enables the team to inject pace when progress is slow.

9c The more successful implementation plans tend to have input from all those involved. This provides a higher level of commitment.

9d Re-defining boundaries requires a re-think of the systems and procedures, but also a culture change if the new systems are to be successful.

9e Pre-planning of the boundary changes to take into account the human aspects makes for a quicker and more effective implementation and a more harmonious working relationship.

It is clear from these propositions that the "people" perspective is fundamental to the Design phase. Whilst it may be obvious that the system selection, implementation plan and relationships with the vendor are all important aspects of the phase, this current work does not address itself to them.

The reason for this, and a possible weakness of the ultimate model, is that the author was instrumental in all three areas in all six cases, so that no cross-case comparisons could be made.

The Design phase is supported from several directions. Firstly it is bounded by the CAD Strategy and the CAD Budget, both developed in the Strategy phase. Secondly it picks up on the Position Definition from the Company Audit and thirdly it has as an input a Vendor Assessment. More particularly this may be a software and equipment assessment in the first instance.

From the Position Definition it derives information on the people - their knowledge, managerial ability aptitudes and attributes. It also derives information on the organisation structure and departmental boundaries and on the operating systems.

A successful Design phase will satisfy the key input requirements of the Action and Review phases and will, in particular, reflect the needs of the implementation as expressed by the propositions.

6.1.4 Phase 4 : Action

All that has gone before is pre-planning, and the fact that there are four such phases indicates the magnitude and importance of this planning. This is supported by the fact that nineteen of the thirty-two propositions relate to the pre-implementation phases.

The fourth phase is all to do with getting the system as defined up and running successfully. The complexity of this phase and the time required cannot be overstated, and no fewer than eight propositions support the phase:

1c The higher the level of integration the greater the number of people involved in the implementation and the higher the likelihood of speedy resolution of problems.

6a A Project Champion who has authority and responsibility for the system makes the implementation move more smoothly.

6b The Project Champion does not have to be the Project Driver for the implementation to be successful.

7a Implementation is more likely to be successful where the Project Champion exhibits a constant or increasing level of commitment in a crisis.

7b High commitment of the Project Champion can 'rub off' on the user group. Low commitment can demoralise the user group.

7c The commitment of the Project Champion overrides that of the user group when the project hits a crisis.

10a Companies who take full advantage of the training offered by the vendor make better progress in implementation than those who take only the minimal training.

10b Draughtsmen who are trained by the vendor tend to be more adventurous with the system and develop novel ways of saving draughting time.

The outcome of this fourth phase is threefold. First and foremost is a system implementation. We do not specify at this stage the effectiveness or otherwise of that implementation. The other two outcomes relate to the re-definition of inter-departmental boundaries and the culture change which goes with this.

No timescale is put on the Action phase, since it will be defined in the Implementation Plan.

It is worth noting the number of inputs to the Action phase. There are no less than six, three of which, people selection, training and management are "people" inputs. This reflects the emphasis on people issues throughout the six cases. All three are components of the People Plan defined during the Design phase.

The other three inputs are no less important. The System Definition, derived from the Design phase, defines the system to be purchased, in hardware and software terms. It also identifies the vendor and the phasing of the purchases. Any maintenance contracts and/or support will also be spelled out.

The implementation plan is also derived from the Action Plan. This will define the timescales for implementation, together with the resource requirements.

The final input is Finance. The Design phase develops the financial justification, and from this the capital expenditure plan can be defined. This will include the sourcing of capital and the phasing of capital spend in line with the Implementation Plan and System Definition.

The Action phase is likely to be the longest in elapsed time, and its end point may not be clearly defined. One could reasonably argue that it never ends, but continues so long as the system is being developed. For our purposes, and for reasons which will become clear later, the Action phase can be regarded as having ended when the Review phase starts.

6.1.5 Phase 5 : Review

All implementations have to pass through a Review phase, whether it is formal or informal. Indeed, the review in Companies 3 and 4 was very informal, consisting of a brief meeting between those involved in the implementation, from which discussions were made on the system's future. Companies 1, 5 and 6 had formal reviews at frequent intervals. These reviews in Companies 1 and 5 had an agenda, and minutes were taken. In all three companies the required actions were recorded and distributed to interested parties.

Company 2 had only one review, and this was formal to the extent that it involved the whole team. The result of the review was that the system was reduced in size and mothballed.

Five propositions refer the Review stage, and indicate some of the thinking behind how the review team may view the implementation.

4d Where expectations are not met by an implementation, the success of the implementation is measured against the justification factors. This does not happen if expectations are met.

4e Expectations are more likely to be met than are the factors for justification.

8a Success in implementation as measured by hitting targets and timescales and success in application as measured by usage of the system need not co-exist.

8b Satisfaction is a corporately held concept. Users and management tend to hold similar views on the satisfaction level.

8c Satisfaction tends to be defined by the System Champion, who communicates it upwards and downwards.

These propositions are clearly important if the questions "How well did we do?" and "How can we improve it?" are to be answered. A comprehensive review will need to take into account the bias and prejudice of the key players if it is to serve a useful purpose rather than to give the team a warm glow.

The review needs to address the major issue of progress in three key areas:

* progress against expectations
* progress against the implementation plan
* progress against justification

It is clear from the foregoing that the outcomes may not be identical, and it is important to record and react to the outcomes.

Implementation effectiveness also needs to be reviewed. This is nothing to do with hitting targets or timescales, but is rather more mechanistic, relating to what the implementation team got wrong, and what they would have done differently with the benefit of hindsight.

The People Review looks at how the management and staff coped with the change, and how they settled into their new roles. It should also look at the effectiveness of the System Champion, Driver and System Manager both during and after the implementation.

The final two inputs to the review are the Boundary and Culture aspects. This part of the review looks at the effectiveness of any changes to roles and boundaries, working relationships and the personal reactions to the changes. It also looks at the culture changes and their effect on the business as a whole.

The outcomes of the Review phase are threefold. Firstly it will almost certainly indicate broader and more far-reaching changes by feeding back into the Design phase. For instance a hardware upgrade may be indicated which requires further justification and a further implementation plan.

Secondly, the review could indicate broader and more far-reaching changes by feeding back into the Design phase. For instance, a hardware upgrade may be indicated which requires further justification and a further implementation plan.

Thirdly the review may indicate changes which require a substantial rethink within the company at the strategic level. This could require changes to the Business Plan. Company 2 was a good example of this. Its decision to abandon the CAD system required a major rethink of company strategy which had an effect on the profitability and hence on the Business Plan.

6.1.6 Summary

The methodological framework developed in Section 6.1 has five principal phases: Strategy; Company Audit; Design; Action; Review. Each of the phases is supported by a number of the propositions developed in Section 5.2, interpreted with logic and common sense. The five phases are best described by the questions which they seek to answer:

1. Strategy - Where do we want to get to?
2. Company Audit - Where are we now?
3. Design - How do we plan to get there?
4. Action - What steps must we take?
5. Review - How well did we do?
   - How can we improve it?

It is worth noting that the model concentrates on the inputs and outputs of the phases rather than on the processes undertaken within the phases. This is important, since inputs and outputs are tangible and can be measured and verified. The propositions point towards the features of the inputs and outputs which need to be measured or verified.

The framework as shown in Figure 6.1 consists of three sequential phases: Design, Action and Review, with two parallel phases, Strategy and Company Audit feeding and informing the Design phase. The philosophy behind this is that without knowing where we are and where we are going we cannot hope to decide how to proceed. This is almost too obvious to merit statement, but one of the case studies shows clearly that not all companies are aware of it.

In principle, these three phases have the same structure as the phases of the Business Plan of the company, and answer the same three questions; Where are we going?, Where are we now?, How do we get there? It is not surprising, then, to find the company Business Plan as one of the inputs to the model, or to find one of the Review outputs feeding back into the Business Plan.

6.2 Primary Validation

Developing a model of this sort in isolation, it is very easy to become wrapped up in the propositions and their interpretation, to the exclusion of basic experience. For this reason, the framework developed in 6.1 was submitted in draft form to three former associates of the author.

All three were working in the area of CAD implementation or had done so within the past six months, and had a track record of successful implementations elsewhere in the UK. The three Consultants were asked the following questions:

1. Does the framework address the major issues of CAD implementation? Are any major issues ignored?

2. Are the inputs and outputs of the phases as described complete and sufficient? What other inputs and outputs should be included?

3. Are any parts of the framework particularly helpful or unhelpful in implementing CAD?

4. Is there anything in the framework which is totally at odds with your experience in implementing CAD?

5. Would a development of the framework into a methodology with its associated work books, charts and guidelines be useful in implementing CAD? In your experience would it be more useful to the small or large company?

6. Could such a tool be used by companies instead of their employing an external Consultant?

Smith et al. (1992) in a current TQ project identify five measures of validity:

Construct validity - does the model encompass those concepts which are seen as relevant to the study of culture elsewhere?

Face validity - does the model produce ways of categorising TQ activities and concerns which are meaningful to those involved as practitioners in implementing TQ?

Content validity - does the model encompass and incorporate those activities and concerns that are seen to be pertinent to the world of TQ by those who are involved in it?

Concurrent validity - does the model reveal a perspective on TQ culture change which occurs with other widely accepted views on implementing TQ?

Predictive validity - does the model enable predictions to be made which can be empirically validated?

Whilst this exercise was aimed at checking Concurrent validity, the discussions and responses encompassed elements of Face and Content validity. Construct validity is demonstrated throughout, and particularly in Section 6.4, whilst Predictive validity cannot be tested until the model is fully developed.

The script and questions were submitted to the Consultants in writing, and all three were invited to prepare their replies for discussion. A meeting of the three Consultants and the author was then held to discuss the individual findings. It was considered that this group format may be useful in developing constructive criticism of the model.

In the event, the consultants were not so critical as the writer had hoped, but a number of useful features did arise.

The comments were subdivided into two types. Those which arose from a misunderstanding of the script or which required simple clarification were incorporated into the script and became part of Section 6.1. Those which required a development of the model or which were critical of the model are described below.

The comments are described in the order in which the questions were asked.

6.2.1 Does the framework address the major issues of CAD implementation? Are any major issues ignored?

All three Consultants were satisfied that the major issues were addressed so far as most companies would be concerned.

Consultants AH and PC had both picked up the issue of competition. For some companies the fact that technology is increasing at a rapid pace is critical, in that their competitors have been driven to implementing CAD for a variety of reasons. In many cases the drive to introduce CAD then becomes more than just a knee-jerk "me-too" reaction, and may be a question of survival. For this reason they considered that the competitive environment should be considered as a major issue.

A second facet of the competition issue arose from subsequent discussion. Some companies look to CAD not as a reaction to their competitor's introduction of CAD but in order to remain ahead of the field. It was considered that up to 25 percent of companies introduced CAD for this reason amongst others.

6.2.2 Are the inputs and outputs of the phases as described complete and sufficient? What other inputs and outputs should be included?

From Section 6.2.1 it was agreed that Competition should be included as an input to the Strategy phase.

The Systems Audit of the Company Audit phase caused some confusion. In line with the propositions from which the model was developed, this was intended to refer to computer based systems elsewhere in the organisation.

Consultants AH and SM both commented on the lack of audit of manual systems and procedures used within the company. This is a valid point and one which had been overlooked in the development of the framework. It is clear that an audit of systems and procedures is essential at the Company Audit stage, since in all probability several of these procedures will be changed during implementation. It could reasonably be argued that the audit need only take account of those systems and procedures which have an impact within those departments affected by the implementation. However, as was pointed out, it is not necessarily easy to define the impact of CAD at the Audit stage, so a thorough Systems and Procedures Audit would be preferable.

Consultant PC saw the merit in a Financial Audit at the Company Audit stage. However, after much discussion it was agreed that the development of a CAD budget at the Strategy stage implied that the financial resources were available.

What did come out of the discussion was a general agreement that if the CAD budget were to be a useful input to the Design phase the financial position may need to be reviewed in the light of the phasing of the expenditure. This was covered to some extent by the Finance input to the Action phase.

It is likely that some of the suppliers or customers of the company have CAD systems, and there may be benefit in considering the electronic transmission of design data. For this reason, Consultant PC suggested the need for an investigation of the systems operated by the major customers and suppliers where appropriate. This would not form part of the Company Audit, but would be an input direct to the Design stage.

Consultant AH raised the issue of physical resources, arguing that CAD has different resource requirements from manual draughting.

It was agreed following lengthy discussion that the major aspects of the physical resources related to the environmental conditions. Such aspects as lighting, physical comfort, drawing office layout and furniture should all be considered, together with the more mundane features such as power supplies. These should be considered at the Company Audit stage.

6.2.3 Are any parts of the framework particularly helpful or unhelpful in implementing CAD?

The one point brought out by all three Consultants was the emphasis on the link between CAD implementation and Company Business Plan. It was felt that this was the most important pointer to successful implementation. All three had had experience of clients who had attempted to implement systems without regard to their impact on the company as a whole.

Consultants AH and SM found the emphasis on a wide ranging review of the company's present position to be particularly helpful. Both admitted that they had on occasions omitted part of this review for the sake of expediency, but that this had introduced an element of risk at the design stage.

Consultant AH found the concentration on people issues at the Action stage to be overstated. Whilst he acknowledged the need for a People Plan, he did not agree that this merited being split three ways, which gave the People issues an equal weighting in numerical terms to all the other inputs to the phase. Consultants PC and SM disagreed, on the basis that their experience suggested that at least half of the failures they had experienced had had people-related causes.

Consultant PC considered that the Culture Change output and the Culture input between Action and Review were unnecessary. Consultant SM supported this, but agreed that it was not only unnecessary but also impossible to measure. Consultant AH agreed with the author that whether it was measurable or not did not negate the fact that culture changes could and did occur.

6.2.4 Is there anything in the framework which is totally at odds with your experience in implementing CAD?

None of the Consultants could identify any such points.

6.2.5 Would a development of this framework be useful in implementing CAD? Would it be more useful to the small or large company?

There was general agreement that such a development would be an exceedingly useful tool for consultants working in the field. A danger was identified that such a tool could become too prescriptive, particularly if used by inexperienced consultants, and that the rationale behind the tool must be clearly understood before it could be used effectively.

Consultants AH and PC were particularly concerned about the testing of such a tool, since the effects of a poor implementation can often not be traced to their source. Conversely, some implementations could be successful despite the tool rather than because of it. Again this may not be easy to identify.

The outcome of the discussion was that provided a comprehensive testing programme could be developed for the tool prior to its launch, it would be of immense value.

So far as the size of company was concerned, it was felt that the smaller company would be most likely to benefit for two reasons. Firstly it had been developed from data gathered from small firms, and there could be no guarantee that the same data would be evident in large firms.

Secondly, larger firms tend to have a different approach to the introduction of computer based systems. It is not uncommon for a large company to send out invitations to tender for equipment and then carry out development work on the selected system at their own expense prior to implementation. This means that a fully proved integrated system is installed, ready for fully trained and properly managed people to use.

Consultant AH also pointed out that a larger firm often has a culture of high technology which requires little change for CAD implementation.

6.2.6 Could such a tool be used by companies instead of their employing an external consultant?

This was not thought to be the case. It could be possible for a company to work through modules of the model, particularly at the Company Audit and Design stages, and possibly at the Review stage. However, the Consultants did not consider this feasible at the Action stage and particularly at the Strategy stage.

The single most difficult problem for companies at the Strategy stage is, in the view of Consultant AH, knowing what the questions are that they should be asking.

In order to develop a CAD strategy, they need to have a detailed awareness of CAD not commonly found in small firms. They have, in plain terms, to know what CAD can do before they decide what they want it to do.

Consultant SM supported this by suggesting that without a knowledge of the CAD marketplace a meaningful budget could not be developed.

The point agreed by all the Consultants was that the Research input to the Strategy phase could only be provided by a specialist in CAD.

At the Action stage, having all the inputs in place was not considered to be sufficient for success. Consultant AH suggested that knowing what to do was important, but knowing how to do it was equally important. Experience of having done it before could be vital if timescales and milestones were to be met.

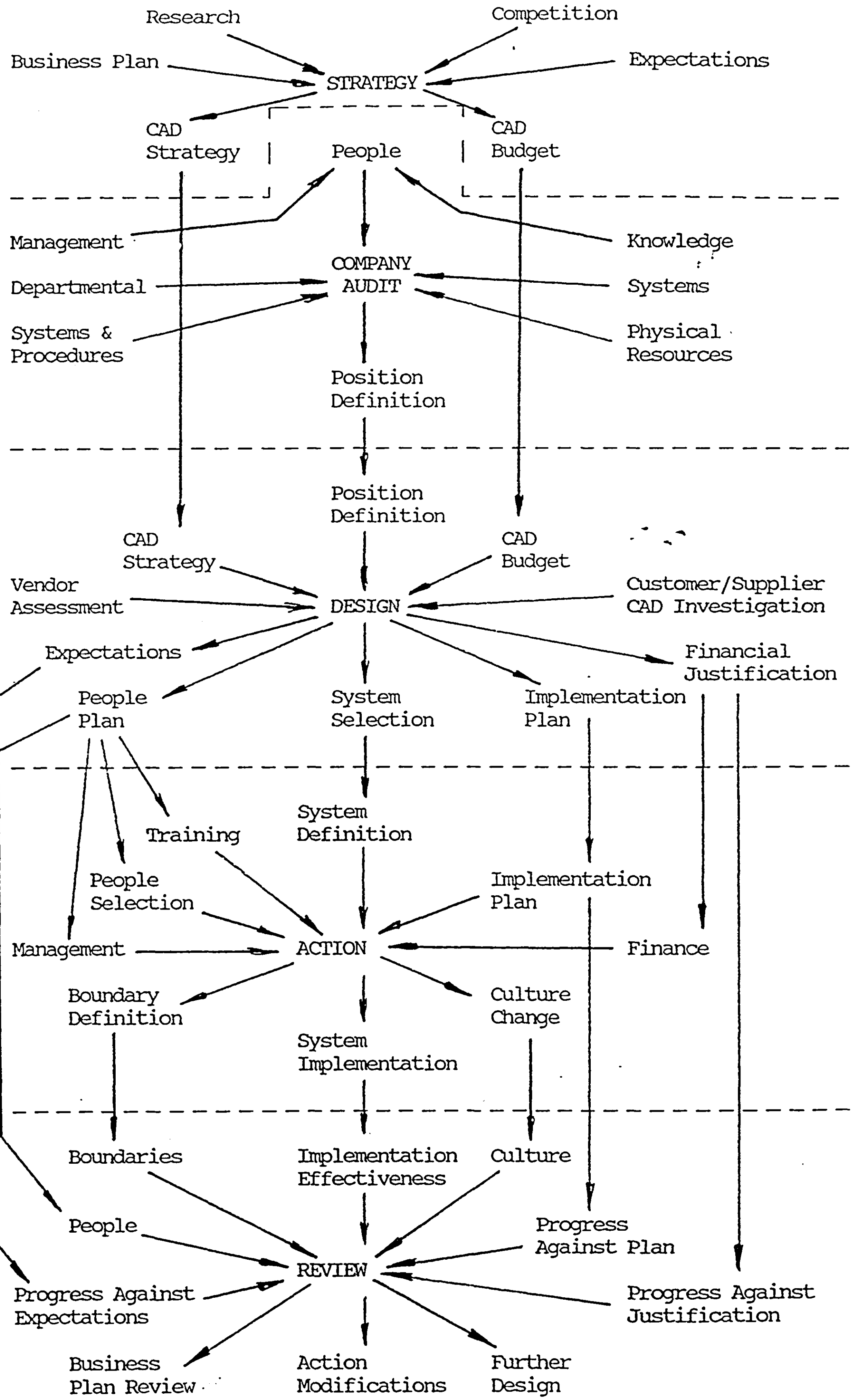
Overall, the Consultants did not fear a do-it-yourself implementation manual.

6.3 Amended Framework

In deference to the considered and valued opinions of potential users of the eventual methodology in the form of three colleagues of the author, the framework was amended to that shown in Figure 6.3.

From this framework, the primary and secondary inputs were derived, and are listed in Figure 6.4. Primary inputs are defined as those derived by reference to the external environment, whilst secondary inputs are the result of an output from a previous stage of the implementation.

It is important to note that the framework is not terminal. In other words, the outputs all feed back into the model as adjustments, amendments or modifications to the implementation. One possible output which has not been shown on this framework would be a report, for instance to the Board. This could conceivably result in further inputs.



Methodology Framework (amended)

Figure 6.3

PHASE	PRIMARY INPUT	SECONDARY INPUT
STRATEGY	Business Plan Research Competition Expectations	
COMPANY AUDIT	Management Audit Knowledge Audit People Audit Departmental Audit Systems & Procedures Audit Physical Resources Audit Systems Audit	
DESIGN	Vendor Assessment Customer/Supplier CAD	CAD Strategy CAD Budget Position Definition
ACTION		Management People Selection Training System Definition Implementation Plan Finance
REVIEW		Progress Against Expectations People Boundaries Implementation Effectiveness Culture Progress Against Plan Progress Against Justification

Primary & Secondary Inputs
Figure 6.4

6.4 Source Material for the Model

A framework such as the one described is of limited use in the real world, and needs to be developed into a methodology. Whilst this is beyond the scope of the present work, some expansion of the inputs will be helpful to anyone embarking upon the task. It may also help to bring together some of the thoughts of the writer and others expressed throughout the work.

It has been decided to develop the inputs in the order shown in Figure 6.4, starting with the primary inputs and moving on to the secondary inputs.

6.4.1 Strategy

(a) Business Plan

The Company Business Plan is a familiar management tool, although in the experience of the writer it is often incomplete in small firms. It should contain the following:

* a mission statement
* a statement of what the company hopes to achieve in a particular timescale
* a statement of where it is starting from

* defined actions for achieving the strategy
* estimates of the financial implications

Embedded in the plan will be an analysis of the strengths and weaknesses of the company and of the opportunities and threats facing it.

All major change within a company will be affected by and will have an effect on the Business Plan, and it is difficult to envisage CAD implementation without such a plan.

(b) Research

A very significant problem facing a Chief Executive embarking on CAD is, in the experience of the author, how it will fit into his Business Plan. Before he can answer this he must make himself aware of the potential for CAD in all its facets.

Research at this stage will enable the Chief Executive and his team to develop a concept of what the eventual system will do for the company, and hence how it should fit in in strategic terms. This is the first stage of definition of a CAD strategy.

The research may take many forms, including background reading, seminars, exhibitions, discussions with users and so on.

Whatever the form, the propositions have shown that detailed consideration improves the chance of effective implementation.

(c) Competition

As described in 6.2.1, the competitive position of the company can provide a compulsion to implement CAD. For this reason an investigation of the competitor's CAD position would be wise, and may have a marked influence on the scale and speed of implementation.

(d) Expectations

Whilst expectations undoubtedly influence the CAD strategy, they tend to be the results of the research and competition elements described above. Nevertheless, it is important that these expectations be considered, even though they may change as a result of later phases or in line with the fast-moving development of CAD.

So far as tools are concerned to measure the inputs to the Strategy phase, none has been suggested. There are no "standard" or "preferred" ways of developing strategy, so long as all the elements have been taken into account, and it is considered sufficient to define these elements.

6.4.2 Company Audit

(a) People Audit

This encompasses the Management Audit and the Knowledge Audit.

The Audit is intended to review the position of the company vis-a-vis the people requirements of the CAD implementation. In terms of management, we are seeking to establish whether the Chief Executive's style is appropriate to rapid progress as required by Proposition 5a. In other words we are looking for good delegation skills and a participative management style. The implication of this is that since we desire these two characteristics, should they not exist we should be prepared to do something about it. This ties up well with the work by Collins & King (1988) described in Section 2.3 and leads on to the training aspect of the people outcome of the Position Definition, which will be discussed further in the Action phase.

We may also, during the People Audit, be seeking suitable candidates for the System Driver and assessing the capabilities of the Drawing Office Manager. Haywood & Bessant (1987) and Tranfield & Smith (1988) give pointers in this direction, as described in Section 2.4.

In the Knowledge Audit we are seeking evidence of prior computer experience, particularly in the Drawing Office and related areas, where Propositions 2a and 2b suggest benefits could be obtained. Evidence of prior CAD knowledge is also sought.

There are several methods of assessing the style of management and staff personnel, but possibly one of the quickest and most reliable would be a psychometric analysis. Together with a team-type analysis valuable information could be obtained on the necessary action. This could be conveniently supplemented by a training needs analysis to define where training would address the shortfalls and the appropriate training medium.

It has to be said that psychometric testing and training needs analysis would not have been the first tools to spring to mind when considering CAD implementation.

(b) Departmental Audit

The team type analysis may also come in useful when looking at departmental teams and boundaries. What we are really seeking, though, is good inter-departmental relationships.

This may seem somewhat obtuse when we are considering breaking down the boundaries, (Haywood & Bessant (1987), Marchrzak et al. (1987) Arnold (1983)), but it is precisely for this reason that the working relationships need to be good.

Where antagonism is found, the roots and reasons must be found and removed if there is any merit in Proposition 5d. One method of dealing with this is the Intergroup Team-Building Meeting, as described by Fordyce & Weil (1971 p 124ff).

(c) Systems and Procedures Audit

This looks at all systems and procedures excluding the computer information system (if any). It aims to identify any procedures which have become obsolete or are replicated by different people.

Flow charting is a particularly effective way of identifying the systems and procedures in terms of the way in which they influence information or production flow. By displaying the flow chart in departmental format the interactions between departments can be identified and analysed, providing further data for the Departmental Audit.

Once this has been completed, it may be useful to display the flow chart in process format, so that the critical path may be identified.

Whilst this may add little to the CAD implementation effectiveness, it may provide significant information for efficiency improvements.

Further expansion of the process flow chart may allow detailed process investigations to be made. The questions:

- "why is this done?" and
- "why is it done by this person?" and
- "could it be done better by others?" will lead to a questioning of the status quo, and possible efficiency benefits.

(d) Physical Resources Audit

The objective of this Audit is to identify those resources which may have an influence on the implementation of CAD.

Since we are dealing with a relatively narrow view of physical resources, a checklist could be developed for this Audit. Manufacturers' literature often identifies the particular resources which need to be reviewed, but the checklist would probably need to address the following issues:

Building Design	- proximity of the Drawing Office to those departments with which it will interact - proximity to the computer information system (if any)

Environment	- lighting and heating
	- space requirements
	- Drawing Office layout
	- furniture
	- physical comfort
Power	- availability of clean power supplies

(e) Systems Audit

This is an adjunct to the Systems and Procedures Audit, and will probably be carried out at the same time and by the same means. However, there are fundamental additional requirements related to the level of integration required. The Systems Audit will therefore require an investigation in depth of the interfaces and protocols available with the existing CAPM software. It will also be necessary to investigate the availability of software which may not have been implemented, but which would have a bearing on the CAD software, such as Bills of Materials and Databases.

The hardware will also need to be investigated, since the platform on which the existing software sits may influence the choice of CAD hardware and software.

6.4.3 Design

(a) Vendor Assessment

One outcome of the Design phase is the selection of a CAD system. This is prompted primarily by the CAD Strategy and CAD Budget.

Once a system specification has been developed, i.e. the company knows what it expects of a system (or thinks that it knows), the specification can be passed to vendors and their proposals can be obtained. Alternatively, a checklist can be produced which contains all the essential and desirable features. Against this, the method by which the several vendors would provide the features can be marked, producing a systems matrix. Such matrices already exist, and the writer has used one which he developed some five years ago. The matrix must include not only the draughting features, but also the communications and integration features, operating system, peripheral software, hardware options and peripherals and maintenance details. Last, but by no means least, it must include a detailed cost breakdown which relates to the system offered, giving estimates for any bespoke development work involved.

This checklist covers the mechanics of vendor selection, but there is a second, equally important facet which must not be ignored. The company will have to work with the vendor for some years to come, and it must assure itself of the stability of the vendor, its technical and support capabilities and the attitudes of the key executives. This can only be done by personal contact at a high level.

(b) Customer/Supplier CAD

There are significant benefits to be obtained by integrating the CAD system with that of the company's customers and/or suppliers. This reduces the number of drawings passed between the companies in hard copy form in favour of electronic data interchange. The questions to be answered before choosing a CAD system are:

1. Do my customers/suppliers have CAD systems?
2. Can I reasonably exchange data electronically?
3. What protocols will I need to support?

(c) CAD Strategy

This will be derived from the Strategy phase, and will be in line with the company's Business Strategy.

Whilst it may be global in format, it should contain certain vital information:

* where the company expects to be going with its CAD and in what timescale
* what milestones are expected to be achieved
* what resources are expected to be needed
* what major changes are anticipated as a result of CAD implementation
* what benefits are expected from the implementation

This information will be key to the development of the Implementation Plan.

(d) CAD Budget

This complements the CAD Strategy and could be argued to be an integral part of it. It defines the finances available for CAD development and the phasing of the expenditure. See Section 2.1 on System Justification, and particularly the work of Senker (1984), Primrose et al. (1985) and Meredith & Hill (1987).

(e) Position Definition

This is the only secondary input to the Design phase from the Company Audit phase. It defines the present position of the company in certain key areas such as management, knowledge, people, systems and procedures, physical resources and departmental organisation. In particular it identifies the strengths and weaknesses of the company in those areas, and outlines the necessary changes required to address the weaknesses.

It is vital that the input is well documented, since any weaknesses and actions will need to be taken into account during the Action phase, which may take place some time later. A simple tabular format has been found to be successful for this type of activity. Headings could be:

* Audit Area
* Strengths
* Weaknesses
* Corrective Action

6.4.4 Action

(a) Management

The Design phase will have detailed who should take charge of the implementation and his terms of reference (see references in Section 2.4). The input is a clear definition of the scope of the management role. The Implementation Manager will hopefully have been appointed on merit following the design of his role and taking into account his personal characteristics.

(b) People Selection

The People input to the Company Audit phase will have identified the key characteristics of the people available, and these will have been matched to the requirements of the job(s) at the Design phase. The input will be a clear definition of who will be required to do what during the implementation.

(c) Training

As described in 6.4.3 above, there will be certain weaknesses which have been identified and which can be addressed by training. The Design phase will have developed a training needs analysis based upon this, which will be an input to the Action phase.

Evidence of a comprehensive training needs analysis related to CAD and specifically to the people involved should be sought. Training of those peripheral to the system who may nevertheless interact with it or experience its effects should also be addressed.

(d) System Definition

At this stage, all the investigation work should be complete, and the system should be fully defined in terms of:

* hardware
* software
* maintenance
* consumables
* environmental requirements
* system implementation phasing
* upgrades
* operational issues

This will provide the input to the Action phase which, together with the available finance will enable the system to be purchased.

(e) Implementation Plan

This is a development of the CAD Strategy into an Action Plan which spans the length of the Action phase. It provides the detail of how the system sf to be developed to provide maximum benefits.

This input will define the following:

* phasing and boundaries of usage
* physical resource requirements
* people requirements
* benchmarks and timescales
* measurement techniques
* links to other internal systems
* links to external systems
* environmental requirements
* departmental requirements
* vendor relationships

(f) Finance

This input is tangible. It represents the funding required to implement the system in line with the Implementation Plan.

6.4.5 **Review**

(a) Progress Against Expectations

The expectations defined here are not those which inform the Strategy phase, but the more detailed expectations which emerge from the Design phase. Here we have a problem, in that expectations are rarely if ever committed to paper, unlike the justification.

Nevertheless, the paper demonstrates that the expectations provide a valuable target against which satisfaction with the system can be measured (see Bikson et al. (1981) and Voss (1988b) in Section 2.5).

As it is possible that expectations may change during the Action phase, as knowledge of the system improves, it may not be feasible to document the expectations. In that case, the measurement of progress against expectations will be subjective.

(b) People

Even in a small to medium firm, it is unlikely that the selection of people and managers will have been perfect, or that all the people selected have remained in post. This input provides details of the performance of the people involved during the Action phase.

The most logical way of producing this input is to develop performance standards during the Design phase which can form part of the People Plan and then to appraise those involved against those performance standards. Standard appraisal techniques can be used for this.

(c) Boundaries

In many firms the inter-departmental boundaries will be moved or removed during CAD implementation. The success of the change provides the input. Measurement will consist of determining:

* whether the barriers to effective implementation were removed
* what the cost of this was in financial and people terms
* whether the people have settled into their new roles
* whether inter-departmental communication has improved or suffered
* whether the newly defined boundaries are stable

No standard techniques are available for this input.

(d) Implementation Effectiveness

This input has little to do with progress, but looks at how well the system was implemented. In other words, what problems if any were encountered with the hardware, software or communications?

Did the system actually perform as it was intended to do? What did the implementation team get wrong?

(e) Culture

This input is much more difficult to define, and hence to measure. We are seeing a change in attitudes which will enable CAD to become an accepted part of the company. We therefore need to identify any cultural blocks to progress which have been thrown up during the Action phase. Techniques for assessing this are described by Schein (1985) in Chapter 5 (p.112).

(f) Progress Against Plan

The Implementation Plan as defined during the Design phase will be quite specific and will normally be well documented. This input takes the milestones laid down by the Plan and compares them with the achievements. In particular, it will compare actual progress against the items defined by the Implementation Plan in Section 6.4.4 (e).

(g) Progress Against Justification

This is a financial measure, and as such it should be relatively easy to assess. The input seeks to compare the actual phasing of costs and benefits against those produced when justifying the system.

In the author's experience, companies rarely meet the measures of justification, but this work suggests that this is less important than that the system meets expectations.

6.4.6 Other Inputs

Three other inputs are worthy of discussion, although they are not shown as such in Figure 6.3. These are the outputs of the Review stage.

(a) Business Plan Review

A technology so far-reaching as CAD can cause major change within a company to the extent that the Business Plan is affected. For instance, the system may allow the company to enter markets formerly closed to it, or the integrative nature of CAD may reduce costs to such an extent that the business targets need to be changed. This outcome of the Review stage will therefore feed back into the Strategy phase via the Business Plan.

(b) Action Modification

CAD implementation rarely goes quite as planned, and one outcome of the review is likely to be to change the short term actions, perhaps to get the project back on line or perhaps to bring forward the planned benefits.

Either way, this outcome will feed back to the Action phase via the Implementation Plan.

(c) Further Design

Once an implementation has "finished" there is the potential for further phases of implementation or integration. Where these were not part of the original plan, the review will indicate that the company is ready to enlarge the system. This outcome therefore feeds back to the Design phase via the CAD Strategy.

6.5 Conclusions

This section reviews the main findings of the research and outlines the contribution that it makes to theory. It then highlights the ways in which further research may be useful.

6.5.1 Main Findings of the Research

The six case studies have yielded a wealth of features which have enabled propositions to be constructed. This has been achieved without resorting to very large scale studies, and without seeking "typical" cases. In this respect the research supports the work of Mitchell (1983), who argues that hypotheses may be developed from a small number of cases. In Mitchell's words (p.200):

> "...the features present in the case study will be related to a wider population not because the case is representative, but because our analysis is unassailable."

Unlike Mitchell's work, the research did not seek to draw the analysis from a single case, but from a small number (six) of cases. This, as Pettigrew (1988) noted, allowed cross-case comparisons to be made to advantage, eliminating or reducing the risk of spurious but well argued findings.

The research was relatively focused, as described in Section 3, looking particularly but not exclusively at issues which had featured widely in the texts. This was not done in order to validate or invalidate the work of others, but rather to provide a well-documented platform from which to develop the investigation. In the event, there was a great deal of support of former texts.

The six cases were to some extent self-selecting from an initial shortlist of around 20, and offered a wide variety of experiences in implementation. Having a case which proved to be an unsuccessful implementation was a bonus, since little or nothing has been written about lack of success, and many of the propositions arose from the ability to draw comparisons between success and failure. This may well be the first well documented failure of CAD implementation, and a great deal of useful information was gleaned from it.

Whilst the research by no means concentrates on the elements of failure, the ability of the author to observe and document the cases from selection to full running enabled the high and low points to be investigated equally and to good effect.

The cases were analysed under ten headings, each prompted by earlier work in CAD or related fields such as Information Technology implementation.

Level of Integration looks at the degree to which the Companies aspired in terms of cross-functional integration, from a stand-alone electronic drawing board to a two-way CAD/CAPM link. It does not venture into the integration levels of Open Systems, since none of the companies aspired to this.

Computer Knowledge Base investigates the extent to which computers were used within the companies, and particularly in the drawing and design sections.

Expectation of the System considers the expressed aspirations of the system proponents prior to the start of the implementation, and the estimated degree of difficulty in reaching the target.

Prior Justification differs from expectation in that it relates to financial or "survival" measures of success rather than to technical measures.

Management and Organisation investigates the structure of the companies, their management styles and internal relationships. It also investigates the inter-departmental boundaries.

Management "Ownership" is to do with the level of commitment of the senior management to the CAD implementation. It looks at the formation of the implementation team, and the sources of power and authority.

Commitment to the System assesses the commitment of the "System Champion" and "User Group" at four key stages; selection, before a major setback, immediately after the setback and after the setback had been resolved. These stages were chosen with care and represent critical periods of development.

Level of Satisfaction shows the consensus of the implementation team at various stages during the implementation. It compares the ultimate satisfaction level with the measured success in implementation and success in application.

Implementation Planning looks at the extent to which the companies committed resources to planning the implementation, and the apparent effect of this.

Vendor Relationships and Training investigates the level of training taken up by the companies from their vendor, as an indicator of the relationship between the company and the vendor.

Using the outcomes of these ten analyses, no fewer than 32 propositions were developed. Whilst they were developed under the same headings as the analyses, it became clear that they fell into four categories:

- those propositions relating to planning of the CAD system and its position in the company
- those propositions relating to existing features of the company such as organisation, management, people, knowledge and training
- those propositions relating to preparation for the CAD system
- those propositions relating to the achievement and monitoring of targets.

A review of the propositions suggested a parallel between their sequence and what may be regarded as a "traditional" business plan, which addresses the questions:

- where are we now ?
- where do we want to get to ?
- how do we plan to get there ?
- what steps must we take ?
- how will we know when we get there ?

To find a series of derived propositions pointing so clearly to a formal plan came as something of a surprise, yet the link was undeniable. The consequence was clear. If the propositions indicate a structure, then by developing that structure to incorporate the propositions, we should end up with a methodology for implementation.

This methodology should, if followed through, avoid the pitfalls and provide the benefits described in the propositions, and hence lead to a successful implementation.

With this in mind, a framework for the methodology has been developed, based around five distinct stages or phases:

- Strategy
- Company Audit
- Design
- Action
- Review

The framework has been validated using three former associates of the author and amended accordingly.

The framework represents a significant step forward in the understanding of CAD implementation, despite the fact that it holds no surprises.

Firstly it is built up from information gathered by a CAD specialist during actual implementations, giving it credibility.

Secondly it provides firm guidance on a "best" way of implementing CAD, encapsulating elements of advice and best practice described by other authors.

Thirdly it forms the basis of an "implementation toolkit" for use by small firms and their advisors when planning a CAD project.

Fourthly in concentrating on small firms, it addresses the sector of industry which can least afford failure yet equally can least afford external specialist help.

The following sections highlight the ways in which further research may be useful. Section 6.5.2 outlines the way in which the methodology for implementation may be developed to a point where it becomes an implementation tool. Section 6.5.3 picks out some of the areas described earlier which would make interesting or productive research in themselves.

6.5.2 Development of a Methodology

The framework for the methodology described in earlier sections is the bare bones of a potential implementation tool which, if developed, could be useful for the Consultant and/or the company wishing to implement Computer Aided Design.

Section 6.4 suggests some possible sources for material which may be used for inputs to the model, but stops far short of detailing the method of collecting the material.

The next stage would be to produce a workbook consisting of the necessary guidelines and checklists. For instance, when looking at the people aspects of the Company Audit, psychometric testing had been suggested for analysing management styles. This in itself raises several questions.

Firstly, what in detail do we want to achieve by the psychometric test? Secondly, which of the several tests available would therefore be most appropriate? Thirdly, what quality of information will be made available by that particular analysis? The same questions could be asked when seeking a suitable team type analysis and training needs analysis methodology.

Several of the inputs require the collection and analysis of information, some of which will be subjective, some will be value judgement and some will be deliberately or innocently misleading. Any questionnaires developed for collecting such information will need to take this into account.

For instance, when attempting to identify the quality of inter-departmental relationships, it would not be surprising for a relatively wide spectrum of opinions to be obtained.

Collecting data for the inputs is clearly important to the model, but since it relies on a particular quality of input, the researcher will inevitably be faced with the problem of what to do if the analysis is unfavourable. For instance, it has been suggested that inter-departmental antagonism can cause implementation problems.

So, having found such antagonism, the workbook will need to suggest actions which may be taken, and a method of identifying whether and when these actions have had sufficient effect to remove the potential barrier to implementation. This "what to do if......." type of guidance is seen as fundamental to the success of the package.

This type of guidance is also important in other areas. For instance, the environmental aspects of CAD such as lighting, layout, physical comfort and rest periods have been well researched, and a checklist can be produced to compare present/proposed practice against best practice.

What may not be so clear is the minimum acceptable standards, and the effects of falling short of the ideal. Clearly, many companies will, for a variety of reasons, fall short of the ideal environmental standards, and not all will face failure in implementation.

Several of the inputs have no obvious method of standardised assessment, and this will be an obstacle to the developer of a methodology. For instance, to what extent is the presence of a Business Plan fundamental to the creation of a CAD Strategy? Clearly there should be some relationship, but the author knows of several installations where the Business Plan has only existed in the mind of the Chief Executive or owner, yet CAD has been implemented.

The extent to which this is important as an issue needs to be explored. All we are attempting to do with the methodology is remove barriers and potential barriers to implementation.

If this requires the explicit definition of a written Business Plan, then so be it, but there are probably those Chief Executives or owners who would dispute it.

The methodology, in its finished format, should:

(a) Define the inputs at each stage.

(b) Check that they have been verified.

(c) Suggest action if they are inadequate.

(d) Define the action required by the stage.

(e) Define the outputs required.

(f) Check that the standards of output are achieved.

It should lead the Consultant/company stepwise through the procedures, explaining at each stage the rationale and reasoning behind the steps being taken and measurements being made. It should also provide for comprehensive reviews at each stage, not just at the post-implementation Audit stage, to ensure that the project is proceeding to plan.

As with all new tools, the test will be a dry-run on a number of companies. Two possible outcomes should be observed.

(a) If the company follows the methodology from beginning to end, it should achieve a successful implementation in the terms expressed elsewhere in this paper.

(b) If the company deviates significantly from the methodology it should experience relevant problems with the implementation which may be addressed by remedial action within the methodology.

Only when this has been demonstrated on a significant number of cases and the necessary amendments made to the methodology, can it be considered to be a success. At this stage, it can be developed into a packaged "toolkit" and launched on an unsuspecting market.

6.5.3 Further Research Opportunities

a) Section 6.1.2 identifies the need for a particular style of management in the implementation of CAD, but notes that this is a "preference". The work does not identify the precise relationship between management style and implementation effectiveness, and this would benefit from further investigation.

A suitable title which would encompass this would be "The effect of management style on the implementation of advanced technology in small and medium enterprises".

b) This work, as noted in Section 6.1.3, does not address itself to the effects of vendor relationships, system selection and implementation plan on the implementation. This is acknowledged to be a weakness of the model brought about by the author's involvement as consultant in all cases.

There is therefore significant potential for at least two research projects in this area. One could deal with the vendor relationships and system selection, which are almost inextricably bound together, whilst the second could deal with the implementation plan. A useful title could be "The effects of a detailed implementation plan on the success of implementation of advanced technology".

c) The Audit phase described in Section 6.1.5 addresses progress against three key measures:

* progress against expectations
* progress against implementation plan
* progress against justification

It makes the point that the outcomes of these measures may not be the same, and gives some reasons for the possible differences. This area of study has been neglected in the texts, and merits further investigation. It would be most interesting to look into the psychology of this type of decision making, and why one measure should be subjugated with respect to another. Why, for instance, does the measure of justification have less importance once the decision to implement has been taken?

d) All the cases studied for this research have been UK based British owned companies. It would be most interesting to carry out a similar exercise in other European countries, but particularly interesting in Japan and the United States, using companies of a similar size and similar stage of development. The Japanese research would be of particular interest in the Organisational and Managerial aspects, because of the differences in culture and hierarchical style.

e) Probably the most significant area of research lies in investigating the relevance of the framework outside the scope of the cases from which it was developed. For instance the current research does not address whether the framework is only valid for small firms, and if so, how small, or is equally valid for larger firms.

The more integrating the technology (CAD / CAM / CAPM etc.) the more lines of demarcation it cuts.

This is particularly true in large companies which tend to be more strongly divisionalised, and less so in small companies which coordinate by mutual adjustment. The larger firm may therefore experience significantly different problems in the organisational aspects of implementation.

7.0 BIBLIOGRAPHY

ADLER P S (1988) Managing Flexible Automation California Management Review V30.

ADLER P S & HELLELOID D A (1987) Effective Implementation of Integrated CAD/CAM: A Model IEEE Transaction on Engineering Management May 1987.

ALTSCHULER B ET.AL(1984) The Future of the Automobile Industry MIT Press Cambridge Mass. 1984.

ARNOLD E (1983) Information Technology as a Technological Fix: CAD in the UK. In Winch G (ed) 1983 (a).

ARNOLD E & SENKER P (1982a) Computer Aided Design in the UK Engineering Industry Paper presented to CAD 82 5th International conference on computers in design engineering. Brighton England March 1982.

ARNOLD E & SENKER P (1982b) Designing the Future: The skill implications of interactive CAD. EITB (Watford) occasional paper No.9.

BESSANT J R & DIXON K E (1982) Issues in the Adoption of Microelectronics. London. Pinter.

BESSANT J & GRUNT M (1985) Management and Manufacturing Innovation in the United Kingdom and West Germany Vermont Gower

BESSANT J R (1991) Managing Advanced Manufacturing Technology: The Challenge of the Fifth Wave NCC Blackwell

BESSANT J LEVY P TRANFIELD D SMITH S & LEY C (1990) Management and Organisation for Computer Integrated Technologies Paper submitted to International Journal of Human Factors in Management

BESSANT ET AL. (1992) Organization Design for Factory 2000. International Journal of Human Factors in Manufacturing V2(2) 1992

BIKSON TK GUTEK BA & MANKIN D A (1981) Implementation of Information Technologies in Office Settings: Review of relevant literature. Rand paper series P6697 Santa Monica, California in Marchrzak et. al. (1987).

BOGDAN R & TAYLOR S J (1975) Introduction to Qualitative Research Methods : A Phenomenological Approach to the Social Sciences. New York : Wiley 1975.

BREWER J & HUNTER A (1989) Multimethod Research : A Synthesis of Styles. Sage Library of Social Research 175. Newbury Park, California.

CARNALL C A & MEDLAND A J (1984) Computer Aided Design: Social and technical choices for development. In Warner (ed) 1984.

CARRIE A S & BANNERJEE S K (1984) Approaches to Implementing MIS Omega: Vol 12 1984.

CLEGG D E (1988) Hatching a Plot: Cadcam International Dec 1988 pp29-31.

COLLINS P D & KING D C (1988) Implications of Computer Aided Design for Work and Performance: Journal of Applied Behavioural Science Vol 24 No2 pp173-190.

COOK T D & CAMPBELL D T (1979) Quasi-Experimentation : Design and Analysis Issues for Field Settings. Chicago. Rand McNally.

DELBEKE J (1983) Recent Long-wave Theories: A Critical Survey. in C Freeman (ed) Long Waves in the World Economy. London, Pinter.

DENZIN N K (1970) The Research Act; A Theoretical Introduction to Sociological Methods Aldine Chicago

DYER W G JR. & WILKINS A L (1991) Better Stories, not Better Constructs, to Generate Better theory : A Rejoinder to Eisenhardt. Academy of Management Review Vol 16 No 3 pp613-619.

EASON K D (1982) The Process of Introducing Information Technology: Behaviour and Information Technology Vol 1 No2 April-June 1982.

EASON K (1988) Information Technology and Organisational Change. London. Taylor and Francis

EISENHARDT K M Building Theories from Case Study Research. Academy of Management Review v14 n4 pp532-550 (1989)

ETTLIE J E (1973) Technology Transfer from Innovators to Users Industrial Engineering Vol 5 1973 pp 16-23.

ETTLIE J E (1984) The Implementation of Programmable Manufacturing Technology. Working Paper. De Paul University March 1984.

EVERED R & LEWIS M R (1981) Alternative Perspectives in the Organisational Sciences : "Inquiry from the Inside" and "Inquiry from the Outside". Academy of Management Review v6 n3 pp385-95.

FORDYCE J K & WEIL R (1971) Managing with People Addison Wesley

FRIEDRICHS J & LUDTKE H (1975) Participant Observation : Theory and Practice. Farnborough. Saxon House.

GALBRAITH D (1977) Organisation Design Reading: Addison Wesley.

GERWIN D (1988) A Theory of Innovation Processes for Computer Aided Manufacturing Technology IEEE Transaction on Engineering Management Vol 35 No2 May 1988.

GERWIN D & TARONDEAU J C (1982) Case Studies of Computer Integrated Manufacturing Systems: A View of Uncertainty and Innovation Processes. J Operations Management Vol 2 No 2 pp 87-99 1982.

GILL J & JOHNSON P (1991) Research Methods for Managers. London Paul Chapman.

GLUCKMAN M (1961) Ethnographic Data in British Social Anthropology. Sociological Review v9 pp5-17.

GOODE W J & HATT P K (1952) Methods in Social Research. New York. McGraw Hill.

HAGE J (1980) Theories of Organizations New York: Wiley.

HAYES R H & ABERNATHY W J (1980) Managing Our Way to Economic Decline: Harvard Business Review July/August 1980.

HAYWOOD W & BESSANT J (1987) Flexible Manufacturing Systems and the S-M Firm Innovation Research Group, Brighton Business School.

HAYWOOD-FARMER J & HILL N F (1989) The Impact of CAD on Consulting Engineering Firms: A Survey of CAD Users and Non-users. The Science Industries Journal Vol 9 No 4 pp 71-89 October 1989.

HILL T (1989) Manufacturing Strategy: The Strategic Management of the Manufacturing Function. London. Macmillan Education.

JOHNSON B M & ASSOCIATES (1985) Innovation in Office Systems Implementation. NSF Report No. 8110791. Oklahoma.

KAPLINSKY R (1982) Computer Aided Design London. Frances Pinter.

KAPLINSKY R (1984) Automation: The Technology and Society. Harlow. Longman.

KEEN P G W (1981) Information Systems and Organisational Change Association for Computing Machinery 24(1) 1981.

KOLB D A & RUBIN I M & MCINTYRE J M (1979) Organisational Psychology : An Experiential Approach. London. Prentice Hall.

LAWLER E E (1985) Pay and Organization Development Addison Wesley

LEONARD-BARTON D & KRAUSS W (1985) Implementing New Technology. Harvard Business Review Nov/Dec 1985.

LUCAS H C Jr (1985) The Analysis, Design and Implementation of Information Systems New York McGraw Hill.

MARJCHRZAK A et.al. (1987) Human Aspect of Computer Aided Design London, Taylor & Francis.

MCCLELLAND D C (1965) The Achieving Society Princeton Van Nostrand

MENSCH G COUTINHO C & KAASCH K (1983) Changing Capital Values and the Propensity to Innovate. in C Freeman (ed) Long Waves in the World Economy. London, Pinter.

MINTZBERG H (1979a) The Structuring of Organisations Englewood Cliffs: Prentice Hall.

MINTZBERG H (1979b) An Emergency Strategy of "Direct" Research. Administrative Science Quarterly v24 pp580-589.

MITCHELL J C (1983) Case and Situational Analysis. Social Review v31 pp187-211.

PECCEI R & GUEST D (1984) Evaluating the Introduction of New Technology: The case of word processors in B.R. In Warner (ed) 1984.

PEREZ C (1983) Structural Change and Assimilation of New Technologies in the Economic and Social Systems. Futures. Vol 15 No 5 1983 pp 357-375.

PEREZ C & FREEMAN C (1988) Structural Crises of Adjustment, Business Cycles and Investment Behaviour. in G Dosi et. al. (eds) Technical Change and Economic Theory. London, Pinter.

PETTIGREW A (1988) Longitudinal Field Research & Change : Theory and Practice. Paper Presented to National Science Foundation Conference on Longitudinal Research Methods in Organisations. Austin 1988.

PRIMROSE P L CREAMER G D & LEONARD R (1984) Identifying and Quantifying The Company-Wide Benefits of CAD Within The Structure of a Comprehensive Investment Programme. In Rhodes E & Wield D (1985).

RAYMOND L (1989) Management Information Systems: Problems and Opportunities. International Small Business Journal Vol 7 No 4 P 44 1989.

RHODES E & WIELD D (1985) Implementing New Technologies Oxford Blackwell.

ROTHWELL R & ZEGVELD W (1982) Industrial Innovation and Public Policy. London. Frances Pinter.

ROTHWELL R & ZEGVELD W (1983) — Innovation and the Small and Medium Sized Firm. London. Frances Pinter.

SCHEIN E H (1985) — Organizational Culture and Leadership Jossey Bass

SCHEIN E H (1987) — The Clinical Perspective in Fieldwork. Sage University Paper Series on Qualitative Research. Vol 5. Sage, California.

SCHEIN E H (1969) — Process Consultation: Its Role in Organisation Development. Addison-Wesley. Reading, Mass.

SENKER P (1984a) — Implications of CAD/CAM for Management. Omega Vol 12 1984.

SENKER P (1984b) — Training for Automation. in Warner M (ed) 1984.

SMITH S TRANFIELD D WHITTLE S & FOSTER M (1992) — Research Methodology CMRU Working Paper

SMITH J S ET AL. (1991) — Manufacturing Organisation for Computer Integrated Technology. Sheffield Business School Change Management Research Unit & Brighton Polytechnic Centre for Business Research.

TRANFIELD D & SMITH S (1987) — A Strategic Methodology for Implementing Technical Change In Manufacturing British Academy of Management Inaugural Conference 13-15 Sept 1987.

TRANFIELD D & SMITH S (1988) Sprinting for Success: Making Rapid Changes in Manufacturing Companies Management Decision Journal Vol 20 No 1.

TRANFIELD D & SMITH S (1990) Managing Change : Creating Competitive Edge. Bedford. IFS.

TRANFIELD D ET AL. (1991a) Factory 2000: Organisation Design for the Factory of Future

TRANFIELD D ET AL. (1991b) Coordination: Key Design Dimensions for the Factory of the Future

TWISS B (1984) Managing Technological Innovation. London. Longman.

VOSS C A (1988) Implementation: A key issue in MT: The Need for a Field of Study. Research Policy Vol 17 1988 pp 55-63.

WAINWRIGHT D & BOWKER P (1988) Towards an Holistic View of Manufacturing Systems Implementation Newcastle-upon-Tyne Polytechnic.

WALLACE W L (1971) The Logic of Science in Sociology. Chicago Aldine Publishing Co.

WARNER M (ed) (1984) Microprocessors, Manpower & Society Aldershot Gower.

WATERLOW J G & MONNIOT J P (1986) A Study of the State of the Art in Computer-Aided Production Management in UK Industry. ACME Directorate, SERC. April 1986

WINCH G M (ed) (1983a) Information Technology in Manufacturing Processes London Rossendale.

WINCH G M (1983b) Organisation Design for CAD/CAM. In Winch (ed) (1983a).

WINCH G VOSS C & TWIGG D (1991) Organisation Design for Integrating Technologies. Warwick Business School Research Papers. April 1991.

YIN R K (1981) The Case Study Crisis : Some Answers. Administrative Science Quarterly. March 1981 v26.

ZALTMAN G DUNCAN R B & HOLBEK J (1973) Innovations and Organizations New York Wiley

IMPLEMENTATION OF CAD/CAM IN SMALL FIRMS

INTERVIEW SCHEDULE

COMPANY CODE NUMBER ....

INFORMANT'S POSITION ....

All information collected during this interview will be treated as confidential. The Company agrees to publication of extracted information as part of a research project provided that the identity of the Company is not divulged.

SECTION 1. THE COMPANY AND ITS ENVIRONMENT

1. Please describe briefly the history of the Company from its formation, including its ownership.

2. Is the Company part of a Group? If so, please give the name of the Group.

3. How many people does the Company employ on the site(s) involved in the Implementation Project?

4. What is the turnover of the operations on that site or sites?

£

5. Please describe the manufacturing facilities available.

6. Were any computer systems in use prior to the CAD implementation? If so, please describe them.

____

____

____

____

7. How does the Company normally obtain capital for investment projects?

____

____

____

____

8. How are decisions on capital expenditure normally made, and by whom?

____

____

____

____

9. Please provide a management structure diagram.

10. How would you describe communications within the management structure? Tick the appropriate box(es).

	INFORMAL	FORMAL
VERTICAL		
HORIZONTAL		

11. How would you describe the effectiveness of the communications network? What are the problems?

____

____

____

____

____

12. Did you have a person or people with skills in operating, implementing or managing computer systems prior to the implementation? Please indicate the numbers below. How many of these had specific CAD experience?

	No. of people	No. with CAD experience
Operator		
Analyst		
Programmer		
System Manager		
External Consultant		

SECTION 2. COMPANY PRODUCTS/PROCESSES AND MARKETS

1. What is the main function of the site in broad terms?

____

____

____

____

____

2. What are the major product lines of the Company? Please estimate the percentage turnover of each?

	Description	Percentage
Product 1		%
Product 2		%
Product 3		%
Other Products		%
		100 %

3. Which three product lines require the heaviest input from the Drawing Office (D.O.), and what percentage of the D.O. time do they take up?

	Description	Percentage
Product 1		%
Product 2		%
Product 3		%
Other Products		%
		100 %

4. What share of the available market do you enjoy for the three major products of Q3, and for your products as a whole? Is this share rising, falling or static?

Product 1	%	Rising/falling/static
Product 2	%	Rising/falling/static
Product 3	%	Rising/falling/static
Whole range	%	Rising/falling/static

5. Can you estimate the position of the three products on their life-cycle?

	New Market	Market Growing	Market Static	Market Declining
Product 1				
Product 2				
Product 3				

6. How often is it necessary to prepare an estimate or tender to obtain an order? (Please tick)

Never	......	50% - 69%	......
0% - 9%	......	70% - 89%	......
10% - 29%	......	90% - 99%	......
30% - 49%	......	Always	......

7. How many tenders or estimates would you expect to produce in a 12-month period? ______________________________

8. How many hours of Drawing Office time will be required for these proposals? ______________________________

9. What is your approximate conversion rate from proposals to orders?

______________ %

SECTION THREE. DRAWING OFFICE OPERATIONS

1. How many people are involved in the Drawing Office operations?

____

2. Please describe the functions of these people using the grid below.

	Electronic	Electrical	Mechanical	Hydraulic	Pneumatic	Other
Clerk						
Tracer						
Apprentice Draughtsman						
Draughtsman						
Senior Draughtsman						
Designer						
Senior Designer						
Design Draughtsman						
Chief Draughtsman/Designer						
Other (Specify)						

3. What CAD system experience had been obtained before the implementation by the above, in-house, at other companies or in further education. Please list the people and describe their experience.

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4. Please describe the work of the Drawing Office by indicating against the items below - and any others you may wish to add - the number of hours per year spent on each:

	Man Hours/Year
Creative or Graphics Design	
Original Design	
Modification of a Design	
Creation of 'Similar' Designs	
Creation of Sketches	
Tracing	
Part Listing	
Drawing Checking	
Non-Graphical Design (eg Calculations)	
Non-Graphical Manufacturing Paperwork	
Preparation of Data for Manuals	
Production Support	
Supervision and Management	
Other (Specify)	

5. Please indicate who in the management structure takes responsibility for the quality of the Drawing Office output, and what is his/her job title.

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____

6. Why did the Company decide to investigate the use of CAD? Please tick one or more:

- Pressure from customers .... ☐
- Major competitors already had CAD .... ☐
- Shortage of draughtsmen .... ☐
- Shortage of Drawing Office space .... ☐
- Quicker response to enquiries .... ☐
- Need to reduce order lead time .... ☐
- Reduced clerical time in the preparation of parts lists etc ..... ☐
- Parts of the work could not be done manually .... ☐
- Other (please specify) .... ☐

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SECTION 4. CAD SELECTION

1. Who was the instigator of the investigation into CAD? (Position in Organisation)

2. Who was given the delegated authority for controlling the selection process? (Position in Organisation)

3. What were the terms of reference for the person nominated in (2) above? Please attach any documents.

4. How was the external consultant retained to select the system chosen?

Please tick as appropriate:

He had worked with the Company previously .... ☐

He was recommended:

* by another Company .... ☐
* by the Department of Trade and Industry .... ☐
* by PERA .... ☐
* by a trade association .... ☐
* by another consultant .... ☐
* by an employee .... ☐

He knocked on the door at the right time .... ☐

Other (Please Specify) .... ☐

....

....

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....

....

5. Were other consultants considered? If so, how many? ____________

6. What terms of reference were given to the consultant prior to the selection process?

a) None, because we wanted a totally independent audit of our CAD and CAM requirements. ☐

b) Very broad guidelines on the areas on which we wished him to concentrate, but no detailed instructions of budget. ☐

c) Detailed guidelines on what we expected of the system, the payback we were looking for, the projected expansion path and the level of integration we were expecting. ☐

Please select one of the above or indicate the terms of reference below. If a written specification was prepared, please attach it.

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7. Did you have any criteria for acceptance or rejection of the consultant's recommendations? If so, please state them.

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8. What justification was expected for a decision to proceed with implementation? How was this justification decision reached, and by whom?

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9. Did you have a budget for the purchase of the CAD system before the selection took place? If so, how much had been allocated for:

a) initial hardware and software £..........

b) annual costs £..........

c) staff training £..........

10. Was it envisaged that the CAD system would have an impact on the areas of the organisation than the Drawing Office? If so, which?

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11. Were other departments listed in (10) consulted prior to retaining the consultant? If so, which?

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SECTION 5. IMPLEMENTATION PLANNING

1. How many systems were involved in the final selection process?

2. Who was involved in setting up the guidelines for final selection?

3. Was a benchmark test developed for the selection? If so, please give details.

4. Were formal guidelines and criteria prepared and declared to the system vendor prior to demonstration? If so, please give details.

5. Who was 'in charge' of the system demonstrations? (Position in Organisation)

6. How did the system demonstrated differ from the system which had been quoted? Was this different from the system quoted after the demonstration?

7. How long did the demonstration take? Was the chosen system demonstrated once or more than once?

8. Were any significant questions raised in the selection guidelines left unanswered after the demonstration? If so, please detail them.

9. Who was involved in the final selection? Was the decision made by a team?

10. What part did the consultant take in the final selection process?

11. What part did the consultant take during the pre-implementation period?

12. What changes took place in your views of systems integration as a result of:

a) the initial selection

b) the final selection process

SECTION 6. IMPLEMENTATION PROCESS

1. Please describe the final hardware configuration planned.

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2. How did the initial purchase of hardware relate to this? Was it:

a) A single workstation with no immediate expansion plans. ☐

b) A single workstation with plans to expand within twelve months. ☐

c) More than one workstation (please state how many) with no immediate expansion plans. ☐

d) More than one workstation (please state how many) with plans to expand within twelve months. ☐

e) One or more workstations (please state how many) with plans to integrate the system with Computer Aided Production Management (CAPM), design calculation software, Numerical Control (NC), Finite Element Analysis (FEA) or other CAD systems (please specify). ☐

____

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f) Other (please specify). ☐

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4. How much money was spent on the initial purchase? £__________

5. How did this relate to the budget shown in Section 4 Q9?

6. If the expenditure was higher than budget, please explain why.

7. How was the initial purchase financed?

8. Was the implementation managed by an implementation team? If so, what was its makeup? If not, who was responsible for the installation process?

9. What brief was given to the implementer(s)?

10. What external assistance was given by:

a) consultants

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b) the vendor

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c) the system suppliers

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11. Please describe the relationship with the vendor before, during and after the implementation.

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12. What were the criteria for the success of the system implementation? Were these expressed explicitly before implementation?

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13. What were the expected benefits from a successful implementation?

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14. What was the timescale of the implementation from purchase to the achievement of the criteria for success? How did this relate to the expected timescale?

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15. On the continuum below, please describe the success of the implementation.

0	1	2	3	4	5	6	7	8	9
Total Failure				Moderate Success					Total Success

16. If the implementation was not a total success, please explain where the system fell short.

17. What action was taken during the implementation to try to make the system a success?

18. To what degree was the software tailored to meet the requirements of the Company (other than programming using the software tools provided)?

19. What organisational changes took place during the implementation phase?

20. What training was provided:

a) in CAD draughting and design

b) in system support

c) in non-CAD but related activities

d) in system management

e) other

21. Please describe the integration between CAD and other systems which was carried out during the implementation.

22. What were the major problems encountered:

a) with CAD implementation

b) with integration

23. What specific 'people' problems were encountered during the implementation, and how were they overcome?

SECTION 7. POST-IMPLEMENTATION ANALYSIS

1. In retrospect, what are your measures of success?

2. How did the implementation match up to these measures?

3. How meaningful was the implementation plan?

4. How reasonable were the implementation timescales?

5. How would you describe the support you received from your vendor?

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6. What disputes, if any, arose, and how were they resolved?

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7. How effective was the training supplied by the vendor?

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8. Were any unforeseen benefits obtained? If so, what?

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9. Was there anything you got completely wrong?

10. Overall, what would you have done differently?

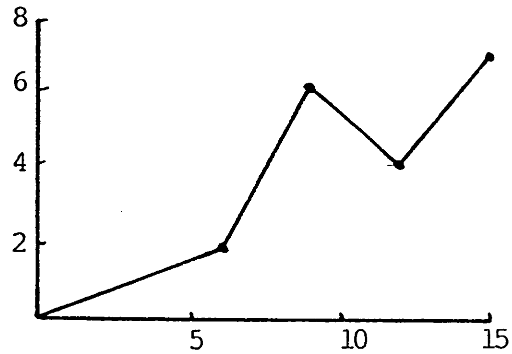
SECTION 8. THE FUTURE

1. What are your expansion and/or integration plans?

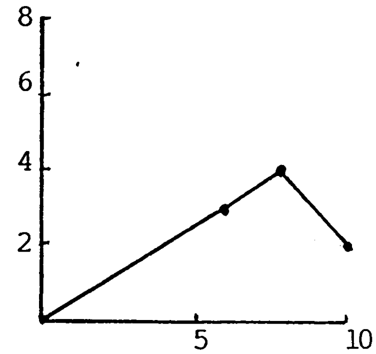
2. What further training do you envisage?

3. Do you have a policy for improving the system? If so, please describe the proposed improvements.

SATISFACTION CURVES



Case 1



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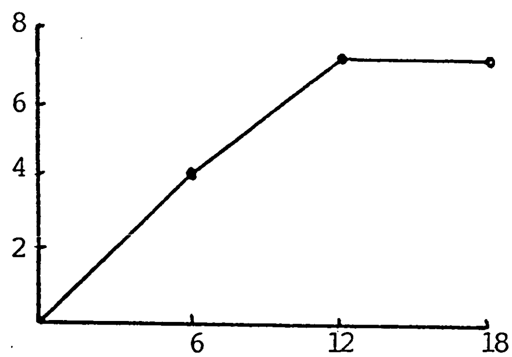

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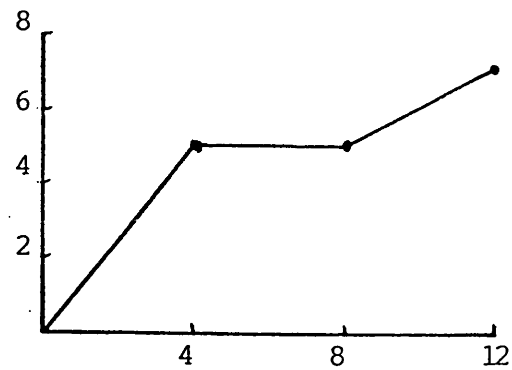

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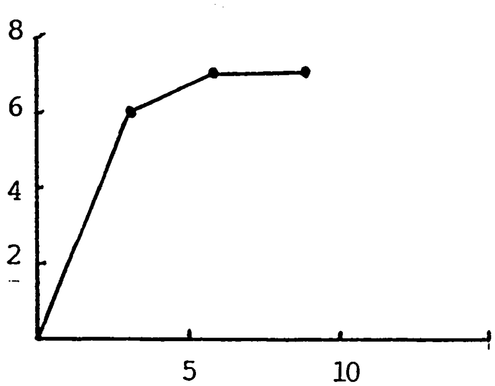

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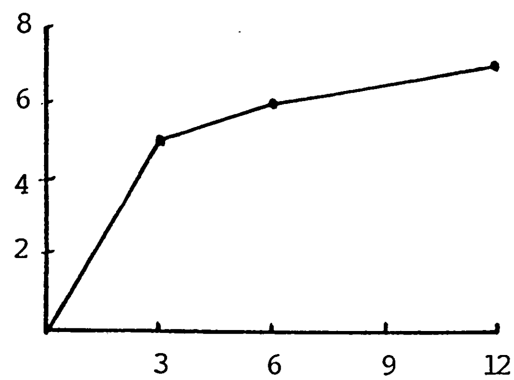
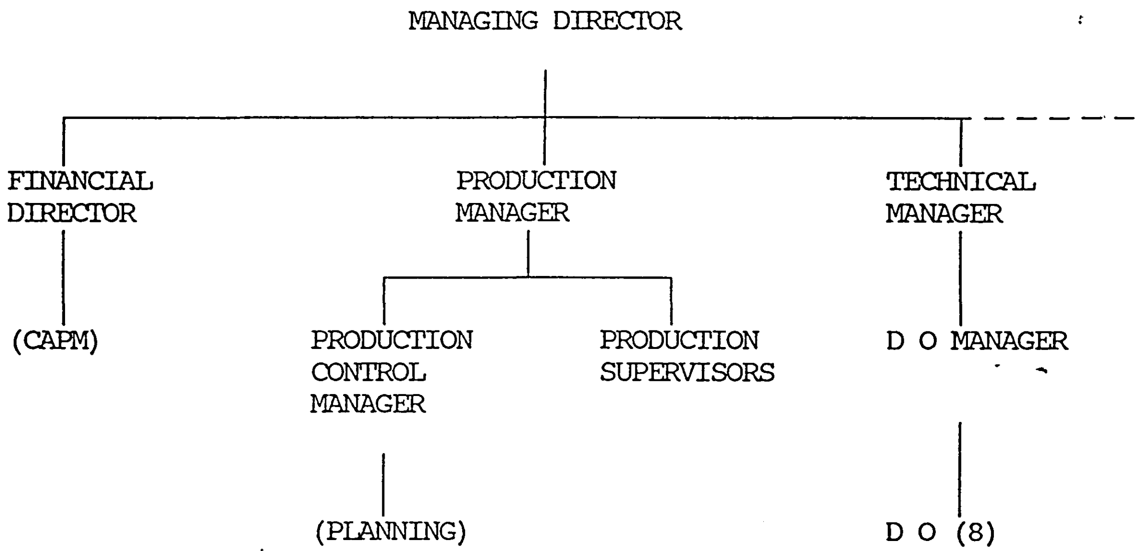


Case 6

ORGANISATION STRUCTURE

COMPANY 1



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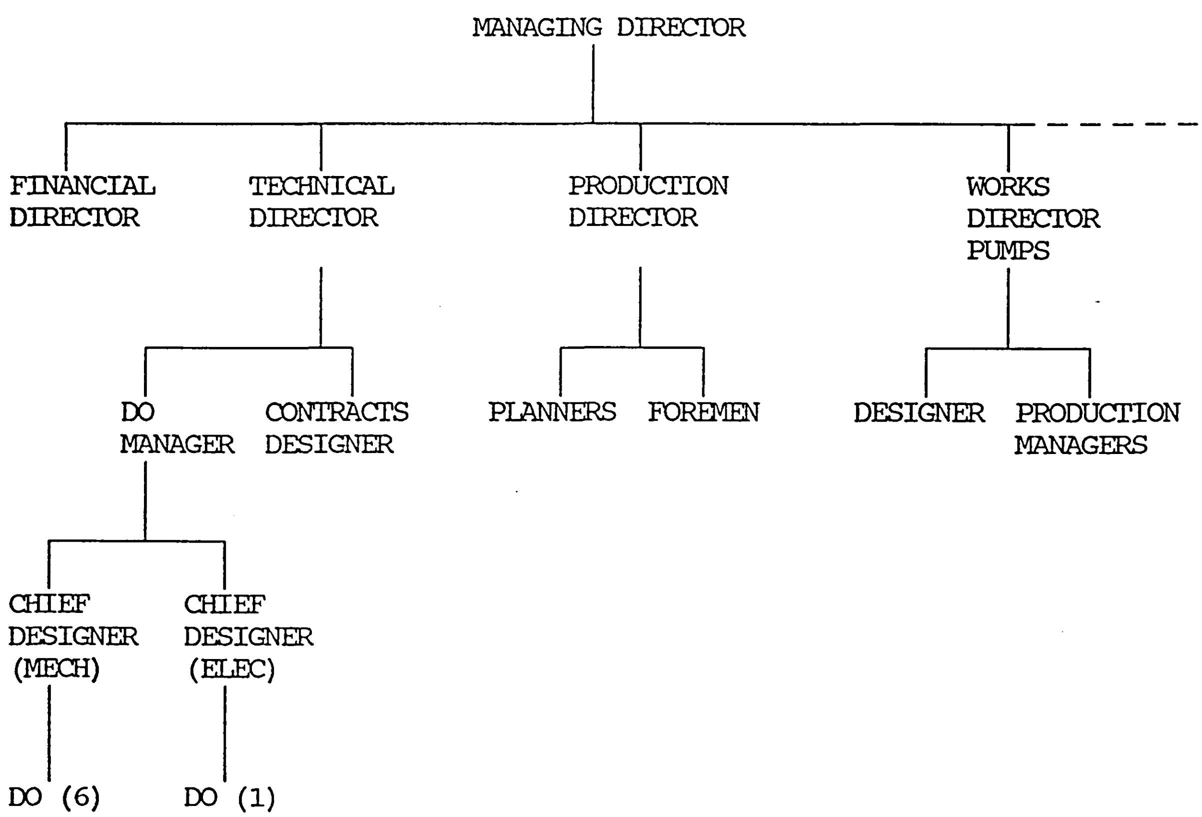

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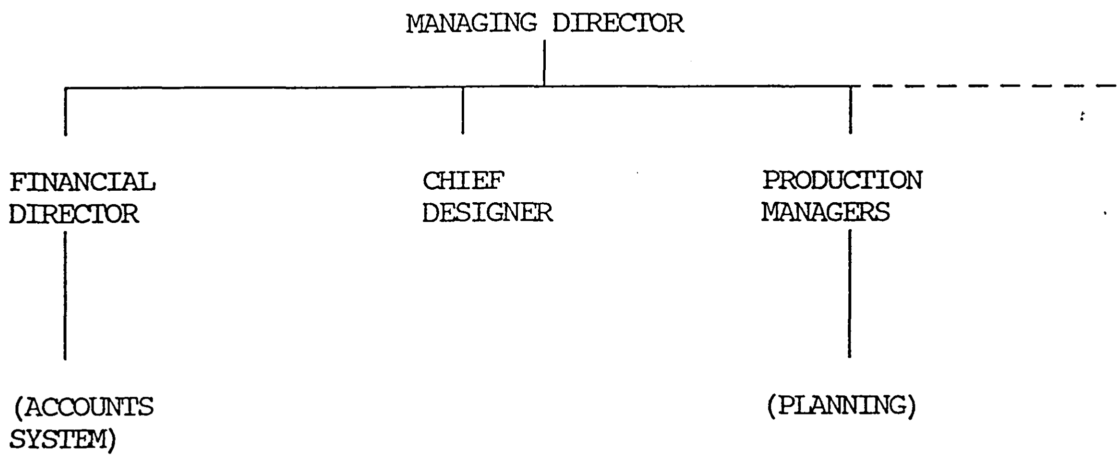

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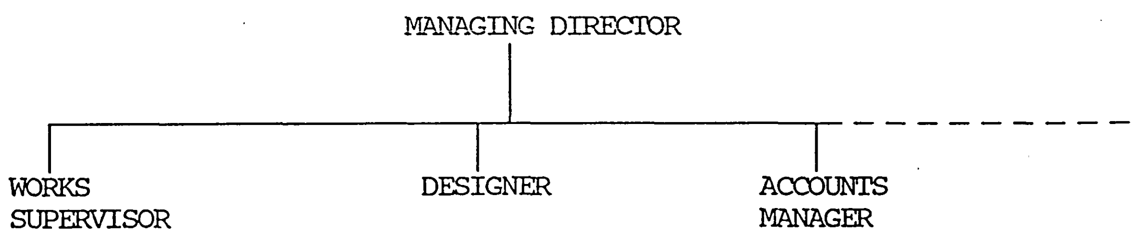

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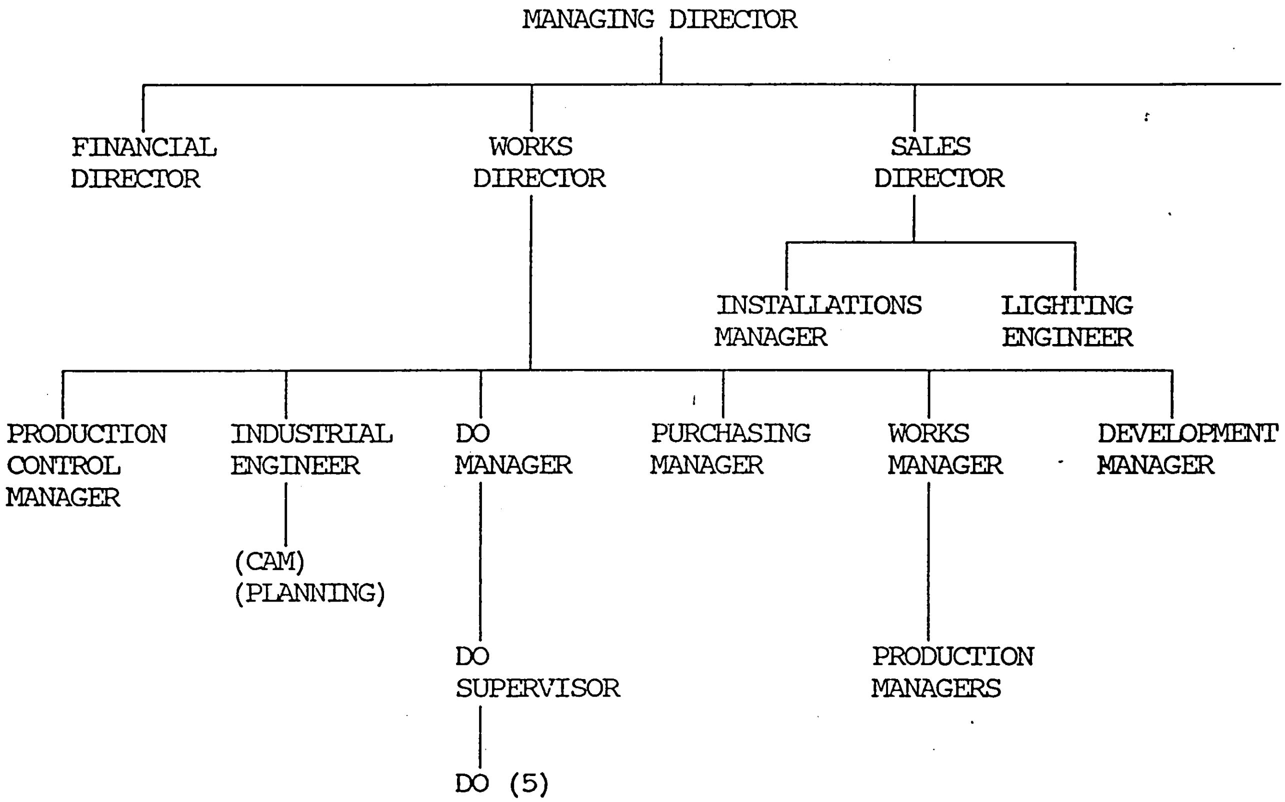

COMPANY 6